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Remedial Investigation/Feasibility Study
Tourtelot Cleanup Project
Benicia, California

Volume I
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TOURTELOT CLEANUP PROJECT

This Remedial Investigation/Feasibility Study report was prepared under the overall guidance of Peter Russell, Ph.D., P.E., and Ted Splitter, P.E., G.E., both of Northgate Environmental Management, Inc. The Remedial Investigation portion of the report, with the exception of the screening-level Health Risk Assessment, was prepared under the direction of Sandra Cuttino, P.E., and William Muir, R.G., of Earth Tech, Inc. The Non-Ordnance Screening Health Risk Assessment portion of the report was prepared under the direction of Renee Kalmes, C.I.H., of Exponent. The Feasibility Study portion of the report was performed under the direction of Alan Leavitt, P.E., of Northgate Environmental Management, Inc.

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TOURTELOT CLEANUP PROJECT

All engineering information, conclusions, and recommendations in the Feasibility Study portions of this report (Chapters 10.0 through 12.0 and Appendix H) have been prepared under the supervision of and reviewed by a Northgate Environmental Management, Inc., California Registered Engineer.

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TOURTELOT CLEANUP PROJECT

All information, conclusions, and recommendations in the screening-level Health Risk Assessment contained in Chapter 7.0 and Appendix F of the Remedial Investigation/Feasibility Study report have been prepared under the supervision of and reviewed by Exponent.

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List of Acronyms

Ag	silver
Al	aluminum
amDNTS	sum of 2-amino-4,6-dinitrotoluene and 4-amino-2,6-dinitrotoluene
ARAR	applicable or relevant and appropriate requirement
ARCS	Assessment and Remediation of Contaminated Sediment
As	arsenic
ASR	Archives Search Report
ASTM	American Society for Testing and Materials
ATF	Alcohol, Tobacco, and Firearms
Ba	barium
BAAQMD	Bay Area Air Quality Management District
Babcock	E.S. Babcock & Sons
Be	beryllium
bgs	below ground surface
BIP	blow in place
BTAG	Biological Technical Assistance Group
BTEX	benzene, toluene, enthylbenzene, xylene
C	Celsius
Ca	calcium
CADHS	California Department of Health Services
Cal/EPA	California Environmental Protection Agency
Cal/OSHA	California Occupational Safety and Health Administration
CAM	California Assessment Manual
CCC	Continuous Chronic Concentration
CCR	California Code of Regulations
CCV	Continuing Calibration Verification
Cd	cadmium
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability
CESPK	U.S. Army Corps of Engineers, Sacramento District
CFR	Code of Federal Regulations
cm/sec	centimeters per second
CNDDB	California Natural Diversity Data Base
Co	cobalt
COI	chemical of interest

Cr	chromium
Cu	copper
CWA	Clean Water Act
cy	cubic yard
o	degree
%D	Percent Difference
DDESB	Department of Defense Explosive Safety Board
DDT	4-4'-dichlorodiphenyltrichloroethane
DEM	Department of Environmental Management
dh/dl	averaged hydraulic gradient
DHS	Department of Health Services
DNB	dinitrobenzene
DNT	dinitrotoluene
DOD	Department of Defense
DOT	Department of Transportation
DQO	data quality objective
DTSC	Department of Toxic Substances Control
DWR	Department of Water Resources
EE/CA	environmental evaluation/cost analysis
EIR	environmental impact report
EM	electromagnetic
ENGEO	ENGEO, Inc.
EOD	Explosive Ordnance Disposal
EPA	Environmental Protection Agency
ESA	Endangered Species Act
F	Fahrenheit
Fe	iron
fps	feet per second
FS	feasibility study
GC	gas cromatography
gpm	gallons per minute
GPR	ground-penetrating radar
GRA	general response action
Granite	Granite Management Corporation
GSA	General Services Administration
HASP	Health and Safety Plan
HE	high explosive
Hg	mercury

HI	Hazard Index
HMX	octahydro-1,3,5,7-tetranitro-1,3,5-trizine
HRA	Hazard Risk Assessment
K	potassium
K_{oc}	soil sorption coefficient (normalized for organic carbon content)
LCL	lower control limit
LDC	Laboratory Data Consultants
LDR	land disposal requirement
LIDAR	light distance and ranging
LOEC	lowest observed effect concentration
LUFT	leaking underground fuel tank
µg/L	micrograms per liter
µL	microliter
µmhos/cm	micromhos per centimeter
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
Mg	magnesium
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mL/g	milliliter per gram
mm	millimeter
MMI	Modified Mercalli Intensity
Mn	manganese
Mo	molybdenum
mph	miles per hour
MPM	most probable munition
MS/MSD	matrix spike/matrix spike duplicate
MSA	Minimum Separation Area
MSD	Minimum Separation Distance
MSL	mean sea level
mV	millivolt
Na	sodium
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
ne	estimated effective porosity
Ni	nickel
NOAEL	no-observed-adverse-effect level
non-OE RI	Non-Ordnance and Explosives Remedial Investigation
NORCAL	NORCAL Geophysical Consultants, Inc.

NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Unit
O&M	operation and maintenance
OB/OD	open burn/open detonation
OCDD	1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin
OE	ordnance and explosives
ONSITE	Onsite Environmental Laboratories (Mobile Facility)
P	phospherus
PAH	polynuclear aromatic hydrocarbon
Pb	lead
PCB	polychlorinated biphenyl
PE	performance evaluation
PeCDF	pentachlorodibenzofuran
PETN	pentaerythritol tetranitrate
pg/g	picograms per gram
ppm	parts per million
PQL	Practical Quantitation Limit
PRG	Preliminary Remediation Goal
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
QCSR	Quality Control Summary Report
Quanterra	Quanterra, Inc.
%RSD	percent relative standard deviation
RAO	remedial action objective
RAP	Remedial Action Plan
RAW	Removal Action Work Plan
RCRA	Resource Conservation and Recovery Act
RDX	cyclonite
RF	response factor
RI	remedial investigation
RL	reporting limit
RRF	Relative Response Factor
RRR	Records Research Report
RWQCB	Regional Water Quality Control Board
S	sulfur
SAP	Sampling and Analysis Plan
SAR	synthetic aperture radar

SARA	Superfund Amendments and Reauthorization Act
Sb	antimony
Se	selenium
SECOR	SECOR International, Inc.
SEVERN	Severn Trent Laboratories
Si	silicon
SSHP	Site-Specific Health and Safety Plan
SUXOS	Senior Unexploded Ordnance Supervisor
SVOC	semivolatile organic compound
TBC	to be considered
TCDD	tetrachlorodibenzo-dioxin
TCDF	tetrachlorodibenzo-furan
TDEM	time-domain electromagnetic
TEC	threshold-effect concentration
TEF	toxicity equivalent factor
TEQ	toxicity equivalent
TEPH	total extractable petroleum hydrocarbon
Ti	titanium
Tl	thalium
TMF	total magnetic field
TNB	trinitrobenzene
TNT	trinitrotoluene
TPH	total petroleum hydrocarbon
TRV	toxicity reference value
TSS	total suspended solids
UMDA	Umatilla Depot Activity
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	underground storage tank
UTL	upper tolerance limit
UV	ultraviolet
UXO	unexploded ordnance
UXOSO	Unexploded Ordnance Site Safety Officer
V	vanadium
VOC	volatile organic compound
Vp	linear pore water velocity
VSD	voluntary separation distance

EXECUTIVE SUMMARY

DOCUMENT DESCRIPTION

This Remedial Investigation/Feasibility Study (RI/FS) document consists of two sections. The RI section presents the results of the investigations conducted at the Tourtelot Project Site in Benicia, California (Project Site). These investigations characterize ordnance and explosives (OE) and chemical (non-OE) impacts at the Project Site. The investigative work performed led to the identification of several areas of interest where site activities may have impacted fill materials, native soil, bedrock, sediments in wetland areas, surface water, and groundwater.

The FS section is based upon the data collected in the RI. The FS identifies and evaluates potential remedial alternatives for the Project Site and presents the recommended alternative. Eight alternatives were developed and screened for effectiveness, implementability, and cost. Five of these alternatives were retained for further screening, focusing on the nine criteria contained in regulatory guidance (overall protection of human health and the environment; compliance with regulatory requirements; long-term effectiveness and permanence; short-term effectiveness; reduction in toxicity and mobility; or volume; implementability; cost; regulatory acceptance; and community acceptance). In addition, this RI/FS assesses, through screening level assessments, the human health and ecological risks associated with the impacts identified in the RI. The RI/FS was prepared to comply with requirements set forth in the *Imminent and/or Substantial Endangerment Determination and Remedial Action Order (Docket No. I/SE 98/99-011)* (the "Order") issued on June 1, 1999, by the California Environmental Protection Agency (Cal/EPA), Department of Toxic Substances Control (DTSC).

PROJECT SITE

The 220-acre Project Site includes features known as the South Valley, Ridge, North Valley, and the Unit D-1 Parcel. Figure ES-1 shows the locations of these features and the identified areas of interest. The Project Site has been fenced with controlled access and ispatrolled by a security firm since 1996.

BACKGROUND

From 1849 through 1958, the United States acquired, by lease, license, or in fee, over 2,700 acres in Benicia, Solano County, California, for the Benicia Arsenal. The Benicia Arsenal began at the shore of the Carquinez Strait and extended northward. Over its 100-year history, the Benicia Arsenal was used as a principal depot for ordnance storage, issuance, and transshipment. The Tourtelot Property (which is contained within the Project Site) consists of approximately 200 acres of undeveloped grassland northwest of the former Benicia Arsenal. The Tourtelot Property was leased to the U.S. Army from 1944 to 1960; for that period of time, the property was part of the Benicia Arsenal. Between 1945 and 1960, the U.S. Army conducted several Arsenal-related activities on the property, including

artillery testing, demilitarization, and demolition of damaged and obsolete munitions.

After the Benicia Arsenal was closed in 1964, the Tourtelot Property changed hands, and plans for private residential development were initiated. In 1990, initial grading activities were conducted on the Project Site. Soils were cut from the Ridge, the McAllister Drive Land Bridge was constructed, and the Unit D-1 lots were graded. In 1996, concrete-filled howitzer shells and live ordnance were discovered. This finding prompted the developer of the property, Granite Management Corporation (Granite), and the U.S. Army Corps of Engineers (USACE) to characterize the site for OE and soil and groundwater impacts.

INVESTIGATIONS PERFORMED

The first part of this document presents the results of the historical and geotechnical investigations at the Project Site. USACE conducted historical investigations of the former Benicia Arsenal, including the Project Site, in 1994, 1996, and 1999 (see the March 1994 Archives Search Reports (ASRs), the May 1997 Supplemental ASR, and the 1999 Records Research Report). In addition, USACE performed an engineering evaluation/cost analysis (EE/CA) to evaluate potential OE and assess safety risks at the former Benicia Arsenal. A geophysical survey was conducted in 1996 over the entire Project Site, excluding the cut portion of the Ridge, the west portion of the South Valley, and the wetland area in the South Valley, to assess the distribution of metallic anomalies. An additional geophysical survey of select areas throughout the Project Site was conducted in 1999. A preliminary investigation of surface soil and surface water conducted in 1998 identified the presence of chemicals of interest (COIs) in soil at the Project Site.

The geophysical surveys conducted identified anomalies at the Project Site. The data collected from these surveys were used to perform OE clearances in August and December 1996 and to support a USACE OE investigation of the former Benicia Arsenal, including the Project Site and adjacent property, in March 1999. Additionally, in May 2000, an OE clearance of proposed excavation locations at the North Valley Military Landfill was conducted to facilitate the characterization of soil beneath the landfill. About one-half of the geophysical anomalies cleared from the North Valley Military Landfill were OE scrap. No OE was encountered.

As a result of previous clearances and investigations, a total of nine OE items related to site activities have been recovered from the Project Site. All nine items have been recovered from the South Valley and the south portion of the Ridge. No OE items have been recovered from the North Valley or on the slopes of the North Valley. All OE and OE scrap recovered from the Project Site, outside the demolition sites in the South Valley, were recovered at depths less than 2 feet below ground surface (bgs), except in two areas disturbed by grading activities. The absence of OE and OE scrap at depths greater than 2 feet bgs indicates that OE at the Project Site is likely to be buried at a shallow depth that is consistent with the historical use of the Project Site.

Four investigations were conducted between May 1999 and August 2000, primarily to evaluate the presence of chemicals in the areas of interest identified as being associated with site activities. The four investigations include the interim investigation, RI, data gaps investigation, and the removal action investigation. These investigations performed to date, with the exception of the removal action investigation, were performed using techniques to avoid metallic anomalies (ordnance avoidance techniques).

Data from these and the previous investigations were used to help define the nature and extent of OE and COIs at the Project Site to the extent possible based on ordnance avoidance techniques and to evaluate remedial action alternatives.

The Army's historic activities at the Project Site were conducted in the South Valley, the Ridge, and the North Valley. The results of the investigations are summarized by area of interest and feature below:

TNT Strips - North Valley. There are five linear features on the northern hillside of the North Valley, referred to as the TNT Strips. Trinitrotoluene (TNT) has been detected in the upper 2.5 feet of soil along the axis of the strips at concentrations exceeding 100,000 milligrams per kilogram (mg/kg) (i.e., 10 percent by weight) at 2 locations in 3 samples, out of a total of 84 samples collected along the axis of the strips within the upper 3 feet. Soil containing TNT at a concentration of 10 percent or greater is classified as OE. At a depth of approximately 10 feet bgs in the strips, TNT concentrations are typically non-detect or less than 16 mg/kg, the proposed remediation goal for TNT in residential areas. TNT concentrations also decrease significantly away from the axis of the strips. At a distance greater than 20 feet in the downslope direction and 10 feet in the upslope direction, TNT concentrations in the soil within the upper 4 feet are non-detect or less than 16 mg/kg.

Concentrations of TNT less than 200 mg/kg have been detected in isolated surficial soil samples northwest of the TNT Strips. Concentrations of TNT less than 100 mg/kg have also been detected sporadically in the surficial soil along the ridge top above the TNT Strips area near the Project Site boundary. TNT at 17 mg/kg or less has been detected in the soil/bedrock along the floor of the North Valley. Other COIs identified at the TNT Strips include unknown hydrocarbons, polynuclear aromatic hydrocarbons (PAHs), and dioxins/furans (combustion by-products).

Howitzer Test Facility and Stockpile #3 - North Valley. The Howitzer Test Facility was used to test gun barrels manufactured in Benicia by firing dummy/ gravel-filled rounds into test tunnels. Low concentrations (less than 100 mg/kg) of petroleum hydrocarbons in the motor oil range, as well as other hydrocarbons (representing weathered fuels), have been detected in the near-surface soil in roads and other areas historically used for access and parking at the Howitzer Test Facility. The source of these petroleum hydrocarbons is unknown, but is thought to be related to historical practices of oiling roads and parking areas for dust suppression.

In addition, low concentrations (less than 20 mg/kg) of petroleum hydrocarbons in the motor oil range were detected at two locations at depths of up to 10 feet and 20 feet bgs, respectively. The source of these hydrocarbons is unknown. Other COIs detected at this site include benzene, toluene, and xylenes, which were detected at low concentrations (less than 0.0055 mg/kg) in one sample at 10 feet bgs in the vicinity of former Buildings 540 and 542. A low concentration of benzene (0.0018 mg/kg) was detected at one other nearby location at 20 feet bgs. 1,2,3-trichlorobenzene and 1,2,4-trichlorobenzene were also detected at low concentrations (less than 0.0016 mg/kg) in a near-surface sample in the same general area. These compounds are typically associated with petroleum hydrocarbons, oils, and/or lubricants.

Low concentrations (0.11 mg/kg or less) of PAHs and moderate levels (200 mg/kg or less) of petroleum hydrocarbons and unknown hydrocarbons were detected in samples from Stockpile #3.

North Valley Military Landfill - North Valley. Wood crates, pallet and packing materials, a crushed metallic structure, and OE scrap were found in this 0.33-acre area that the Army reportedly used as a landfill. Other hydrocarbons, volatile organic compounds (VOCs), two dioxins/furans, and one pesticide were detected in various soil samples in the fill material and at 2 feet below in the underlying soil. Estimated low concentrations of two explosive compounds (HMX at 0.26 micrograms per liter [µg/L] and 2,4-dinitrotoluene [2,4-DNT] at 0.66 µg/L), other hydrocarbons (less than 200 µg/L), and one dioxin (OCDD at 260 picograms per liter [pg/L]) were detected in grab groundwater samples collected from test pits excavated within the landfill. With the exception of the hydrocarbons, none of these compounds has been detected in the groundwater monitoring wells downgradient of the landfill.

Ammunition Renovation/Primer Destruction Site and Stockpiles #1 and #2 - North Valley. The Ammunition Renovation/Primer Destruction Site was an area where ordnance was inspected and refurbished and where ordnance primers were destroyed by burning in a cage. Low concentrations (typically less than 75 mg/kg) of petroleum hydrocarbons in the motor oil range, as well as other hydrocarbons, have been detected in both the near-surface and deeper soil (up to 10 feet bgs) toward the northwest end of the Ammunition Renovation/Primer Destruction Site. Petroleum hydrocarbons in the motor oil range (less than 100 mg/kg) were also detected at depth (30 feet bgs) in the northeast corner of the site. Although the source of the petroleum hydrocarbons in this portion of the North Valley is unknown, it is assumed that the source in the shallow soils is related to historical practices of oiling roads and parking areas for dust suppression.

Toward the southeast corner of the site, other petroleum hydrocarbons (up to 310 mg/kg) were detected in the near-surface soil. Petroleum hydrocarbons in the diesel range were detected in the same area in one sample at a concentration of 220 mg/kg and another at 630 mg/kg at depths of 22 feet bgs and 17.5 feet bgs, respectively. Two geophysical anomalies in this area have been interpreted as possible underground storage tanks (USTs) and associated piping, and are thought to represent the source of the impact.

Low concentrations of PAHs (0.46 mg/kg or less) and moderate levels of petroleum hydrocarbons (1,400 mg/kg or less) were detected in samples from Stockpiles #1 and #2.

Dynamite Burn Site - Ridge. Dynamite was reportedly destroyed by burning in this area. No COIs related to site activities were detected at this site. Analysis of the site grading activities indicate that soil from this area was placed in the McAllister Drive Land Bridge.

Flare Site - South Valley. This area was reportedly used to destroy flares by burning. Five metals related to these activities were identified in soil at the Flare Site. The metals and their maximum-detected concentrations are as follows: antimony (150 mg/kg), barium (20,000 mg/kg), copper (8,100 mg/kg), lead (7,600 mg/kg), and zinc (2,000 mg/kg). Dioxins/furans were also detected at a maximum concentration of 490 picograms per gram (pg/g) (Total tetrachlorodibenzo-furan [TCDF]). Also, potential OE impact was evaluated by USACE in its EE/CA report. This area will be further investigated for chemical impacts after OE clearance activities are completed.

Demolition Site #1 - South Valley. This area was identified as a potential ordnance open burn/open detonation (OB/OD) area because of the distribution of metal anomalies. No COIs related to site activities were detected at this site. Also, the USACE EE/CA report evaluated potential OE in this area. This area will be further investigated for chemical impacts after OE clearance activities are completed.

Demolition Site #2 - South Valley. No COIs related to site activities were detected at this site. In addition, because no physical evidence or ordnance-related activities were found at this site, the site was eliminated from further investigation.

Demolition Site #3 - South Valley. Physical evidence and geophysical studies indicate that this area was used to destroy ammunition by open burn/open detonation. The only COI related to site activities detected in shallow soil at Demolition Site #3 is mercury at a maximum concentration of 2.1 mg/kg. Also, the USACE EE/CA report evaluated potential OE at this area. This area will be further investigated for chemical impacts after OE clearance activities are completed.

South Valley Wetland/Sediment - South Valley. One metal related to site activities (i.e., mercury) was detected in the wetland sediment at a maximum concentration of 11.3 mg/kg. TNT and benzo(a)pyrene were also detected at maximum concentrations of 1.5 mg/kg and 0.094 mg/kg, respectively.

Surface Water. Surface water at the Project Site has not been impacted by site activities.

Groundwater/Seeps. Low concentrations of petroleum hydrocarbons (less than 210 µg/L) have been detected in groundwater samples collected from one well (MW-4A) in the North Valley. Low levels of explosive compounds (TNT, HMX, 2,4-DNT, 4amDNT, and amDNTs) have been detected in grab groundwater samples

and grab seep samples in the North Valley at a maximum concentration of 4.9 µg/L. One PAH (acenaphthylene) was detected in two of the three grab seep samples from the North Valley at less than 5.8 µg/L. One VOC (p-cymene [p-isopropyltoluene] at 0.61 µg/L), and one pesticide (p'p'-DDD at 0.0077 µg/L) were also detected in one of the North Valley grab seep samples.

One explosive compound (3-nitrotoluene) has been detected once in a groundwater sample collected from a well in the South Valley at a concentration of 0.59 µg/L. No explosive compounds were detected in this well during the recent (August 2000) groundwater sampling event, nor were explosives detected in the first monitoring event. The groundwater data from downgradient wells indicate that the low concentrations of explosives and dioxin associated with the unfiltered grab samples in the North Valley are a result of low levels of these compounds in sediment (turbidity) being detected. These low concentrations do not indicate dissolved chemicals in groundwater.

Ridge Area Stockpiles. Soil stockpiles brought to this area from off-site areas exhibit low levels of petroleum hydrocarbons (ranging from 7.7 mg/kg "J" to 53 mg/kg "J"), typical of soil handled by heavy earth-moving equipment.

McAllister Drive Land Bridge. The project records, including the review of aerial photographs, show that soil used to construct the McAllister Drive Land Bridge was obtained from a borrow area situated on the Ridge. Since the former Dynamite Burn Site was situated on the Ridge, soil from the Dynamite Burn Site would be in the lower portion of fill used to construct the land bridge. It is not known if the soil from the Dynamite Burn Site was chemically affected. Soil samples collected from three boreholes near the toe of the land bridge showed low levels of nitrate and nitrite ranging from 0.44 mg/kg to 1.2 mg/kg and from 0.038 mg/kg to 0.042 mg/kg, respectively.

Off-Site Soil Issues. In addition to the impacts listed above within the Project Site boundary, the RI/FS identified two potential off-site issues: (1) adjacent properties to the north and east of the TNT Strips, and (2) off-site fill areas.

All off-site TNT issues will be addressed through confirmation sampling, analysis, and risk assessment during the site remediation (see Table 8-1). If necessary, additional excavation of soils will be undertaken, as needed. A detailed sampling and analysis plan for confirmation sampling will be included in the non-OE Remedial Design Document (non-OE RDD) and all analyses performed will be summarized in a report of findings submitted for DTSC approval, prior to certification and closure of the Project Site.

On August 10, 2000, a Benicia resident reported to local authorities that he had encountered an ordnance-related item on his property. Granite's OE Specialist and USACE have inspected the item and have come to the following conclusions:

- The tail fin is from a mortar.
- The condition of the tail fin indicates that the mortar was destroyed by demolition.

- The mortar had not been fired as evidenced by the unpierced percussion primer at the base of the tail fin.
- Given that no firing ranges have been identified at the former Benicia Arsenal, the likely point of origin for the tail fin was an OB/OD site.
- The tail fin has been determined to be OE scrap.
- A total of 15 tail fins were found during the EE/CA investigation, 5 of which were recovered in Sector 3B (a portion of the Project Site) and 10 were recovered in Sector 5 (the Camel Barn area). USACE designated all these items as OE scrap.
- The tail fin is nonhazardous and does not pose a safety risk.
- There is currently no basis to believe that a dangerous condition exists at the residential lot.
- At this time, additional information is needed to assess the likelihood that OE items exist in areas that have previously received fill soils.

Discussions have occurred between DTSC, USACE, and Granite concerning future activities that are appropriate to address the off-site issue. The following three points have resulted from these discussions:

- During the clearance work to be conducted at the Project Site and the former Benicia Arsenal (the Gonzalves property), additional information regarding potential source areas and the distribution of OE and OE scrap will be obtained. This information, combined with existing information, will be evaluated by DTSC, USACE, and Granite and will be used to determine if further action is warranted.
- USACE is currently developing a Community OE Safety Program. The program focuses on educating the City of Benicia emergency staff on ordnance recognition, proper safety procedures and notification, community education through workshops for adults and children, fact sheets, and newsletters.
- The final site conceptual model will be based on data collected during the point clearance phase of the OE investigation and remediation at the Project Site, which is scheduled to begin in late fall 2001, and during the work at the former Benicia Arsenal, which began in May 2001. Evaluation of the data may be available in the first quarter of fiscal year 2002. Based on the final site conceptual model and consistent with USACE procedure, if DTSC determines that OE was distributed to residential areas outside the Project Site boundary and as a result there is risk that OE items can be encountered in a manner presenting a significant risk of injury or death, then concurrent with the areawide clearance phase of work activities, a plan will be developed in accordance with an order or agreement to identify and address these off-site areas. This plan will be presented to the public. If required, the plan will include an analysis of response alternatives for

these areas. Response alternatives may include the development of a Community Awareness Plan to educate the public, institutional controls, surface clearance of OE, and/or detection and clearance of OE to depth.

RISK ASSESSMENT

A screening-level risk assessment was performed to assess the potential risks to human health and the environment associated with chemicals at the Project Site. This assessment was based on data collected during the RI. The results of the human health and ecological screening assessments were used to identify chemicals to be remediated. Remediation goals were proposed for these chemicals that are protective of both human and ecological receptors. A post-remediation risk assessment will be conducted to evaluate data from confirmation samples and non-remediated areas to ensure that the residual chemical concentrations are protective of human health and the environment.

Human Health Screening Assessment

A Human Health Screening Assessment of current Project Site conditions was conducted separately for chemicals detected in soil in each area of interest and in groundwater and surface water in the North Valley or South Valley. This screening assessment was based on maximum-detected concentrations and readily available screening criteria (U.S. EPA Region IX Preliminary Remediation Goals [PRGs]) to rapidly screen detected chemicals against risk-based criteria to identify chemicals for which remediation goals will be developed. As such, the screening risk estimates are based on a hypothetical resident under current site conditions, and do not take into account that several areas of interest will never be used for residential purposes, and that much of the future residential area will be constructed on top of clean, imported fill material. Additionally, shallow groundwater at the Project Site is not currently used for any purpose, and is not expected to be used in the foreseeable future, due to limited groundwater occurrence and low formation permeability that does not yield sufficient quantities of water for drinking or irrigation purposes. Domestic water will be supplied to the residential development from other sources. Finally, surface water at the Project Site is limited to the wetland in the South Valley, which is outside the area to be developed for residential use. (Intermittent seeps are discussed within the context of groundwater samples.)

Estimated screening-level total excess cancer risks for chemicals detected in soil ranged from 2x10-2 to 5x10-7, depending on the area of interest and whether the naturally occurring metal arsenic was included in the calculation. The estimated screening-level total non-cancer hazard indices ranged from 40 to 0.009, depending on the area of interest and whether the naturally occurring metals iron and manganese were considered in the calculation. Based on these results, several explosive compounds in the TNT Strips area: benzo(a)pyrene and dibenz(a,h)anthracene) in stockpiles in the Ammunition Renovation/Primer Destruction Site or Howitzer Test Facility; and dioxins and furans, antimony, barium, copper, lead, and zinc in the Flare Site contributed most significantly to

the screening risk estimates. Soil remediation goals have been proposed for these chemicals in these areas. Although arsenic, iron, and manganese in some areas of interest contributed to risk estimates, further statistical analysis, cumulative probably plots, comparison to background literature values, and an evaluation of spatial distribution indicate that site soils do not appear to have been impacted by these chemicals. Therefore, no remediation of soils is proposed based on concentrations of arsenic, iron, or manganese at the Project Site. No other chemicals were detected in site soil at concentrations that would contribute significantly to potential health risks to future on-site residents.

Estimated screening-level total excess cancer risks for chemicals detected in groundwater or surface water ranged from 4x10-4 to 1x10-6, and the estimated screening-level total non-cancer hazard indices ranged from 10 to 0.2. The majority of the chemicals that contributed most significantly to the screening risk estimates were metals that may be attributable to ambient conditions. The other chemicals were detected infrequently or only in grab groundwater samples. Based on downgradient well data and the nature of the compounds detected in the grab groundwater samples (relatively insoluble), it is concluded that the trace detections in grab groundwater samples are not representative of groundwater conditions at the Project Site. Based on these results, residual chemicals in groundwater and surface water do not appear to be of human health concern.

Ecological Screening Assessment

An Ecological Screening Assessment of current Project Site conditions was conducted for chemicals detected in soil, surface water, or sediment in areas of the site where wildlife habitat will remain following post-grading and redevelopment activities (i.e., North Valley grassland, and South Valley freshwater marsh wetland and surrounding upland grassland areas). This screening assessment was based on a comparison of maximum-detected concentrations and ecological screening criteria for terrestrial, aquatic, or sediment-dwelling organisms to rapidly screen detected chemicals against risk-based criteria to identify chemicals for which remediation goals will be developed.

Several explosive compounds in soil at the TNT Strips; antimony, barium, copper, lead, and zinc in soil at the Flare Site; and mercury in soil at Demolition Site #3 were detected at concentrations greater than their respective soil screening criteria and found to warrant further consideration. Soil remediation goals have been proposed for these chemicals in these areas. The only chemical in surface water detected at concentrations greater than the water screening criteria was aluminum. Aluminum poses a threat to aquatic organism only in low pH and low hardness waters, whereas surface water in the wetland is believed to have a neutral pH (based on measurements of site groundwater) and hardness of approximately 400 milligrams per liter as $CaCO_3$ (based on measurements of calcium and magnesium in surface water). Therefore, no remediation goal is proposed for aluminum in surface water.

With regard to sediment, copper, iron, manganese, and mercury were detected at concentrations above their respective screening criteria for sediment-dwelling

organisms. However, the exceedance of a screening criterion in sediment is insufficient evidence by itself to warrant remediation, and further evaluation of the available data indicates that (1) sediment does not appear to have been impacted by copper, (2) iron is normally present at percent levels and generally only bioavailable (and potentially toxic) in acidic (low pH) conditions, (3) the maximum-detected concentration of manganese in sediment is essentially equivalent to its sediment quality criterion, and other sediment samples contained manganese at concentrations well below the screening criterion, and(4) only three of ten surface sediment samples had mercury concentrations exceeding the screening criterion, the average mercury concentration in these samples is only slightly greater than the screening criterion, and a remediation goal will be established for mercury-affected soil upland of the South Valley wetland. Therefore, no remediation goal is proposed for copper, iron, manganese, and mercury in sediment.

Three of the chemicals in sediment were considered to be potentially bioaccumulative (benzo[b]fluoranthene, methyl mercury, and 2,4,6-trinitrotoluene). No relevant toxicity data were available for TNT and benzo(b)fluoranthene; however, these chemicals were found at low concentrations in sediment and below screening criteria for sediment-dwelling organisms. The maximum concentration of methyl mercury was below it screening criterion indicating that the risk of bioaccumulation from sediment is negligible. Therefore, no remediation goals were proposed for these chemicals in sediment.

Soil Remediation Goals

Soil remediation goals were developed for specific chemicals in specific areas that may pose a potential risk to human health under the conservative baseline residential conditions or a potential risk to ecological receptors using conservative ecological screening criteria. The proposed soil remediation goals for the identified metals are the calculated upper tolerance limit (UTL) of the ambient soil samples. These concentrations are protective of both human and ecological receptors. The proposed soil remediation goal for dioxins and furans is based on ambient concentrations, whereas the proposed remediation goal for the PAHs is non-detect. Although not necessary to protect human health or the environment, a soil remediation goal was proposed for TPH based on California Regional Water Quality Control Board risk-based screening levels for protection of groundwater (1995). Finally, the proposed soil remediation goals for explosive compounds were based on the lowest risk-based levels calculated for protection of human and ecological receptors.

Table ES-1 provides the soil remediation goals that have been established to satisfy the remedial action objectives (RAOs) for the Project Site.

Post-Remediation Risk Assessment

A post-remediation risk assessment will be conducted to ensure that the residual chemical concentrations are protective of human health and the environment. This assessment will be based on data collected from confirmation samples and in areas that were not remediated, and will be completed in accordance with standard state and federal guidance for baseline risk assessments. The post-

Table ES-1. Soil Remediation Goals

	Remediation Goal	Area of Cleanup
Metals in Soil		
Antimony	2.84 mg/kg	Flare Site
Barium	642 mg/kg	Flare Site
Copper	87.7 mg/kg	Flare Site
Lead	148 mg/kg	Flare Site
Mercury	0.77 mg/kg	Demolition Site #3
Zinc	142 mg/kg	Flare Site
Organic Compounds in Soil		
Dioxins	12 pg/g[a]	Flare Site
2,4,6-TNT	16 (residential) mg/kg[b]	TNT Strips
2,4,6-TNT	53 (recreational) mg/kg[b]	TNT Strips
2,6-DNT	non-detect (PQL = 0.5 mg/kg)[c]	TNT Strips
benzo(a)pyrene	non-detect (PQL = 0.03 mg/kg)[c]	Ammunition Renovation/Primer Destruction Site - Stockpiles #1 and #2
dibenz(a,h)anthracene	non-detect (PQL = 0.05 mg/kg)[c]	Howitzer Test Facility - Stockpile #3
TPHs	500 (residential) mg/kg[d]	Areas to be determined based on potential UST

Notes: (a) Dioxin concentrations are expressed in terms of 2,3,7,8-TCDD TEQ.

(b) Individual remediation goals for all other explosives detected in soils have not been proposed. This decision is based on cumulative risks indicating that explosive compounds are likely to be below de minimus risk levels if TNT and 2,6-DNT are removed to remedial goals.

(c) Goals are estimated PQL values. Because these are laboratory-specific numbers, they may change once the laboratory for the remedial action phase has been selected. DTSC will be notified if there are changes in the PQL from the values noted.

(d) This value will be used as a basis for remediation of the North Valley.

DNT = dinitrotoluene
DTSC = Department of Toxic Substances Control
mg/g = milligrams per gram
pg/g = picograms per gram
PQL = Practical Quantitation Limit
TCDD = tetrachlorodibenzo-p-dioxin
TEQ = Toxicity Equivalence
UST = underground storage tank

remediation risk assessment will be used to help identify any additional areas requiring evaluation, if necessary, and to identify the final clean-up levels for the Project Site that are protective of human health and ecological impacts.

REMEDIAL INVESTIGATION AND RISK ASSESSMENT RECOMMENDATIONS AND CONCLUSIONS

Based on the risk analysis documented in Chapter 7.0, the following conclusions and recommendations are made about the sites.

Sites Requiring Remediation or Further Investigation

TNT-Strip Areas. Detected concentrations of TNT and associated explosive compounds were determined to exceed human and ecological screening criteria. This site is recommended for remediation. Additional extent and confirmation sampling is proposed to define the lateral and vertical extent of soils requiring remediation.

Howitzer Test Facility and Stockpile #3. Detected concentrations of dibenz(a,h,)anthracene exceed human health screening criteria in Stockpile #3. It is planned to remove the stockpiled material from the sites for appropriate disposal at an off-site facility. Confirmation sampling beneath the stockpile will be conducted following removal to verify that all impacted soil has been removed. No further action is recommended for the remainder of the Howitzer Test Facility.

Ammunition Renovation/Primer Destruction Site and Stockpiles #1 and #2. Detected levels of benzo(a)pyrene exceed human health screening criteria in Stockpiles #1 and #2. It is planned to remove the stockpiled material from the site for appropriate disposal at an off-site facility. Confirmation sampling beneath the stockpiles will be conducted following removal to verify that all impacted sol has been removed. No further action is recommended for the remainder of the Ammunition Renovation/Primer Destruction Site, except for the area where the UST investigation will occur.

Flare Site. Detected concentrations of antimony, barium, copper, lead, and zinc exceeded human health and ecological screening criteria and dioxin levels also exceeded human health screening criteria. This site is recommended for remediation.

Demolition Site #1. Based on sampling to date, detected concentrations of COIs at Demolition Site #1 do not exceed human or ecological screening criteria, and no further action is required. Because geophysical anomalies prevented complete characterization of the site, additional sampling will be conducted during the OE point clearance activities, and the data will be included in the post-remediation risk assessment.

Demolition Site #3. Detected concentrations of mercury did not exceed human health screening criteria but did exceed ecological screening criteria. This site is recommended for remediation.

Ridge Area Stockpiles. Low concentrations of oil were detected below human health and ecological screening criteria. Additional testing is proposed during

remediation to assess if the stockpiled soils can be used as fill in the North Valley or must be hauled off site to a suitable landfill.

McAllister Drive Land Bridge. Based on sampling to date at the McAllister Drive Land Bridge, detected concentrations of chemicals do not exceed human health screening criteria. At the request of DTSC, additional characterization of the McAllister Drive Land Bridge will be conducted.

Groundwater, Seeps and Surface Water. The maximum concentrations of three detected metals in groundwater exceeded human health screening criteria based on the ingestion of groundwater. Groundwater is not currently used for any purpose and is not expected to be used in the foreseeable future because of the limited amount of groundwater available. General water quality will continue to be evaluated at the site through a focused groundwater monitoring program. No impact to surface water was identified in the South Valley and no further action is recommended.

Sites Requiring No Further Action

North Valley Landfill. Chemicals detected in the North Valley Landfill do not exceed human health screening criteria, and the screening-level risk estimates were near "J" or below benchmark levels of $1x10^{-6}$ or an HI of 1. No further action is recommended.

Dynamite Burn Site. No COIs were identified at the Dynamite Burn Site and no further action is recommended.

Demolition Site #2. No evidence DOD of activities was found at this site and it was eliminated from further investigation.

FEASIBILITY STUDY

An FS was completed to identify a range of alternatives to remediate OE and chemically affected soil and address groundwater at the Project Site. The FS utilized data and analyses generated as part of the RI and screening-level Health Risk Assessment to develop potential alternatives for COIs in soil.

The FS process was completed in accordance with U.S. Environmental Protection Agency (EPA) guidance (1988), the National Contingency Plan (EPA, 40 Code of Federal Regulations Part 300), and the California Environmental Quality Act (CEQA). This process included the identification and screening of remedial technologies and process options, and the development, screening, and analysis of comprehensive alternatives to meet the RAOs and other regulatory requirements.

A total of 13 potential alternatives were initially considered in the FS. These alternatives were screened to focus on those alternatives with the greatest potential to remediate the Project Site. In addition, the No-Action/No Project alternative was evaluated and retained, in accordance with EPA and CEQA guidelines.

Portions of the Project Site are zoned for residential use. Accordingly, only remedial alternatives consistent with residential standards were carried through the full evaluation process in the FS.

The following eight alternatives were carried forward for detailed analysis:

Alternative 1. No-Action.

Alternative 2. Institutional Controls and Monitoring

Alternatives 5A and 5B. OE point clearance over the entire Project Site; areawide OE clearance in the North Valley and Ridge areas having a potential for containing OE and intended for future residential use, as well as overburden soil and soil fill associated with Unit D-1 lots; excavation, treatment, and disposal of chemically affected soil above RAOs; installation of a layer of crushed bedrock in future residential areas; and institutional controls and monitoring.

Alternatives 6A and 6B. Include Alternative 5 components plus the excavation of the South Valley potentially OE-impacted soil and placement in the North Valley and adjacent to the South Valley wetlands; with additional geophysical scanning of potentially OE-impacted soil in lifts during placement.

Alternatives 8A and 8B. Include Alternative 5 components plus the excavation of the South Valley potentially OE-impacted soil and replacement in the South Valley; with additional geophysical scanning of potentially OE impacted soil in lifts during placement in South Valley.

Alternatives 5A, 6A, and 8A include testing of soils during remedial activities and treatment by homogenization of soils containing TNT concentrations greater than 10 percent to levels acceptable for off-site transport and disposal. Alternatives 5B, 6B, and 8B include composting to treat soil containing TNT to nonhazardous levels acceptable for off-site transport and disposal. If treated soil meets all RAOs, it may be left on site.

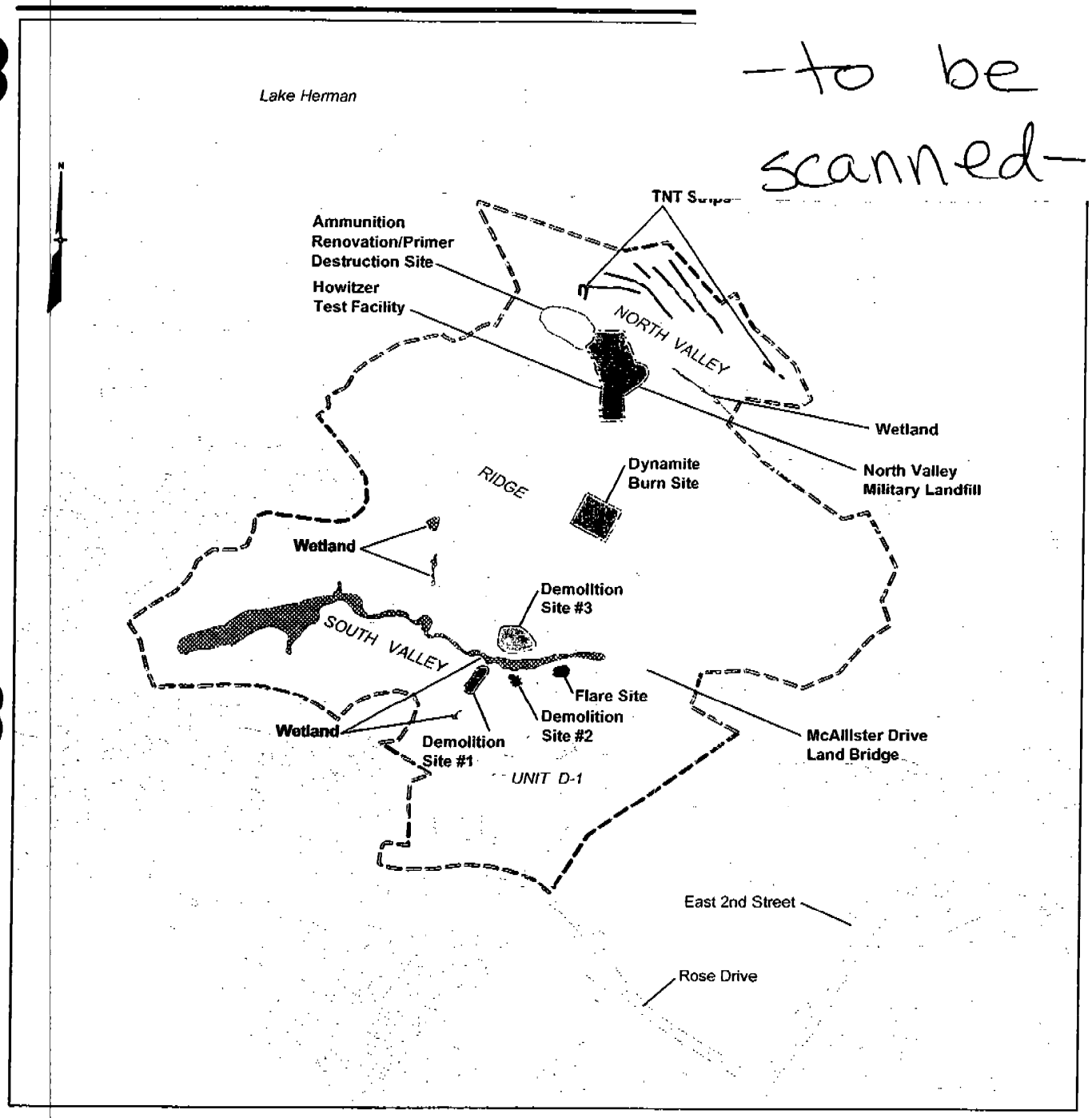
The above alternatives were evaluated in detail, in accordance with the nine criteria specified in the National Oil and Hazardous Substance Pollution Contingency Plan and EPA guidance. Alternatives 1 and 2 would not satisfy the RAOs or provide long-term permanent remedies for OE and chemically affected soils at the Project Site. Alternatives 5, 6, and 8 would achieve the RAOs and effectively remediate the Project Site. These alternatives would remediate all areas of interest. Alternatives 5, 6, and 8 vary primarily with respect to the location and quantity of soil in the South Valley that would be remediated for OE using areawide clearance procedures. There would be potential short-term impacts for all alternatives related to excavation and construction activities, and implementation of a minimum separation distance when remediating the Project Site for OE.

Alternative 5A is the recommended alternative, since this alternative is OE protective, reduces the environmental and aesthetic impacts to the South Valley, includes point clearance and areawide clearance in residential areas having a potential for containing OE, and includes removal and disposal of chemically affected soil exceeding RAOs. Future residential areas would be founded on bedrock. Soils removed through areawide clearance would be covered with 14 feet

of OE-free crushed bedrock or with a minimum of 4 feet of crushed bedrock and underlain by bedrock, following placement of areawide clearance soil in the North Valley. Institutional controls would be applied to limit future excavation in the paved portions of the McAllister Drive Land Bridge and Unit D-1 paved areas, as well as in the North Valley and South Valley. After remediation, additional groundwater monitoring wells would be installed at the east and west ends of the North Valley and at the east end of the South Valley to monitor groundwater in the alluvium and bedrock. In addition, water quality sampling would be performed for a specified period on water from the North Valley subdrain system and any surface water and seeps in the North Valley and South Valley.

color picture

-to be scanned-



EXPLANATION

Project Site Boundary

0' 450' 900'

SCALE

Note: Contour interval equals 25 feet.

FINAL

Figure ES-1
Project Site Layout Map

Tourtelot Cleanup Project
Benicia, California

July 2001

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1.0 INTRODUCTION

This Remedial Investigation/Feasibility (RI/FS) Study report presents the results of the soil and water quality RI and the characterization of the nature and extent of ordnance and explosives (OE) at the Tourtelot OE Remediation Project Site in Benicia, California (Project Site). This RI/FS is being submitted in response to the Imminent and/or Substantial Endangerment Order (Docket No. I/SE 98/99-011) (the "Order"), signed June 1, 1999, and issued for the Project Site by the California Environmental Protection Agency (Cal/EPA), Department of Toxic Substances Control (DTSC).

For the purposes of this document, OE is defined as ammunition, ammunition components, and explosives that have been abandoned, lost, discarded, and buried, as well as explosives that have been expelled from demolition pits or burning pads. OE also includes mixtures of explosives in soil, sand, clay, or other solid media at concentrations such that the mixture itself is potentially explosive (i.e., the media contains 10 percent or more by weight of explosives). The term "non-OE" refers to chemical compounds associated with the use of OE, or derived from the use of OE, as well as any other chemical that may be associated with past use of the Project Site. Collectively, the results of the investigation of chemical compounds is referred to as the non-OE RI. Results of the non-OE RI and the OE investigation and partial removal activities at the Project Site were both used to develop remedial alternatives. The alternatives, including the recommended alternative, are presented and evaluated in the FS portion of this document. The final remedial action alternative for the Project Site will be presented in the Remedial Action Plan (RAP).

1.1 OBJECTIVE AND APPROACH

The objectives of the non-OE RI were to (1) evaluate the nature and extent of chemicals that may have impacted the soil, sediment, surface water, and/or groundwater as a result of Department of Defense (DOD) or other activities at the Project Site; (2) identify potential exposure pathways through environmental media; and (3) assess whether there has been a release at the Project Site and if there have been impacts to public health or the environment. The non-OE field investigation work was generally performed using ordnance avoidance techniques. The objective of the investigation was to characterize the extent of chemically impacted soil sufficiently enough to develop and evaluate remedial action alternatives. The ultimate goal was to remediate portions of the Project Site to levels acceptable for residential land use. Other activities that may have impacted the Project Site have been addressed in this document; specifically, the placement of debris stockpiles (consisting of soil, concrete, and asphalt) on the Project Site that were derived from off-site construction.

Chemicals of interest (COI), as defined in this document, consist of organic and inorganic constituents known or suspected of representing impacts associated to site activities.

In order to achieve the non-OE RI goal described above, Data Quality Objectives (DQOs) were developed to generate data of sufficient quantity and quality to meet the specific objectives, as well as to assist in project decision making. Integral to this process was a review of the following information:

- *Benicia Arsenal Records Research Report (RRR), Final* (Jacobs Engineering, 1999)
- *Archives Search Report (ASR) Findings* (U.S. Army Corps of Engineers, St. Louis District, 1994a), *ASR Conclusions and Recommendations* (U.S. Army Corps of Engineers, St. Louis District, 1994b), and *Supplement to the March 1994 ASR for Benicia Arsenal* (U.S. Army Corps of Engineers, St. Louis District, 1997)
- Historical aerial and ground-level photographs (Appendix A)
- Previous geologic and geotechnical investigation data (see Section 3.1)Previous analytical data (see Section 3.2)
- Sitewide geophysical survey data (see Section 3.3 and Chapter 10.0).

The DQO development process is described in the U.S. Environmental Protection Agency (EPA) guidance documents entitled *Guidance for the Data Quality Objectives Process* (U.S. Environmental Protection Agency, 1994a) and *Data Quality Objectives Process for Superfund: Interim Final Guidance* (U.S. Environmental Protection Agency, 1993a). DQOs are qualitative and quantitative statements developed by data users to specify the quality and quantity of data from field and laboratory data generation activities required to support project decision making or regulatory actions, while minimizing data collection expenditures by defining data requirements and acceptable levels of decision errors during the planning stages of a project. The DQO process provides a systematic procedure for defining the criteria that a data collection design should satisfy, including when and where to collect samples, the tolerable level of decision errors for the study, and how many samples to collect. The final product of the DQO process is a Sampling and Analysis Plan (SAP) and associated Quality Assurance (QA) Project Plan (QAPP); together, they present a data collection design that meets the quantitative and qualitative needs of the study. The DQOs were periodically reviewed during the non-OE RI as additional information became available to ensure they still met the needs of the project.

Non-OE RI data were collected during four phases of investigative fieldwork conducted between May 1999 and August 2000. The four phases of this fieldwork are identified in this document as follows: the interim investigation; the RI; the data gaps investigation; and the removal action investigation.

An iterative and focused approach was used for the non-OE RI. The interim investigation, conducted May through July 1999, was the initial phase of investigative fieldwork. Based on the history of the Project Site (see Section 2.3) and the results of the interim investigation, the following "areas of interest" were identified for further investigation:

North Valley

- 2, 4, 6-Trinitrololuene (TNT) Strips
- Howitzer Test Facility and associated Stockpile #3
- North Valley Military Landfill
- Ammunition Renovation/Primer Destruction Site and associated Stockpiles #1 and #2.

Ridge

- Dynamite Burn Site.

South Valley

- Flare Site
- Demolition Site #1
- Demolition Site #2
- Demolition Site #3.

These specific areas of interest represent potential "release sites" resulting from DOD activities at the Project Site. The "boundaries" defined for each area of interest were based on a combination of historical records, aerial photographic review, field observations, topography, and site geophysical data. The potential impact of these sites, beyond the limits of each area of interest, was also studied through investigation of the following:

- North Valley groundwater
- South Valley wetland sediment and surface water
- South Valley groundwater
- McAllister Drive Land Bridge.

A number of debris stockpiles situated on the Ridge between the North and South Valleys were also investigated as part of the non-OE RI. These stockpiles are considered "other activities" not related to DOD activities at the Project Site. The stockpiled material, consisting predominantly of soil with some concrete, is from development activities adjacent to the Project Site and was placed on the Ridge by Granite Management Corporation (Granite) beginning in mid-1990. The Ridge stockpiles were included in the non-OE RI to assess potential site impact and to determine eventual disposition of the stockpiled material.

Data from the interim investigation, which was conducted prior to the development of a formal work plan, were used in the development of a Conceptual Source and Transport Model and DQOs for each area of interest. The Conceptual Source and Transport Model, DQOs, and resulting SAP and QAPP are presented in Chapters 1.0, 2.0, and 3.0 of the *Final Non-Ordnance and Explosives Remedial Investigation (RI)/Feasibility Study (FS) Work Plan*, dated February 15, 2000 ("Final Work Plan") (Earth Tech, 2000b). It should be noted that the RI was conducted in December 1999 after preparation of the *Draft Final Non-Ordnance and Explosives Remedial Investigation (RI)/Feasibility Study (FS) Work Plan*, dated November 16, 1999 ("Draft Final Work Plan") (Earth Tech, 1999c), and after conditional approval of the *Remedial Investigation/Feasibility Study Site-Specific Health and Safety Plan, Benicia, California*, dated November 5, 1999 ("HASP") (Earth Tech, 1999a), and associated amendments to the HASP. The amendments to the HASP were subsequently incorporated into the *Draft* and *Final Tourtelot Cleanup Project Site-Specific Safety and Health Plans* ("SSHP"), dated February 9 and March 27, 2000, respectively (Earth Tech, 2000a, 2000e). On April 3, 2000, DTSC approved the SSHP provided that specific changes were incorporated into the document. All of the changes were incorporated, and a Final SSHP was issued on September 29, 2000 (Earth Tech, 2000g). In a DTSC letter dated November 24, 1999, it was requested that additional sampling and analysis be incorporated into the RI program. These additional requirements were completed during the RI and subsequently incorporated into the Final Work Plan. The Final Work Plan has not been approved by the DTSC; however, the DTSC concurred that the non-OE RI could proceed at Granite's own risk. Comments on the Final Work Plan have been addressed in this document.

The RI data were used to update the project DQOs, SAP, and QAPP. The updated DQOs and SAP are presented in Section 5.0 of the *Technical Memorandum for Remedial Investigation*, dated March 2, 2000 (the "Tech Memo") (Earth Tech, 2000c); an addendum to the QAPP is presented in Appendix A of the same document. A preliminary QA review of the RI data by Earth Tech revealed a number of data gaps that needed to be filled in order to meet the non-OE RI objectives. In addition, data gaps were identified by the DTSC and the U.S. Army Corps of Engineers (USACE), Sacramento District (CESPK). The data gaps investigation, presented in the Tech Memo, was conducted between February and May 2000. Additional phases of work to the data gaps investigation were conducted in June 2000 and August 2000 after the scope of the additional work was submitted to DTSC in three letters dated June 5, 2000, July 31, 2000, and August 21, 2000, respectively. These letters served as addenda to the Final Work Plan (Earth Tech, 2000b) and the Tech Memo (Earth Tech, 2000c).

The removal action investigation for the North Valley Military Landfill was conducted in May and June 2000. This investigation could not be incorporated into any of the previous investigations since this investigation required potential "OE removal" in order to complete the fieldwork, rather than "OE avoidance," which was practiced during the interim, remedial, and data gaps investigations. The removal action investigation SAP is presented in Chapter 8.0 of the *Removal Action Work Plan*, dated May 9, 2000 (the "RAW") (Earth Tech, 2000f).

Data from each phase of the non-OE RI are presented and evaluated in the following chapters of this document. All analytical results have been fully verified and validated in accordance with the QAPP, unless otherwise stated. The analytical data collected during the non-OE RI were determined to have met the DQOs.

As data became available during the non-OE RI process, it was necessary to reevaluate the DQOs required to achieve the ultimate goal of remediating the Project Site to levels acceptable for residential land use. At the start of the non-OE RI process, DQOs were established to facilitate "clean closure" of the Project Site (i.e., all identified COIs would be remediated to background levels or non-detect). For certain COI, it became apparent that to reduce the concentrations detected at the Project Site to background levels or non-detect was neither practical nor technically feasible. Therefore, data from the non-OE RI were used in a screening-level Health Risk Assessment (HRA) to evaluate the human health and ecological risks posed by exposure to the COI. The DQOs established for a clean closure approach were reviewed and determined acceptable for the screening-level HRA approach.

The objectives of the FS portion of this document are (1) to develop remedial action objectives (RAOs) for soil that are protective of human health and the environment; and (2) to develop and evaluate a range of alternatives that would remediate a portion of the Project Site to levels acceptable for residential land use, including measures that would create a layer of OE-free material of sufficient thickness to protect future residents and service workers from coming in contact with soil cleared from areas that could potentially contain OE.

1.2 REGULATORY FRAMEWORK

The RI/FS was conducted in response to the Order issued by DTSC for the Project Site. The responsible parties for the RI/FS include Granite (the current owner of the Tourtelot Property) and the USACE. DTSC is the lead agency overseeing the investigation and remediation of the Project Site.

The RI/FS was based on *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (Comprehensive Environmental Response, Compensation, and Liability Act) (U.S. Environmental Protection Agency, 1988). However, due to the need to use ordnance avoidance techniques in some areas of the Project Site, complete characterization and/or definition of vertical and lateral extent of the COI was not achieved during the non-OE RI. Additional investigation will be performed after the sitewide OE point clearance, and during the subsequent site remediation through the use of confirmation sampling and standard investigation methods. A human HRA and an ecological risk assessment will be conducted to verify that the Project Site remediation goals have been achieved and all regulatory requirements have been met. Further sampling and/or remediation will be conducted if remediation goals have not been reached as a result of the cleanup, or post-remediation risk assessments show an unacceptable hazard or risk.

1.3 REPORT ORGANIZATION

This document is organized as follows:

- **Chapter 1.0: Introduction** - presents the overall project objectives and approach, regulatory framework, and report organization.
- **Chapter 2.0: Site Background Information** - presents project location and description, environmental setting, regional geology and hydrology/hydrogeology, history of the Project Site, including a summary of past grading activities.
- **Chapter 3.0: Previous Investigations** - presents a summary of previous site investigations, including work performed by ENGEO, Inc. (ENGEO), SECOR International, Inc. (SECOR), as well as Earth Tech.
- **Chapter 4.0: Non-OE Remedial Investigation Program** - presents a summary of the scope of work for the four phases of field investigation work that comprise the non-OE RI, as well as a discussion of the site-specific geology and hydrology/ hydrogeology. This chapter also presents a summary of the COI and Conceptual Source and Transport Model used in the determination of the scope and rationale for the various field sampling programs.
- **Chapter 5.0: Non-OE Remedial Investigation Analytical Results** - presents the verified and validated analytical data from each phase of the non-OE RI at the Project Site.
- **Chapter 6.0: Nature and Extent of Chemicals of Potential Concern** - summarizes the COI detected at reportable concentrations at the Project Site, specific media impacted (i.e., soil, sediment, surface water, groundwater), and an evaluation of the nature and extent within the affected media.
- **Chapter 7.0: Risk Assessment** - presents an evaluation of the human and ecological risks posed by exposure to non-OE COI determined to be neither practical nor technically feasible to remediate to ambient levels or non-detect.
- **Chapter 8.0: Non-OE Remedial Investigation Conclusions** - presents a summary of the non-OE RI in terms of the scope and objectives defined in Chapter 1.0.
- **Chapter 9.0: Ordnance and Explosives Remedial Investigation** - presents a summary and evaluation of currently available OE data.
- **Chapter 10.0: Identification and Screening of Technologies** - presents the goals and objectives of proposed remedial actions and the areas requiring remediation. This chapter also identifies and evaluates the potential technologies and process options to achieve the RAOs.

- **Chapter 11.0: Development and Screening of Alternatives** - develops and screens preliminary remedial action alternatives for the Project Site in accordance with the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) and EPA guidelines. This screening process has been integrated with the California Environmental Quality Act (CEQA) requirements to identify a reasonable range of alternatives for the environmental impact report (EIR) being completed for the Project Site.

- **Chapter 12.0: Detailed Analysis of Alternatives** - provides a more detailed description of the proposed remedial action alternatives and a comparative analysis of the alternatives in accordance with the NCP criteria and EPA guidance. This screening analysis has been supplemented to include an impact analysis of the affected environment pursuant to the requirements of CEQA.

- **References** - presents a list of references used in support of this document.

Supporting information to the RI/FS is included in Volumes II through IV of this document. Associated figures are included in Volume II and IIa. The following appendices are included in Volume III: Appendix A - updated review of historical aerial photographs; Appendix B - previous investigation borehole logs and trench/test pit schematics prepared by ENGEO; Appendix C - summary of the fieldwork performed by Earth Tech during the non-OE RI, including borehole logs, well construction logs, and field forms; Appendix D - field permeability testing data; Appendix E - metals and other inorganic COIs statistical data prepared by Earth Tech; Appendix F - Health Risk Assessment Discussion prepared by Exponent Failure Analysis; Appendix G - OE geophysical investigations equipment and procedures and sitewide OE data prepared by Earth Tech; and Appendix H - an analysis of regulatory requirements prepared by Earth Tech and remedial cost estimates prepared by Northgate Environmental Management, Inc. Data Quality Control Summary Reports (QCSRs) prepared by Earth Tech for each investigative phase of the non-OE RI are presented in Volume IV.

In addition, copies of the Certified Analytical Reports for each phase of the non-OE RI, provided by the analytical laboratories, have been forwarded to DTSC and USACE, and copies of the aerial photographs included in Appendix A have been provided to DTSC and placed in the public information repository for the Project Site at the Benicia Library, located at 150 East L Street, Benicia, California 94510 (Telephone: 707 746-4351).

2.0 SITE BACKGROUND INFORMATION

This chapter presents a summary of site background information including a general site description, overall environmental setting, regional descriptions of geology and seismicity, hydrology, and hydrogeology, and the history of the Project Site from its use by the U.S. Army, as part of the Benicia Arsenal, through the most recent grading activities and the discovery of OE.

2.1 PROJECT LOCATION AND SITE DESCRIPTION

The Project Site is situated completely within the City of Benicia, Solano County, California, approximately 25 miles northeast of San Francisco and approximately 2 miles north of the Carquinez Strait, which connects San Pablo Bay to the west and the Sacramento Delta to the east (Figure 2-1). Consisting of approximately 220 acres, the Project Site is partially within the boundaries of the former Benicia Arsenal (Figure 2-2). The Project Site encompasses the Tourtelot Property, and includes portions of adjoining properties owned by the City of Benicia and FN Projects, Inc. (an affiliate of Granite), and a portion of a parcel owned by the Valero Energy Corporation (formerly owned by Exxon Corporation) (Figure 2-2A). The Project Site has rolling topography that includes areas referred to as the "Ridge," which separates the North Valley and the South Valley, both of which have areas of steep terrain (Figure 2-3). Both the North Valley and South Valley contain wetland areas, the one in the South Valley being considerably larger. The Project Site is bordered by the Southampton residential development to the west and south, a refinery to the southeast, industrial and commercial facilities to the east, open space to the north and northeast, and the Lake Herman Recreational Area to the northwest.

2.2 ENVIRONMENTAL SETTING

This section describes the environmental setting of the Project Site, including climate, topography, geology, groundwater, surface water, air quality, biological resources, and demographics.

2.2.1 Climate

Climate in the City of Benicia is described as "temperate and Mediterranean," resulting in warm summers and moderate winters (City of Benicia, 2000). The nearest weather station to the City of Benicia is in Martinez, California (approximately 2.5 miles to the south-southeast of Benicia on the south shore of the Carquinez Strait). Climatological data from the Benicia area indicate the following:

- Average rainfall of 18.5 inches per year (falling mostly from December through April) within a "rain shadow" due to the hilly terrain

- Mean annual temperature of 63 degrees (°) Fahrenheit (F) with average winter daily maximums and minimums of mid- to high 50s and high 30s to low 40s, respectively, and average summer daily maximums and minimums of high 80s and mid-50s, respectively
- Prevailing winds from the west to the southeast, with average annual wind speed of 8.2 miles per hour (mph) and the strongest winds in the afternoon when wind speeds of 15 to 20 mph are common.

2.2.2 Topography and Drainage

The City of Benicia is situated in an area of coastal mountain ranges, inland valleys, and bays. The Project Site is in a hilly area dominated by a central-northwesterly-trending ridge (referred to as the "Ridge") that acts as a drainage divide between a major drainage swale to the south, referred to as the South Valley, and a smaller drainage swale to the north, referred to as the North Valley. Project Site elevations range from approximately 60 feet to 250 feet above mean sea level (MSL) in the South Valley and 110 feet to 260 feet above MSL in the North Valley. The flat top of the Ridge, which was excavated as part of previous grading activities (see Section 2.3.3), is presently approximately 230 feet above MSL toward the southeast end and approximately 260 feet above MSL toward the northwest end. The maximum current elevation on the ungraded western portion of the Ridge is approximately 300 feet above MSL.

2.2.3 Regional Geology

The Project Site is in the northwesterly-trending hills north of the Carquinez Strait of San Francisco Bay within the eastern foothills of the Coast Ranges Geomorphic Province. The Coast Ranges are a series of north-to-south-oriented mountains extending from the southern limit of the Klamath Mountain block in Oregon to the north boundary of Santa Barbara County. The Sulphur Springs Mountains begin at Benicia and stretch northwest, forming a ridge that defines the eastern flank of the Napa Valley. Lake Herman is situated along the northwest boundary of the Project Site at the southern terminus of the Sulphur Springs Mountains. The nearby Carquinez Strait, south of the Project Site, is a submerged canyon cutting through the Coast Ranges formed by the ancestral flow of the Sacramento and San Joaquin River drainages. The strait is a narrow, deep channel cut simultaneously with the uplift and folding of the Coast Ranges. Connecting the Sacramento and San Joaquin rivers with the San Francisco Bay, the strait is tidally influenced; there is a gradual change from seawater in the San Francisco Bay to the west to brackish water in the Sacramento Delta to the east.

As shown on the geologic map of the Santa Rosa Quadrangle (Wagner and Bortugno, 1982), the geologic units in the region consist of Lower Cretaceous to Upper Jurassic marine, clastic, sedimentary rocks, referred to as the Great Valley Sequence. The Great Valley Sequence is extensively distributed in the Coastal Ranges to the west and the Sierran foothills to the east.

The Project Site is underlain by several thousand feet of shales of the Cretaceous Panoche Formation (Dibblee, 1980) (Figure 2-4). The Panoche Formation consists primarily of marine micaceous shales, but includes minor thin interbeds of siltstone and sandstone. The lack of diagnostic fossils or marker beds makes it virtually impossible to correlate the Panoche Formation from one location to another. The Panoche Formation is often overlain by the Domengine Sandstone, a quartzitic sandstone that is 250 to 300 feet thick. It is distinctive in both borehole cuttings and in outcrop, and is the primary marker unit in the area; however, the Domengine Sandstone has not been identified at the Project Site.

The regional trend of bedding is northwest-southeast strike and moderate dips to the southwest. The regional geologic structural framework consists of a series of east- and west-dipping thrusts. The Southampton Thrust, west of Benicia, is a back-thrust of the Franklin Thrust that forms the mouth of the Delta. The Sulphur Springs Thrust extends north-south along the bottom of the valley just east of the Project Site. Bedrock trends in the Project Site are controlled by small thrusts that splay from the Sulphur Springs Thrust. None of the thrusts is considered active (ENGEO, Inc., 1989a).

Site-specific geology is further discussed in Section 4.3.

2.2.3.1 Seismicity and Faulting.

The Project Site is situated in a highly seismic region that has been subjected to several strong historic earthquakes during the last two centuries. Earthquakes have occurred over the entire region, but most have been concentrated along known active fault traces, such as the San Andreas, Hayward, and Calaveras fault zones. The great 1906 earthquake on the San Andreas fault had an epicenter 38 miles west of Benicia and subjected the Benicia area to a Modified Mercalli Intensity (MMI) of VIII (moderate damage). Other earthquakes that reportedly caused damage in Benicia include the October 21, 1868, earthquake along the Hayward fault with an MMI of X and IX in the epicentral area; the 1892 Vacaville earthquake; the October 1, 1969, Santa Rosa earthquake (Richter Scale Magnitude 5.7) on the Rodgers Creek fault; and the October 1989 Loma Prieta earthquake (Richter Scale Magnitude 7) along the San Andreas fault. The closest recorded major earthquake to the Project Site was a Richter Scale Magnitude 5.4 earthquake on October 23, 1955, which had an epicenter on the Concord fault, between Walnut Creek and Concord, approximately 9 miles southeast of the Project Site. In Benicia, damage was limited to cracked plaster and chimneys. This brief historic account of earthquake activity suggests that the Project Site will be subjected to very strong earthquake shaking in the future.

Active and potentially active faults (Figure 2-5) that could be the source of strong earthquakes in the project region include the Concord fault, situated 2-1/2 miles to the southeast of the Project Site, the Green Valley fault (2 miles east of the Project Site), the Southampton fault (1-1/2 miles west of the Project Site), the Calaveras-Franklin fault (6 miles southwest of the Project Site), the Hayward fault

(12 miles southwest of the Project Site), the Rodgers Creek fault (18 miles northwest of the Project Site), and the San Andreas fault (30 miles west of the Project Site).

Numerous faults were mapped in the Benicia area, including the Project Site. However, based on previous fault investigation (including trenching), there is no evidence to indicate that the faults are active or potentially active (ENGEO, Inc., 1989a).

2.2.4 Groundwater Occurrence

Groundwater occurs intermittently at the Project Site in the alluvium/colluvium horizon and the underlying weathered and fractured Panoche Formation (bedrock). Although these geologic units contain groundwater, they cannot, by definition, be considered "aquifer" material because they do not transmit significant quantities of water under ordinary hydraulic gradients (Freeze and Cherry, 1979). During the non-OE RI at the Project Site, hydraulic testing was conducted to evaluate the hydraulic conductivity for the alluvium/colluvium horizon and the Panoche Formation (see Section 4.4). The low hydraulic conductivities measured during these investigations (approximately 10^{-5} centimeters per second [cm/sec]) are consistent with the fine-grained sediments (primarily silts and fat clays) encountered at the Project Site, as described in Section 4.3. Additionally, the sediment thickness in most portions of the Project Site does not support the minimum well seal of 20 feet as required by Solano County for residential water supply and 50 feet for industrial or community wells.

Groundwater beneath the Project Site does not occur in quantities and/or yields that would allow for economically feasible extraction. This is supported by both the past and present water use practices in the vicinity of the Project Site. There is no history of significant groundwater use or supply in the vicinity of the Project Site during the past 150 years. Until the early 1900s, the City of Benicia obtained its water from the Carquinez Strait. Physical alteration of the Delta between 1870 and 1920 caused intrusion of brackish water into Suisun Bay. By the late 1910s, the cities of Benicia, Antioch, and Pittsburg had lost their water supplies and were forced to locate alternative water sources. Antioch and Benicia constructed reservoirs, while Pittsburg was able to drill wells (Figuers, 1998). The majority of drinking water for the City of Benicia is currently obtained from the Sacramento River via the North Bay Aqueduct; additional water for the City is obtained from Lake Herman, approximately 1,000 feet northwest of the Project Site.

The Project Site is not situated within a designated groundwater basin as specified by the San Francisco Regional Water Quality Control Board Basin Plan. There are no municipal wells within several miles of the Project Site, and no significant groundwater supplies are known to occur in the area. The Project Site was not included in the water resource and groundwater study of Solano County by the U.S. Geological Survey (USGS) (Thomasson, et al. 1960). No groundwater basin was identified in the immediate vicinity of the Project Site by the California

Department of Water Resources (DWR) in their statewide evaluation of groundwater basins (California Department of Water Resources, 1980). The nearest designated groundwater basins are the San Pablo Ridge Basin to the south, Sonoma Valley Basin and Napa-Sonoma Basin to the north and northwest, and the Suisun-Fairfield Valley Basin to the east (Figure 2-6).

2.2.5 Surface Water and Surface Drainage

The surface hydrology of the region is defined by the drainage basin of Sulphur Springs Creek, which is controlled by the Lake Herman dam and reservoir immediately northwest of the Project Site. Northeast of the site, Sulphur Springs Creek flows from the northwest to the south-southwest. The North Valley and South Valley drain to the east and join Sulphur Springs Creek outside the Project Site boundaries. The northwesternmost area of the Project Site drains to the northwest, toward a small tributary of Sulphur Springs Creek immediately southeast (and downstream) of Lake Herman.

The Project Site is situated within the Suisun Basin Hydrologic Planning Area (Planning Area 7; San Francisco Regional Water Quality Control Board, 1995); however, it is not situated within a designated groundwater basin. The Project Site is south-southeast of Lake Herman and is not situated within the Significant Subwatershed Boundary of Lake Herman (Figure 2-7). Lake Herman is owned by the City of Benicia and has been part of the municipal water supply for the City since 1905. The reservoir has a surface area of 110 to 136 acres; the drainage area for the lake is 10.2 square miles.

2.2.6 Air Quality

Wind patterns heavily influenced by the Carquinez Strait (the east side of the only major sea level pass through California's Coast Range) have a significant effect on air quality at the Project Site and surrounding area. Prevailing winds are from the west in the Carquinez Strait, particularly during the summer and fall. This is caused by a pattern of high offshore pressure coupled with thermal low pressure in the Central Valley, resulting in the channeling of marine air at speeds commonly in the range of 15 to 20 mph, eastward through the Carquinez Strait. There are industrial facilities in the area of the Project Site (e.g., a refinery) that produce air emissions. The emissions are usually moderated by the high wind speeds through the Carquinez Strait; however, there have been short-term pollution episodes from industrial facilities in the area.

2.2.7 Biological Resources

The Project Site and surrounding area supports a number of biological resources. The following sections provide information pertaining to vegetation, wildlife, and sensitive species that may occur on or near the Project Site.

2.2.7.1 Vegetation

Non-native Grasslands

The majority of the Project Site is covered with non-native annual grassland vegetation. Present on the hillsides, ridgetops, and some of the valley floor areas of the Project Site, this habitat is dominated by weedy introduced plant species such as slender wild oats (*Avena barbata*), ripgut brome (*Bromus diandrus*), red brome (*Bromus madritensis* ssp. *rubens*), foxtail barley (*Hordeum jubatum*), wild radish (*Raphanus sativus*), fennel (*Foeniculum vulgare*), cheeseweed (*Malva parviflora*), and cardoon (*Cynara cardunculus*). Some native plant species are present, including California wild poppy (*Eschscholzia californica*), various lupines (*Lupinus* sp.), blue dicks (*Dichelostemma capitatum*), and coyote brush (*Baccharis pilularis*) (U.S. Army Corps of Engineers, Sacramento District, 1997).

Willow Riparian and Freshwater Marsh Areas

The unnamed creek that crosses the southern portion of the Project Site (South Valley) supports both willow riparian and freshwater marsh vegetation. Vegetation occurs along the creek and in seep areas on the hillsides. Creek wetlands consist mainly of freshwater marsh species such as narrow-leaved cattail (*Typha angustifolia*), Olney's bulrush (*Scirpus americanus*), and tule (*Scirpus acutus* var. *occidentalis*). Scattered arroyo willows (*Salix lasiolepis*) occur along the length of the creek (Wetlands Research Associates, Inc., 2000e). Plant species present in the seep areas include iris-leaved rush (*Juncus xiphioides*), creeping wild rye (*Leymus triticoides*), narrow-leaved cattail, and common velvet grass (*Holcus lanatus*) (Wetlands Research Associates, 1999, 2000d).

2.2.7.2 Wildlife

Common Species

Portions of the Project Site have been disturbed. Such areas may support species tolerant of disturbance. Common species observed in these areas include northwestern fence lizard (*Sceloporus occidentalis occidentalis*), house finch (*Carpodacus mexicanus*), Brewer's blackbird (*Euphagus cyanocephalus*), American crow (*Corvus brachyrhynchos*), house sparrow (*Passer domesticus*), and California ground squirrel (*Spermophilus beecheyi*) (Earth Tech, Inc., 1999b).

The non-native grassland areas present on the Project Site provide habitat for several reptiles, birds, and mammals. Common species present include northwestern fence lizard, Pacific gopher snake (*Pituophis melanoleucus catenifer*), lesser goldfinch (*Carduelis psaltria*), western meadowlark (*Sturnella neglecta*), ring-necked pheasant (*Phasianus colchicus*), California towhee (*Pipilo crissalis*), Botta's pocket gopher (*Thomomys bottae*), coyote (*Canis latrans*), and mule deer (*Odocoileus hemionus*). Several raptor species may utilize the Project

Site for foraging; species observed include red-tailed hawk (*Buteo jamaicensis*), American kestrel (*Falco sparverius*), and northern harrier (*Circus cyaneus*) (Earth Tech, 1999b; Wetlands Research, Inc., 1998, 2000a, 2000b.

In March and April, 2000, Wetlands Research Associates (WRA) conducted pre-construction breeding surveys for raptors at the Project Site. A pair of northern harriers was observed occasionally flying over the South Valley. A single red-tailed hawk and a single Cooper's hawk (*Accipiter cooperii*) were also observed flying over the South Valley. The survey did not identify any nest structures on the Project Site (Wetlands Research Associates, 2000b).

The wetlands present on the Project Site provide habitat for a variety of species including Pacific treefrog (*Hyla [Pseudacris] regilla*), California newt (*Taricha torosa*), red-winged blackbird (*Agelaius phoeniceus*), common yellowthroat (*Geothlypis trichas*), and beaver (*Castor canadensis*).

Sensitive Species

The majority of sensitive species listed on the California Natural Diversity Data Base (CNDDB) as occurring on the Project Site and surrounding area are associated with northern coastal salt marsh habitats, which are well south and east of the Project Site (California National Diversity Data Base, 2000). No habitat exists for these species on the Project Site. Specific surveys were performed for California red-legged frog (*Rana aurora draytonii*) during July 1998 by WRA, and follow-up surveys in July 1999 by Earth Tech and in May/June 2000 by WRA. California red-legged frogs were not observed during these surveys and have not been historically recorded on the Project Site (Wetlands Research Associates, 1998, 2000a). Similarly, no giant garter snakes (*Thamnophis couchii gigas*) have been observed on the Project Site during surveys. The Suisun song sparrow (*Melospiza melodia maxillaris*), a federal Species of Concern, has been observed in the immediate Project Site vicinity and may occur on the Project Site. The federally listed endangered American peregrine falcon (*Falco peregrinus anatum*) may forage over the Project Site, but would not be expected to nest in the area because of the lack of suitable cliff sites.

In April 2000, WRA conducted a field survey for Johnny jump-up plants (*Viola pedunculata*) at the Project Site; no Johnny jump-up plants were identified on the Project Site (Wetlands Research Associates, 2000c). Johnny jump-ups are the host plants for the larvae of the silverspot butterfly (*Speyeria callippe callippe*)federally listed as an endangered calippe species. The callippe silverspot butterfly is known to occur in grass-covered hills in Solano County (California Environmental Protection Agency, Department of Toxic Substances Control, 1996); however, there have been no sightings of this butterfly recorded at the Project Site.

2.2.8 Demographics

Benicia is the fourth largest city in Solano County, ranking fourth in population after the cities of Vallejo, Fairfield, and Vacaville. The current population of Benicia is estimated to be 28,300 (City of Benicia, 2000). The median age of a Benicia resident is 37 years, and the 35- to 44-year age group is the largest population group at 19.3 percent. The largest single employer in Benicia is a refinery (owned by Valero Energy Corporation) with approximately 400 employees (City of Benicia, 2000). The 1990 census documented a total of 9,587 housing units, of which 64 percent were single-family detached units.

2.3 HISTORY OF PROJECT SITE

The Benicia Arsenal was created in 1849 on a leased 345-acre parcel of land and expanded to over 2,000 acres in 1941. In 1944, the U.S. Army leased a 200-acre piece of undeveloped ranchland now known as the Tourtelot Property, which was situated next to the north end of the Benicia Arsenal. By 1958, the Benicia Arsenal had reached a maximum area of approximately 2,728 acres. The Benicia Arsenal was used variously as a depot for storing, issuing, repairing, and distributing ordnance, testing gunpowder, and holding and storing ammunition and explosives.

Between 1945 and 1947, the Army began developing the Tourtelot Property for a number of different activities in the North Valley, on the Ridge, and in the South Valley (Figure 2-8). These activities included artillery testing, demilitarization, and demolition of damaged and obsolete ammunition.

In 1955 and 1960, the Army's leases for the Tourtelot Property terminated. In January 1962, DOD initiated the disposal of the Benicia Arsenal by declaring leased portions as excess (Jacobs Engineering, 1999). DOD announced plans to deactivate the Benicia Arsenal on March 30, 1961, and closure was set for March 30, 1964. The actual process of closing the Benicia Arsenal was finalized in February 1965, when the General Services Administration (GSA) quitclaimed approximately 1,785 acres to the City of Benicia.

Portions of the former Benicia Arsenal were developed in the late 1960s. Development included the construction of several buildings and tanks in the refinery area south of the Project Site, and other structures on the former Benicia Arsenal property in adjacent areas. However, the Tourtelot Property remained under private ownership and was not developed. In 1971, portions of the Tourtelot Property were acquired by developers; the remaining 110-acre parcel was acquired from Mary Tourtelot in 1981 as part of the Southampton residential development. In 1989, the City of Benicia approved the EIR (EIP Associates, 1989) for residential development of the land. In 1990, grading activities were conducted on the Project Site in support of off- and on-site residential development (see Section 2.3.3).

In mid 1996, during the initial site preparation activities associated with development of the Project Site, concrete-filled howitzer shells were unearthed, and Granite promptly took several steps to make the Tourtelot Property safe, including discontinuing preliminary construction activities, alerting officials about the shells' discovery, putting a fence around the site, and hiring a security service. The Cal/EPA DTSC performed a site visit on May 3, 1996. This site visit was in response to concerns raised by local citizens concerning possible hazards on the property due to past DOD activities. Following that site visit, DTSC recommended that a thorough investigation of the site be performed, including a Preliminary Endangerment Assessment and an OE Waste Assessment. DTSC also recommended that further development activities at the site be curtailed pending completion of the site investigation. Granite subsequently retained military-trained explosives specialists and initiated preliminary site investigations for OE. Part of the investigation included collection of geophysical data across the majority of the Project Site (see Section 3.3 and Chapter 9.0). In late fall 1996, live ordnance was first encountered and reported by Granite to local military personnel for handling. Granite provided its investigation data to USACE for inclusion in its work. In 1998, USACE began investigation of the Project Site as part of the former Benicia Arsenal investigation to characterize the area for OE.

The Project Site remains undeveloped, except for one structure, and is currently fenced with controlled access and patrolled by a security firm.

2.3.1 Department of Defense Activities at Project Site

During the period when the Project Site was used by DOD, it accommodated a range of activities. Based on a site inspection, data collected by USACE for the *Final Engineering Evaluation/Cost Analysis, Former Benicia Arsenal, Benicia, California* (Earth Tech, 2000d), review of historical aerial photographs and photographs taken at ground-level, data presented in the RRR (Jacobs Engineering, 1999), and review of geophysical data collected across the majority of the Project Site, the following DOD-related areas of interest were identified (see Figure 2-8):

North Valley

- TNT Strips
- Howitzer Test Facility
- North Valley Military Landfill
- Ammunition Renovation/Primer Destruction Site.

Ridge

- Dynamite Burn Site.

South Valley

- Flare Site
- Demolition Site #1
- Demolition Site #2
- Demolition Site #3.

The hillside on the north side of the North Valley was used to dispose of 2,4,6-TNT (known as the TNT Strips). Approximately 6 acres in the North Valley were developed with roads and structures where the accuracy of howitzer gun barrels was checked (Howitzer Test Facility), ordnance was inspected and renovated, and primers were destroyed in a "squirrel cage" (Ammunition Renovation/Primer Destruction Site). A disposal area referred to in this document as the North Valley Military Landfill was also situated in the North Valley. Part of the Ridge was used to dispose of aged, out-of-service dynamite (Dynamite Burn Site).

In the South Valley, there was a Flare Site and up to three suspected demolition sites (Demolition Sites #1, #2, and #3). The Flare Site was used to burn old, out-of-service flares. This generally was accomplished by placing a number of flares in a pile and igniting them. Demolition activities generally consisted of placing various amounts of out-of-service munitions in a "pit," placing a countercharge on top of the items, and detonating them. Often, these areas were used multiple times, resulting in a deep pit or crater.

Table 2-1 summarizes the types of DOD activities that are believed to have occurred at each area of interest and the time period over which activities within a particular area may have taken place, thus providing a timeline as to when potential releases may have occurred at the Project Site. The timeline was developed on the basis of interpretation of historical aerial photographs and ground-level photographs, and a review of descriptions of Area R, the Revetment/Explosives Holding Area of the Arsenal, contained in Volume I of the RRR (Jacobs Engineering, 1999). Supplemental information can be found in the updated historical aerial photographic review presented in Appendix A. Other features not considered to have caused chemical impacts are discussed in Section 2.3.2 below.

2.3.1.1 TNT Strips.

The TNT Strips are visible on the hillside to the north of the North Valley (see Figure 2-8). The authors of the RRR (Jacobs Engineering, 1999) and the ASR

(U.S. Army Corps of Engineers, St. Louis District, 1994a,b) did not find anything in the available records stating what type of activities may have produced the strips. The TNT Strips are clearly visible in a December 1947 aerial photograph, but are not visible in a January 1945 aerial photograph. The record does not indicate when actual TNT destruction operations took place or the method of destruction.

Today, the TNT Strips are still clearly visible, marked by the pronounced lack of vegetation along the strips. There are five strips lacking vegetation varying in length from approximately 100 feet to 800 feet; each is approximately 6 feet wide. Exposed soil along the strips is characterized by a deep red color with crystalline materials observed in the dry season. A possible sixth strip may exist between TNT Strip #3 and #4 based on the aerial photographic review (see Figure 2-8 and Appendix A). This additional strip was identified on the 1973 aerial photograph, but not on earlier or later photographs, and is not currently characterized by a lack of vegetation. It has been assumed that the burning of explosives, similar to that reported for the Dynamite Burn Site (see Section 2.3.1.5), resulted in the TNT Strips on the hillside above the North Valley. The only activity thought to have occurred at the TNT Strips is the burning of TNT.

2.3.1.2 Howitzer Test Facility.

The Howitzer Test Facility consisted of four structures in the North Valley (see Figure 2-8). The first structure, Building 181, consisted of two parallel concrete tunnels constructed in 1945 on an excavated pad into the northeast-facing flank of the Ridge; each had a 10-foot by 10-foot opening and extended approximately 100 feet toward the hillside. The concrete tunnels were oriented approximately north-south and were partially covered with soil.

The second structure, Building 182, which was also constructed in 1945 in the middle of the North Valley, at the base of the southwest-facing hillside, approximately 450 feet north of the entrance to the tunnels, contained the open test firing butts.

The third structure, Building 183, was a concrete powder loading room immediately west of the test firing butts that was constructed in 1945.

The fourth structure, Buildings 540 and 542, included another unidentified structure. This facility was reported under several names (Calibration Facility, Soil Test Laboratory, and Cement Block Test Cell). In addition, the facility was identified in the Draft RRR as a NIKE Test Cell, a name not included in the Final RRR (Jacobs Engineering, 1999). In the Final RRR, two NIKE Missile Sites were identified as being situated in Area S of the former Benicia Arsenal, an area presently situated by the refinery southeast of the Project Site. This fourth structure was situated between the firing butts and the test tunnels. The buildings probably had several uses and were reportedly built in 1957 (Building 540) and

1958 (Building 542), apparently after the Howitzer Test Facility ceased operations. Building 540 was 12 feet by 20 feet, but no records of the size of Building 542 are available. The analyses of the various vintages of aerial photographs of the site (see Appendix A) indicate that these facilities apparently occupied an area of approximately 20 feet by 20 feet. Records do not clearly reveal what the building or buildings were used for; however, a former employee interviewed for the RRR (Jacobs Engineering, 1999) referred to this facility as a Calibration Facility. Also, according to the RRR (Jacobs Engineering, 1999), two men were witnessed walking from one of these buildings, wearing protective suits and masks. The witness stated, "one carried a tray that appeared to be covered by an unidentified vapor. Smoke and fumes surrounded both men as they exited the building. The man carrying the tray was sprayed down with a hose by the other. After disposing the container in a nearby barrel, both men rushed into the safety showers."

The tunnels and firing butts were used to test howitzer barrels and propellant by firing various-sized howitzer projectiles filled with concrete or gravel into the gravel-filled tunnels. This was performed in order to determine if the barrels functioned correctly and whether the propellant was the right mixture. Gravel was dropped into the tunnels from two gravel fill ports, one located on top of each tunnel. The gravel was used to absorb the howitzer rounds fired into the tunnels. The facility was in operation from approximately 1945 to 1955.

A disposal area where shell casings, OE scrap, and debris that had been dug out from the test tunnels were discarded is believed to have been adjacent and northeast of the entrance to the tunnels (see Section 2.3.1.3).

In September 1996, during initial site preparation for development, all structures within the Howitzer Test Facility were dismantled. Most of the building construction debris and inert OE scrap was removed from the Project Site during these activities. A large number of concrete-filled howitzer shells were unearthed during the dismantling activities, particularly in the vicinity of the test tunnels. Howitzer dummy shells and practice landmine fuzes (OE Scrap) were also reported to have been found beneath the foundation of Building 540 (see Section 9.2 for further details).

During the initial site preparation activities, gravel/debris was removed from inside the test tunnels. The soil cover over the concrete tunnels was also removed, and the tunnels and other structures in the area were dismantled. The removed gravel/debris and soil were screened under the observation of a qualified explosives specialist. The debris from inside the tunnels consisted primarily of gravel and howitzer shells filled with pea gravel or plaster and inert OE scrap. Some non-DOD-related debris was also removed (i.e., a burned-out car). The soil removed from over the tunnels also contained gravel- or plaster- filled howitzer rounds. The gravel/debris and soil were screened for OE and, as much as possible, were sorted into two stockpiles. One soil stockpile was relatively free of OE scrap, and the other stockpile had gravel and small fragments of OE scrap. The area was

mapped geophysically (see Chapter 9.0), and all observed anomalies were investigated and removed. Excavated and screened soil from the OE clearance activities was also placed in the "soil" stockpile. The two stockpiles were subsequently moved around the Howitzer Test Facility area to accommodate a complete geophysical survey of the area. The two stockpiles were eventually consolidated into a single stockpile (hereafter referred to as Stockpile #3).

2.3.1.3 North Valley Military Landfill.

A disposal area referred to as the "North Valley Military Landfill" was reported in the North Valley, just east of the Howitzer Test Facility (see Figure 2-8). The RRR (Jacobs Engineering, 1999) reported that there was a disposal area associated with the howitzer test tunnels where shell casings, OE scrap, and debris that had been dug out from the concrete test tunnels were discarded in an area immediately adjacent to, and northeast of, the entrance to the tunnels. This area may also have been used for disposal of demolition debris. The disposal area apparently was first used when the tunnels were constructed in 1945; the area was in operation until approximately 1955, when the testing activities ceased. The area was originally a poorly defined drainage pathway that was reportedly gradually filled with shell casings, shrapnel, and debris dug out from the test tunnels after artillery testing. According to the RRR (Jacobs Engineering, 1999), the disposal area was eventually filled with debris to a depth of approximately 12 feet. Review of historical aerial photographs (1947, 1952, and 1960) and topographic maps indicates that the ground in the general vicinity of the suspected disposal area appears disturbed. Based on the review of the above data, the approximate extent of the disposal area in 1947 and 1952 has been estimated as shown on Figure 2-8. The nature and extent of the disposal area were the focus of the removal action investigation (see Section 4.2.4).

During the 1996 initial site preparation activities at the Howitzer Test Facility (see Section 2.3.1.2), an area of debris was encountered northeast of the previously estimated disposal area (Earth Tech, 2000f) to a depth of no more than 5 feet below ground surface (bgs). However, the debris uncovered in this area was mainly wood crates, pallets, and packing materials. Some inert ordnance, including practice 155-millimeter (mm) howitzer rounds (gravel- or plaster-filled), was also recovered and removed from this area during the OE clearance of the Howitzer Test Facility. The wood debris and packing materials were added to the screened soil stockpile and eventually consolidated into Stockpile #3.

2.3.1.4 Ammunition Renovation/Primer Destruction Site.

The Ammunition Renovation/Primer Destruction Site is situated in the North Valley adjacent to the Howitzer Test Facility (see Figure 2-8). Two facilities were located at this site; the Primer Destruction Facility and later the Ammunition Renovation Facility.

The Primer Destruction Facility was constructed on a relatively flat-graded surface that was partially paved with asphalt at the upper reaches of North Valley, near the drainage divide; was operational from 1945 to 1947. Typically, at primer destruction facilities, primers were destroyed by dumping and burning them in a "squirrel cage" or metal tank. Primers for various munitions were pulled out and placed onto a conveyor belt, then dropped into a cage and burned. An oil burner was usually attached to the cage or tank and was left running constantly in order to ignite the primers.

The Ammunition Renovation Facility consisted of two wooden buildings and two canvas shelters (Jacobs Engineering, 1999) that were used to inspect and refurbish ordnance items stored at the Benicia Arsenal. A photograph of these facilities taken from outside the security fence that surrounded the entire facility complex in January 1950 is shown on Figure 2-9. The RRR (Jacobs Engineering, 1999) stated that the canvas structure in the middle of the area shown on the photograph was used for breakdown operations, cleaning, and processing of ammunition casings in preparation for painting. Painting was performed in the elongated shelter located immediately to the left (east). This photograph also shows the howitzer test tunnels in the background behind the wooden structure on the left (east) side of the photograph, and what appears to be a mobile, truck-mounted communication tower on the top of the Ridge in the middle of the photograph.

During the 1996 initial site preparation activities, the wooden structures were dismantled, and the construction debris was removed from the Project Site. Asphalt paving, which covered the entire Ammunition Renovation/Primer Destruction Site, was removed along with 1 to 2 feet of underlying soil and placed in two stockpiles situated along the north edge of the site (hereafter referred to as Stockpiles #1 and #2).

2.3.1.5 Dynamite Burn Site.

On the Ridge, aged, out-of-service dynamite was reportedly disposed of through burning. Aged dynamite was burned by placing multiple sticks of dynamite in rows up to 100 feet long on a piece of paper and igniting the paper. This area is reported to have been used continuously for 3 months in 1947 and 1948 until all the dynamite was destroyed (Jacobs Engineering, 1999). The area used for burning of dynamite was reported to be approximately one-half the size of a football field; it was situated approximately 700 feet south of Building 181 (the howitzer test tunnels) (see Figure 2-8). This area exhibited a flatter topography, and was located immediately above and northwest of the truck turnaround apparent at the end of the "J"-shaped road in 1947 (originally at about elevation 225 feet above MSL). Inspection of aerial photographs taken December 1, 1947, reveals a criss-cross pattern of dark and light tone strips oriented approximately northeast-southwest and northwest-southeast that is interpreted to represent the burn strips. The March 3, 1948, aerial photographs also show this pattern, with

two prominent dark-toned strips extending approximately northeast-southwest across the top of the Ridge.

The Ridge where the Dynamite Burn Site was located, was excavated in 1990 during grading activities associated with the Southampton residential development. Based on an analysis of past grading activities (see Section 2.3.3), soil from the historical location of the Dynamite Burn Site appears to have been placed as fill at or near the base of the McAllister Drive Land Bridge.

2.3.1.6 Flare Site.

The Flare Site is situated in the South Valley, on the south side of the wetland, and is visually evident by the residual ash on the ground surface and OE scrap and OE fragments recovered from the site (see Figure 2-8). The inspection of aerial photographs indicates that the site was situated over a landslide that is evident since the earliest available aerial photographs (1937). The Flare Site was used to dispose of flares by burning (Jacobs Engineering, 1999). This usually consisted of placing flares on the ground in rows and igniting them. Although no evidence of burning was visible in the aerial photographs, physical evidence of burning (i.e., residual ash) remains at the Flare Site, as observed during recent site visits. It is uncertain if the Flare Site was used to dispose of ordnance. A relatively large number of anomalies are evident in the geophysical data (see Section 3.3 and Chapter 9.0).

2.3.1.7 Demolition Site #1.

Demolition Site #1 is situated near the bottom of the South Valley on the south side of the wetland (see Figure 2-8). A smaller drainage running down the south slope of the South Valley is immediately to the east of the suspected demolition site. The site is clearly visible in a number of the historical aerial photographs reviewed and first appears circa 1945, although no evidence of the type of use is evident on the photographs. A rectangular feature resembling a container is observed in aerial photographs dated 1948 at an approximate elevation of 105 to 110 feet above MSL in the southernmost portion of the site (see Appendix A and Figure 2-8). No live ordnance items have been recovered from this site during previous investigations; however, OE scrap and OE fragments have been recovered around and near the site. The site was included in the sitewide geophysical survey (see Section 3.3 and Chapter 9.0). A large magnetic anomaly is evident in the data at the south end of the suspected site that appears to coincide with the feature observed in the 1948 aerial photograph. Several smaller anomalies are also evident from the data in the north portion of the site.

2.3.1.8 Demolition Site #2.

This suspected demolition site shows little or no evidence of use. This site is on the south side of the South Valley between the Flare Site and Demolition Site #1

(see Figure 2-8). The site was suspected of being a demolition site because it appears disturbed or barren in several historical aerial photographs. However, disturbance in this area is also associated with a landslide/earthflow identified in that area on the 1945 and later photographs. Review of the sitewide geophysical data (see Section 3.3 and Chapter 9.0) does not indicate a high anomaly count, similar to those of Demolition Sites #1 and #3, nor is there field evidence of OE scrap and OE fragments.

2.3.1.9 Demolition Site #3.

Demolition Site #3 is situated on the north side of the South Valley (see Figure 2-8). Several ordnance items were recovered from this site both by Granite and USACE. Also, a half-track armored personnel vehicle was removed from this site, hauled up the north slope of the South Valley, and cut into pieces that were recycled at a local metal fabrication shop. Demolition Site #3 is evident in the sitewide geophysical data (see Section 3.3 and Chapter 9.0); on the aerial photographs (since 1947), it coincides with a bench cut into the hillside. The topographic map shows the bench cut at an approximate elevation of 105 feet above MSL. The surface of the bench appears disturbed in several of the photographs, and craters from explosions were identified on the ground at this location.

2.3.2 Other Site Features

A review of the historical aerial photographs and selected ground-level photographs (described in Appendix A) allowed identification of several features not considered to be directly associated with the DOD activities and the areas of interest described above. These features are shown on the Historical Site Features Map (see Figure 2-8), where they are called out and identified with the year when they were first observed on the aerial photographs.

The earliest vintage set of aerial photographs dates to 1937, when no DOD site activities where evident. However, several site features observed on those photographs can be observed in subsequent aerial photograph vintages and include a prominent fence extending east-west along the north side of South Valley and zigzagging across the Ridge and the North Valley, and seeps in the west end of the South Valley, the east end of a prominent east-west tree line in the North Valley, and the swale where the howitzer test tunnels were built.

Although outside the Project Site, one prominent feature observed in the 1937 aerial photographs that does not appear in subsequent ones, is a fenced area on the hillside facing the Sulphur Springs Creek north of the North Valley. This area appears pockmarked with a pattern of disturbed ground similar to that observed in agricultural areas northeast of the Project Site outside the former Benicia Arsenal. At that time, a bridge crossed Sulphur Springs Creek at that location. These features do not appear to be DOD-related activities.

The aerial photograph taken on January 16, 1945, shows a disturbed ground area adjacent to and south of the prominent tree line extending from the east end of the North Valley toward the Dynamite Burn Site. The area shows a faint texture of irregular topography not seen in the previous photographs, but similar to the pockmarked disturbed ground in agricultural areas outside the former Benicia Arsenal. No roads or other types of ground disturbance indicative of DOD-related activities are visible on the Project Site in the 1945 photographs. Consequently, this area of ground disturbance is not believed to be the result of DOD activities, and was therefore not identified as an area of interest requiring targeted exploration.

The 1947 photographs show one unidentified feature, on the southwest end of the North Valley Military Landfill, and two features interpreted as sentry guardhouse foundations. One of the guardhouses is immediately south of the truck-turnaround of the "J"-shaped road; the other is along the western Project Site fence, immediately above Demolition Site #3.

The 1950 ground-level photograph (Figure 2-9) of the Ammunition Renovation/ Primer Destruction Site shows one semipermanent wooden building on the east end of the site, which can be observed for many years thereafter at that location, as well as two canvas shelters that were used to renovate and paint ammunition. In addition, the photograph shows several features not generally observed in aerial photographs. These include a trailer parked next to a pad by the "J"-shaped road immediately south of the site; a stack of what appears to be wooden crates stored in the middle of the flat graded area of the site; a line of three wooden power poles extending across the site; one power pole has a box that could be a transformer or a switch box; a portable bin is stationed against the west side of the polygonal security fence; vehicles are parked at the site; and several small piles of what appears to be debris are seen at several locations.

On the horizon of the 1950 ground-level photograph, there appears a structure consisting of a tall tower and an elongated feature at its base. This has been interpreted as a mobile communications tower, and the elongated feature was interpreted to represent a support vehicle, possibly a truck-mounted communications center and generator. The location of the feature represented the highest topographic point within the Project Site at that time (prior to excavation), and would have been a logical accessible place for a mobile telecommunications facility. Inspection of 1952 aerial photographs does not reveal evidence of ground disturbance that could have been caused by this facility at the time. Consequently, the location of this feature was not designated as an area of interest requiring targeted exploration.

The 1968 photographs show an unidentified structure immediately adjacent to the west of the Dynamite Burn Site. This feature could be a storage bin and is not observed in subsequent photographs.

Figure 2-8 also shows how the extent of the disturbed area of the North Valley Military Landfill appeared in the 1947 and 1952 aerial photographs. It also shows the varying extent of the berm at the south end of the Ammunition Renovation/Primer Destruction Site in 1947, 1950, and 1962.

2.3.3 Site Grading Activities

Part of the history of the Project Site includes the development of adjacent properties for residential land use. This included mass grading areas immediately to the south of the Project Site, and the use of the Ridge area within the Project Site boundary as a source of borrow materials. The Dynamite Burn Site was situated on the Ridge. Other DOD-related activities that may have impacted the Ridge soil are discussed below. Demolition activities in the South Valley may have resulted in both OE scrap (inert metallic material) and OE (items that may have explosives, but are not expected to be primed or armed to detonate) being "kicked-out" from the demolition sites. Given the explosives hazard associated with OE, it is important to understand where OE may have been distributed across the Project Site. Based on the evaluation of the OE data by military-trained OE experts presented in Chapter 9.0, the OE "Kick-Out Area" is defined as an area where there would be a higher likelihood of encountering OE. The evaluation also concluded that OE would most likely not be kicked-out more than 300 to 500 feet from a demolition pit, and that the OE would not penetrate very deeply (less than 2 feet) into the surrounding soil upon impact. Further details on how the OE Kick-Out Area will be determined are contained in the Final Draft OE Remedial Design document (Earth Tech, 2001).

In order to assess the movement of soil materials from the area of the Dynamite Burn Site and soil potentially containing OE and OE Scrap (Figure 2-10) during past grading activities at the Project Site, the grading history related to the adjacent residential development was reviewed. The following assessment is based on a review of the grading plans (Bissell and Karn, 1990), the preliminary soils and geologic reports (ENGEO, Inc., 1989a, 1989b, 1990a), the field density testing and observation services reports (ENGEO, Inc., 1990b, 1990c, 1991), and historical aerial photographs.

The grading map, provided as Figure 2-10, shows the cut-and-fill areas of the grading for Units D-1, D-2, D-3, D-4, and D-5; the Ridge Cut Area (used as a borrow source); and other features discussed below. These areas and features have been identified and assigned names on the map for ease of reference in the following discussions. The major grading areas and other features are summarized as follows:

- South Fill Area - a fill area south of Rose Drive and includes almost all of Unit D-2, the south portion of Unit D-1, and the east portion of Unit D-3

- West Fill Area - a fill area at the west end of the South Valley and includes the west portion of Unit D-4 along Panorama Drive and the west portion of Unit D-3 along Rose Drive and McCall Drive
- D-1 Cut Area - a cut area adjacent and north of the South Fill Area; includes the north portion of Unit D-1 north of Rose Drive and along McCall Drive and McAllister Drive
- D-3/D-4 Cut Area - a cut area adjacent and north of the South Fill Area and east of the West Fill Area; includes the south portion of Unit D-4 and adjoining Unit D-3 along McCall Drive
- D-3 South Cut Areas - cut areas along Watson and Gray Courts
- McAllister Drive Land Bridge - an embankment fill across the South Valley
- Ridge Cut Area - a designated borrow site for construction of the McAllister Drive Land Bridge and grading of Units D-1 through D-4
- D-1 East Fill Area - a fill area at the east end of Piercy Court in Unit D-1
- Sewer Bench - situated along the south side of the South Valley, which includes several landslide repair and fill areas to support the sewer bench
- D-5 Fill Areas - the three fill areas in Unit D-5
- D-5 Cut Area - the cut area adjacent to Kearney Street in Unit D-5.

2.3.3.1 Assessment of Earth Material Movement during Grading of Units D-1 through D-5.

Grading of Units D-1 through D-4 began in April 1990. Beginning on April 9, 1990, ENGEO provided testing and observation services of the grading (ENGEO, Inc., grading reports, 1990b and 1990c).

A May 13, 1990, aerial photograph shows fill placement in the Unit D-2 portion of the South Fill Area, and excavation of the cut areas immediately to the north. The grading activity in this area did not include the area of Unit D-1 Cut Area within a 500-foot radius of the Demolition and Flare sites. The bottom keyways and subdrains in the West Fill Area are also visible in this aerial photograph. There had been no grading activity in the Ridge Cut Area, the 500-foot radius area, or the McAllister Drive Land Bridge up to this time.

Construction of the McAllister Drive Land Bridge (referred to in the ENGEO grading reports as the "east crossing") began in the middle of June 1990; the first set of field density tests of the initial fill of the land bridge were performed on June 19, 1990 (ENGEO, Inc., 1990c). The land bridge fill elevation at that time was at 39 to

40 feet above MSL, which is approximately 100 feet below the finished grade. The final top finished elevation is about 147 to 160 feet above MSL. Based on field density test records (ENGEO, Inc., 1990c, 1991), fill placement at the east crossing was continuous in the following weeks; fill elevation was in the 60s on June 29, 1990; the 70s by the end of July; and 90s to 100s in mid-August. The last series of field density tests in the land bridge were taken on August 30, 1990, at elevations of 143 to 152 feet above MSL, which is very close to the finished grade (ENGEO, Inc., 1991).

The pre-land bridge topographic map (Detention Basin No. 2, Sheet 2 of 4, Bissell and Karn, 1990) shows that the creek bed extended from an approximate elevation of 65 feet above MSL under the west toe of the current land bridge to an approximate elevation of 50 feet above MSL under the east toe of the land bridge. Since the record indicates that a density test was performed at an elevation of 39 to 40 feet above MSL in the land bridge fill, this indicates that the original ground surface under the land bridge was excavated during construction. It appears that the alluvial soil under the land bridge was removed to firm soil or bedrock. Soil derived from the Ridge would have been placed as compacted fill at the bottom of the excavation (i.e., starting approximately at an elevation of 40 feet above MSL). The alluvial soil excavated from below the land bridge may have been placed as fill in the land bridge after allowing it to dry. This means the alluvial soil would have been placed below an elevation of 65 feet above MSL according to the timeline outlined above.

An aerial photograph taken in September 1990 shows the extent of the excavation on the Ridge Cut Area immediately after completion of the land bridge. The lateral extent of the excavation was scaled off from the aerial photograph and superimposed on Figure 2-10. The excavation area is smaller than the current excavated area (which remains unchanged since an aerial photograph dated February 17, 1991, to the present). The September 1990 aerial photograph also shows an area immediately upgradient of the land bridge on the north side, extending from the Ridge Cut Area to the valley bottom, which appears to be a ramp for earth-moving equipment hauling fill material to the land bridge (see Figure 2-10).

An estimate was made of the quantity of material removed from the excavated area shown on the September 1990 aerial photograph by superimposing the September 1990 graded area onto the pre-grading topographic map (Sheet 15 , Borrow Site, Bissell and Karn, 1990). Assuming a planar excavation surface from the excavation edges shown in the aerial photograph, an approximate quantity of 200,000 cubic yards (cy) was calculated to have been excavated from the area; the same quantity that is estimated for creating the land bridge (approximately 200,000 cy). This information indicates that all material excavated from the September 1990 graded area (including the entire Dynamite Burn Site) was placed in the McAllister Drive Land Bridge. This is further confirmed by review of the density tests that show that the initial fill material placed at the base of the land

bridge was high-plasticity clay, which is only found at the surface across the Project Site. As the Dynamite Burn Site is situated toward the southeast end of the Ridge Cut Area, closest to the land bridge, it would have been excavated during the early stages of land bridge construction and, therefore, most likely placed in the bottom part of the land bridge.

After completion of the land bridge, an additional amount (approximately 400,000 cy) of material was excavated from the Ridge Cut Area. The original estimate of the total amount of excavation from the Ridge Cut Area was approximately 600,000 cy (Sheet 15, Grading Plan Borrow Site, Southampton Units D-1, D-2, D-3, and D-4, Bissell and Karn, 1990). The ENGEO grading report indicates continued fill placement in both the South Fill and West Fill areas from September through November 1990. Material for these fills was most likely obtained from the Ridge Cut Area. It is possible that soil used for fill in these areas contained OE and/or OE scrap.

Based on a review of aerial photographs, grading activities in Unit D-5 began after June 21, 1991, and were completed by September 3, 1993. Unit D-5 shows cut-and-fill areas (see Figure 2-10). Since the current extent of the Ridge cut excavation has not changed since the February 17, 1991, aerial photograph, it is concluded that the Ridge Cut Area was not used as a borrow source during the grading of Unit D-5.

3.0 PREVIOUS INVESTIGATIONS

Several investigations have been conducted at the Project Site prior to the non-OE RI. The nature of these investigations and how they relate to the non-OE RI are presented and discussed in this chapter.

3.1 ENGEO INVESTIGATIONS

Two soil investigations have been conducted by ENGEO specifically to investigate geologic conditions in an area scheduled for residential development, which includes the Project Site. No soil or groundwater samples were collected for chemical analysis during either of these geologic investigations, since the scope of work was to identify specific geologic conditions that would require mitigation during development of the area (including the Project Site), as well as to provide recommendations to aid in developing criteria for mass grading and design of structural foundations. These investigations have provided supplemental information regarding geologic and hydrogeologic conditions at the Project Site, as further discussed in Sections 4.3 and 4.4, respectively.

The first investigation was conducted in November and December 1988. Field work consisted of excavating and logging four exploratory trenches (T-1 through T-4) and ten test pits (TP-1 through TP-10), as well as locating landslides. The approximate locations of the ENGEO trenches and test pits are shown on Figure 3-1. Each trench was extended approximately 5 to 6 feet bgs. The trenches were approximately 270 feet long (T-1), 50 feet long (T-2), 160 feet long (T-3), and 200 feet long (T-4). All the trenches were oriented north-south with the exception of T-3, which was oriented east-west. The test pits were typically between 10 and 40 feet long and approximately 5 feet deep, with the exception of a portion of TP-10, which extended up to 10 feet bgs. Trenches T-2 and T-3 were excavated within the Project Site, as were test pits TP-8, TP-9, and TP-10. Copies of the ENGEO trench drawings and test pit logs are included in Attachment B-1 of Appendix B.

The second investigation was conducted in February 1989 and consisted of advancing exploratory boreholes (B-1 through B-22), and sampling and geotechnical laboratory testing of selected representative soil samples. The approximate locations of the ENGEO exploratory boreholes are also shown on Figure 3-1. Fifteen of the boreholes are situated within the Project Site. Boreholes B-3, B-6, B-9, B-10, B-11, B-12, B-21, and B-22 were advanced along the upper slopes of the South Valley; boreholes B-13 and B-14 were advanced by, and to the east of, the McAllister Drive Land Bridge; and boreholes B-15 through B-19 were advanced in the North Valley. The depth of the boreholes ranged between 9 and 33.5 feet bgs. Groundwater was encountered in four of the boreholes (B-2, B-8, B-9, and B-18). One of these boreholes (B-9) was situated at the extreme west end of the South Valley, while another borehole (B-18) was situated in the North Valley (see Figure 3-1). The remaining two boreholes

(B-2 and B-8) were situated outside the Project Site to the south and west, respectively. Groundwater was first encountered during drilling of borehole B-9, situated in the South Valley, at 10 feet bgs. The groundwater level was subsequently observed to rise to 8 feet bgs. Groundwater was first encountered at 21 feet bgs during drilling at borehole B-18, situated in the North Valley. Copies of the ENGEO borehole logs are included in Attachment B-2 of Appendix B.

Geologic and hydrogeologic data obtained during these investigations are further discussed in Sections 4.3 and 4.4.

3.2 SECOR INVESTIGATIONS

SECOR collected soil and water samples for chemical analysis during an initial investigation conducted on portions of the Project Site in late 1998. The purpose of this initial investigation was to obtain preliminary data for development of the property. The data were not collected in accordance with any specific work plan. Eighty-four soil samples were collected from various areas of the Project Site during this investigation, in particular the north slope of the North Valley in the vicinity of the TNT Strips and the South Valley in the vicinity of the Flare Site and Demolition Sites #1 through #3. SECOR sampling locations are shown on Figure 3-1. The majority of the samples were collected at approximately 2 to 5 inches bgs. Two sets of samples were collected, as follows:

- SS-series - these soil samples (SS-1 through SS-33, and SS-35 through SS-44) were submitted for analysis to Sequoia Analytical Laboratory of Petaluma, California (Sequoia Analytical), a California-certified analytical laboratory

- FSS-series - these soil samples (FSS-1 through FSS-41) were field tested for explosive compounds.

Most of the SS-series soil samples were analyzed for the metals antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, potassium, selenium, silver, thallium, vanadium, zinc, and mercury by EPA Methods SW6010A/7000 series; explosives by EPA Method SW8330; phosphate by EPA Method 365.3; and nitrate as nitrogen and nitrate/nitrite as nitrogen by EPA Method 353.2. The FSS-series soil samples were analyzed for TNT and the high melting explosive hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) (also known as Cyclonite) using the Ensys® Soil Test System, a field testing method. Confirmation analyses of TNT and RDX were also performed by Sequoia Analytical on selected samples for which the field test method was utilized. In addition, two surface water samples were collected from the South Valley wetland area. Water samples were analyzed by Sequoia Analytical for total and dissolved metals by EPA Methods SW6010A/7000 series, explosives by EPA Method SW8330, and nitrate as nitrogen and nitrate/nitrite as nitrogen by EPA Method 353.2.

3.2.1 Screening-Level Analytical Results

The analytical results from the SECOR investigation are presented in Tables 3-1 through 3-9 and summarized on Figure 3-1. These data were provided, as shown by SECOR. Earth Tech has not reviewed the certified analytical reports; therefore, these data have not been verified or validated, and all SS and FSS results are considered to represent "screening-level" data for the purposes of the non-OE RI.

The following soil samples were collected along the axis of the TNT Strips: SS-1, SS-2, SS-3, SS-4, and SS-5, as well as field screening samples FSS-10, FSS-36, and FSS-41 (see Table 3-1). TNT was detected in the SS samples at concentrations ranging from 738 milligrams per kilogram (mg/kg) to 72,400 mg/kg along the axis of the strips. RDX was detected in two of the field screening samples (FSS-10 and FSS-41) at 3.1 mg/kg and 3.4 mg/kg, respectively. One of the field screening samples, FSS-10, was submitted for confirmation analysis at the analytical laboratory; however, RDX was not detected in the confirmation analysis possibly due to the elevated reporting limit. Other soil samples collected along the north slope of the North Valley, in the general vicinity of the TNT Strips, are as follows: SS-6, SS-37, and SS-38, as well as field screening samples FSS-9, FSS-31, FSS-33, FSS-34, FSS-35, FSS-37, FSS-38, FSS-39, and FSS-40. No explosives were detected in any of the samples in the vicinity of the TNT Strips, with the exception of a concentration of TNT at 200 mg/kg in sample SS-6, approximately 300 feet northwest of TNT Strip #4. A field screening sample at the same location (FSS-9) did not detect any explosives. Analytical results for samples SS-1, SS-2, SS-3, SS-4, SS-5, and SS-6 suggest that the metals concentrations generally are not elevated above ambient conditions. The exceptions to this generalization are beryllium, chromium, cobalt, and manganese, with concentrations slightly higher than ambient levels. The assessment of ambient levels is discussed in Chapter 6.0 and supporting statistical evaluations are provided in Appendix E. All six beryllium analyses (SS-5, 1.3 mg/kg, maximum), one chromium analysis (SS-5, 71 mg/kg), one cobalt analysis (SS-5, 27 mg/kg), and two manganese analyses (SS-5, 2,100 mg/kg maximum) exceeded ambient levels. Antimony was not detected in any of these samples; however, the method detection limit (MDL) for antimony in these analyses was higher than the ambient level.

One soil sample was collected at the Howitzer Test Facility (SS-19) and one sample in the Ammunition Renovation/Primer Destruction Site (FSS-32) (Tables 3_2 and 3-3). No explosives were detected in either sample. The metals results for sample SS-19 are below the ambient concentrations, as discussed in Chapter 6.0.

Two soil samples were collected within the Flare Site (SS-22 and FSS-29), and one field screening sample (FSS-2) was also collected approximately 75 feet upgradient of the Flare Site (Table 3-4). RDX was detected in field screening sample FSS-29 at 2.6 mg/kg. No explosives were detected in either sample SS-22 or field screening sample FSS-21. Seven metals were detected at concentrations well above ambient concentrations as discussed in Chapter 6.0,

as follows: antimony (up to 1,470 mg/kg), barium (up to 76,600 mg/kg), chromium (up to 185 mg/kg), cobalt (up to 80.2 mg/kg), copper (up to 24,200 mg/kg), lead (up to 46,600 mg/kg), and zinc (up to 4,560 mg/kg).

One soil sample was collected within Demolition Site #1 (SS-24), while four more field screening samples were collected in the general vicinity (FSS-24, FSS-25, FSS-26, and FSS-27) (Table 3-5). RDX was detected in the field screening sample FSS-26 at 1.4 mg/kg. No explosives were detected in soil sample SS-24 or the other field screening samples. The metals results for sample SS-24 are below the ambient concentrations discussed in Chapter 6.0. Antimony, although it was not detected, had an MDL greater than the ambient level.

One soil sample was collected within Demolition Site #2 (SS-23), while three more field screening samples were collected in the general vicinity (FSS-22, FSS-23, and FSS-28) (Table 3-6). No explosives were detected in soil sample SS-23 or the other field screening samples. Metals results for soil sample SS-23 are at or below the ambient concentrations discussed in Chapter 6.0. Antimony was also not detected in this sample, but again had an MDL above the ambient level.

Four soil samples, including one field screening sample, were collected within Demolition Site #3 (SS-26, SS-27, SS-28, and FSS-3) (Table 3-7). Three more samples, including one field screening sample, were collected in the general vicinity (SS-25, SS-29, and FSS-11). No explosives were detected in any of the samples. Analytical results in these SS samples are below ambient concentrations for all metals except arsenic, cobalt, and mercury. One arsenic sample (SS-26, 19.1 mg/kg), one cobalt sample (SS-27, 23.1 mg/kg), and five mercury samples (SS-29, 2.17 mg/kg, maximum) exceeded ambient concentrations.

The remaining samples (SS-7 through SS-18, SS-20, SS-21, SS-30 through SS-33, SS-35, SS-36, and SS-39 through SS-44, as well as field screening samples FSS-1, FSS-2, FSS-4 through FSS-8, FSS-12 through FSS-20, and FSS-30) were collected away from the areas of interest, in particular toward the upper north slope of the South Valley, the Ridge area northeast of the McAllister Drive Land Bridge, and on the south slope of the North Valley (Table 3-8). No explosives were detected in any of the samples, with the exception of RDX at 1.73-mg/kg in sample SS-39, approximately 700 feet northwest of the TNT Strips. Metals results for all SS samples collected outside the areas of interest show that chromium, cobalt, copper, manganese, nickel, potassium, and zinc are all below ambient concentrations. The following metals were detected above their ambient concentrations in SS samples collected outside the areas of interest: eight arsenic samples (SS-16, 481 mg/kg, maximum), one barium sample (SS-11, 599 mg/kg), three beryllium samples (SS-14, 0.953 mg/kg, maximum), one cadmium sample (SS-16, 1.67 mg/kg), two lead samples (SS-7, 96.7 mg/kg, maximum), and three mercury samples (SS-31, 0.679 mg/kg, maximum).

It should be noted that for most SS samples, the MDLs for antimony, selenium, and thallium were higher than the upper ambient concentration ranges for these

metals. Therefore, an assessment generally could not be made whether any of the SS samples exceeded the upper ambient concentration ranges for antimony, selenium, or thallium.

Two water samples were collected from the South Valley wetland, upgradient (WS-1) and downgradient (WS-2) of the areas of interest in the South Valley (Table 3-9). The following metals (total and dissolved) were detected in sample WS-1: manganese (377 milligrams per liter [mg/L] and 25.9 mg/L), barium (82.3 mg/L and 56.1 mg/L), copper (17.8 mg/L and non-detect), vanadium (11.1 mg/L and non-detect), and zinc (33.6 mg/L and 28.9 mg/L). The following metals (total and dissolved) were detected in sample WS-2: manganese (22.6 mg/L and non-detect), barium (12.3 mg/L and 9.24 mg/L), copper (11.8 mg/L and non-detect), and zinc (61.5 mg/L and 26.0 mg/L). In most cases, higher concentrations were detected in the upgradient sample.

3.3 SITEWIDE GEOPHYSICAL SURVEYS

Several geophysical surveys have been conducted at the Project Site. The primary objective of the geophysical surveys was to identify OE, as part of the OE characterization activities (see Chapter 9.0). However, the geophysical survey data also provide useful information regarding potential buried non-OE-related objects, such as underground storage tanks (USTs).

The initial geophysical surveys at the Project Site in summer 1996 were limited to the Howitzer Test Facility and small dispersed data collection areas across the Project Site. An EM61, a high-resolution, time-domain metal detector, was used to collect data for the initial surveys. In fall 1996, NORCAL (a company that has worked on a number of projects under DTSC oversight) performed a total magnetic field (TMF) vertical gradient survey at the Project Site in an effort to determine whether OE exists within the area.

The results of the geophysical surveys for the Project Site are discussed in more detail in Chapter 9.0. Figure 3-2 shows the geophysical anomalies identified in the Ammunition Renovation/Primer Destruction Site. This area is of particular interest, based on the petroleum hydrocarbons identified in the soil at the Ammunition Renovation/Primer Destruction Site (see Section 5.5.1). A likely source of some of the petroleum hydrocarbons found in this area may be a UST. There is no record of any USTs being installed or removed from the Ammunition Renovation/Primer Destruction Site; however, one of the two geophysical anomalies identified toward the southeast end of the Ammunition Renovation/ Primer Destruction Site does indicate a signature typical of a small UST (Figure 3-2).

4.0 NON-OE REMEDIAL INVESTIGATION PROGRAM

The overall objective of the non-OE RI was to evaluate the nature and extent of DOD or other source-related COIs (excluding OE) in soil, sediment, surface water, and groundwater at the Project Site so that appropriate remedial action alternatives could be fully evaluated in the FS.

An iterative and focused approach was used for the non-OE RI. Data collection was achieved during the following four phases of fieldwork conducted between May 1999 and August 2000: the interim investigation, the RI, the data gaps investigation, and the removal action investigation. The scopes of work associated with each investigative phase are presented in Sections 4.2.1, 4.2.2, 4.2.3, and 4.2.4, respectively. Geologic and hydrologic/hydrogeologic results of these investigations are summarized in Sections 4.3 and 4.4, respectively. Verified and validated analytical data obtained from the non-OE RI are presented in Chapter 5.0.

4.1 APPROACH

The overall investigative strategy for the non-OE RI was based on the identification of specific areas of interest that could be directly related to DOD or other activities at the Project Site, the identification of COIs that may have been associated with the type of activities/operations conducted at the various areas of interest, and the development of the Conceptual Source and Transport Model as a tool used to assess the mechanisms by which those COIs may have migrated through the environment if a "release" had occurred. As introduced in Section 1.1, the DQO process provided a systematic procedure for defining the criteria that the data collection design should satisfy, including when and where to collect samples, the tolerable level of decision errors for the study, and how many samples to collect. The project DQO process included the following seven steps.

- **Problem Statement** - Summarizes the problem that requires environmental data acquisition and identifies the resources available to resolve the problem.

- **Decision Identification** - Identifies the decision that requires acquisition of environmental data to address the problem. Identifies the intended uses of the data projected to be acquired.

- **Identification of Decision Input** - Identifies the information needed to support the decision and specifies the inputs requiring environmental measurements.

- **Definition of Study Boundaries** - Specifies the spatial and temporal aspects of the environmental media that the data must represent to support the decision.

- **Decision Rule** - Develops a logical statement that defines the conditions that would cause the decision-maker to choose among alternative actions.

- **Limits of Decision Error** - Specifies the decision-maker's acceptable limits on decision errors, which are used to establish appropriate performance goals for limiting uncertainty in environmental data.

- **Optimization of the Data Collection Design** - Identifies the most resource-effective sampling and analysis design for generating data that are expected to satisfy project DQOs.

Due to the iterative nature of the non-OE RI, an SAP was developed for each of the investigative phases, based on the data obtained from the previous investigation. Similarly, as data regarding the COIs identified at the Project Site became available during the non-OE RI process, it became necessary to reevaluate the DQOs. At the start of the non-OE RI process, DQOs were established to facilitate clean closure of the Project Site (i.e., all identified COIs would be remediated to background levels [for naturally occurring COIs] or non-detect [for anthropogenic COIs]). For certain chemicals detected at the site, it became apparent that to reduce the concentrations detected at the Project Site to background levels or non-detect was neither practical nor technically feasible. Therefore, data from the non-OE RI were used in a screening-level HRA (see Chapter 7.0) to evaluate the human health and ecological risks posed by exposure to the COIs identified at the Project Site. Prior to conducting the screening-level HRA, it was determined that the DQOs established for clean closure were acceptable for the screening-level HRA approach.

The results, evaluations, and conclusions presented in subsequent chapters of this document are attributable to the application of the DQO process. A detailed discussion of the completeness of the data collected from each of the investigative phases in support of the non-OE RI is presented in the QCSRs presented in Volume IV of this document. This information is also summarized in Section 5.1.

4.1.1 Areas of Interest

The following areas of interest were identified for investigation, based on the history of the Project Site (see Section 2.3):

North Valley

- TNT Strips
- Howitzer Test Facility and associated Stockpile #3
- North Valley Military Landfill
- Ammunition Renovation/Primer Destruction Site and associated Stockpiles #1 and #2.

Ridge

- Dynamite Burn Site.

South Valley

- Flare Site
- Demolition Site #1
- Demolition Site #2
- Demolition Site #3.

These specific areas of interest represent potential "release sites" resulting from DOD-related activities at the Project Site (see Section 2.3.1). Additionally, the following associated areas of investigation were identified.

- North Valley groundwater - potentially impacted by activities in the North Valley areas of interest.
- South Valley wetland sediment and surface water - potentially impacted by activities in the South Valley areas of interest.
- South Valley groundwater - potentially impacted by activities in the South Valley areas of interest.
- McAllister Drive Land Bridge - potentially impacted by soil derived from the Ridge (including the Dynamite Burn Site) as a result of site grading activities.

Investigation of a number of debris stockpiles on the Ridge between the North and South Valleys was also included in the non-OE RI. These stockpiles are considered "other activities" not related to DOD-related activities at the Project Site. The stockpiled materials, consisting predominantly of soil with mixed concrete, are from development activities adjacent to the Project Site that placed it on the Ridge starting in the mid-1990s. The Ridge stockpiles were included in the non-OE RI to assess potential site impact and to determine eventual disposition of the stockpiled materials.

Boreholes were advanced at each of the aforementioned areas and soil, sediment, and water samples were collected for laboratory analysis, as described in Sections 4.2.1, 4.2.2, 4.2.3, and 4.2.4. Field activities conducted as part of the non-OE RI included (1) installation and sampling of groundwater monitoring wells to evaluate the presence and quality of shallow groundwater in the North and South Valleys; (2) collection of shallow soil samples from locations outside the areas of interest, which have not been subject to any grading activities, to assist in the evaluation of ambient inorganic COIs concentrations; (3) collection of soil samples from the McAllister Drive Land Bridge, which appears to have been constructed using soil from the Ridge, including soil from the Dynamite Burn Site (see Section 2.3.3); and, (4) the use of shallow refraction seismic data, test pits, and geotechnical boreholes to evaluate the depth to bedrock at the Project Site to assist in the calculation of volumes of soil that may need to be excavated as part of any remedial alternatives evaluated in the FS.

4.1.2 Compounds of Interest

Soil, sediment, surface water, and groundwater samples collected during the non-OE RI were analyzed for those COIs that were regarded as most likely to have been associated with past DOD-related and other activities at the Project Site (see Section 2.3.1). Section 4.1.2.1 identifies the specific COIs and the basis for their selection. Section 4.1.2.2 presents information on the environmental mobility of specific COIs; this information was used in the Conceptual Source and Transport Model development process for the areas of interest (see Section 4.1.3).

4.1.2.1 Identification.

An iterative investigative approach was used for the non-OE RI at the Project Site, which resulted in four phases of fieldwork; each investigative phase built on the prior phase to focus the list of COIs for each area of interest (see Section 4.1.2). The list of COIs was initially based on substances that could be specifically attributed to past DOD-related and other activities at specific areas of interest (e.g., explosives at the TNT Strips, metals at the Flare Site). As the investigative phases progressed and more information became available, the conceptual model for potential impact of the areas of interest were refined and additional COIs were identified, as necessary, by the Project Team or at the request of DTSC. Some of the later additions were substances that could not be specifically attributed to past Project Site activities, but were (1) believed to be potential by-products of past activities (e.g., dioxins/furans), (2) potentially associated with other COIs (e.g., polychlorinated biphenyls [PCBs] with petroleum hydrocarbons), or (3) have been included at the request of DTSC (e.g., hydrazine, chloropicrin).

The following COIs were identified as being associated or potentially being associated with activities at the Project Site:

- Explosives
- Polynuclear aromatic hydrocarbons (PAHs)
- Total extractable petroleum hydrocarbons (TEPHs) (quantified against a diesel, motor, and kerosene standard)
- Volatile organic compounds (VOCs)
- Metals
- Phosphorus
- Nitrate and nitrite
- Dioxins/furans
- Perchlorate
- Organochlorine pesticides
- Chloropicrin
- Pentachlorophenol
- Hydrazine
- PCBs.

In addition to the COIs listed above, additional chemical or physical parameters were analyzed for selected soil and/or groundwater samples for general characterization purposes. The additional parameters included:

- Total organic carbon
- Grain size
- Sulfate
- Chloride
- pH
- Electrical Conductivity
- Total dissolved solids (TDS)
- Total suspended solids (TSS).

Tables 4-1 and 4-2 provide a detailed summary of the COIs and their association to activities at the Project Site. The COIs are categorized as having a "known" association, a "suspected" association, or a "possible" association to past DOD-related activities. COIs categorized as having a "known" association to past DOD-related activities include those COIs that have a documented history of use at the

Project Site; COIs categorized as having a "suspected" association to past DOD-related activities include COIs that, through knowledge of Project Site activities, were likely used during, or a by-product of, DOD-related activities; and, COIs categorized as having a "possible" association include COIs that have some general connection to OE and related activities, but may or may not have had any direct association to activities at the Project Site.

Table 4-3 summarizes the COIs and the additional parameters analyzed during each investigative phase at each area of interest, with additional details provided in Tables 4-4 through 4-7.

With respect to metals, the California Assessment Manual (CAM) list of "trace" metals was deemed appropriate for the non-OE RI, because this list included metals that have a well documented association to OE (e.g., mercury, barium) as well as metals that, while not having a specific OE connection, are typically analyzed as part of environmental characterization programs. It was recognized that trace metals not having a specific OE connection could still be of interest due to the various activities at the Project Site that could have used metals in some form, either chemically or physically. At the same time, the CAM list is not regarded as all-inclusive with respect to metals that are potentially associated with OE. For example, strontium (in the form of strontium salts), is used as a coloring agent for flares or other pyrotechnics. However, strontium is chemically similar to barium, the latter being used for the same purposes (see Table 4-2) and reacts similarly in the environment. The list of CAM metals is, therefore, regarded as comprehensive enough to address any metals that may have been associated with OE, due to the presence of similar metals species. Most "major" metals, including calcium, potassium, magnesium, and sodium, were also analyzed either because of potential association to DOD-related activities or because they are commonly included in environmental characterization programs. However, it was recognized that the major metals would likely be of limited use for identifying potential DOD-related impact because of their ubiquitous presence as the major inorganic components of natural soil.

Metals present a particular challenge for use as indicators of potential DOD-related impact at the Project Site. While many of the COIs (e.g., explosive compounds) are solely of anthropogenic origin (and, therefore, clear indicators of DOD-related impact), metals occur naturally in soil and water; therefore, the natural or ambient concentrations of metals must first be characterized in order to make any meaningful judgments on potential DOD-related impact with respect to metals. The same is true for other naturally occurring elements and compounds analyzed during the non-OE RI (e.g., nitrate, phosphorus [as derived from naturally occurring phosphates]). The characterization of natural or ambient concentrations for the major metals is particularly problematic due to their mobility in the soil zone (see Section 4.1.2.2). Relative to most trace metals, the major metals tend to form more soluble compounds (e.g., calcium/ magnesium carbonate) that can be readily leached from shallow or well-drained soils. Therefore, weathering reactions and leaching near the surface can produce widely varying concentrations of major

metals. For this reason, trace metals, which tend to be significantly less mobile than the major metals in the shallow soil zone, are the primary focus of the natural or ambient concentration calculations.

4.1.2.2 Mobility of Compounds of Interest.

Understanding the environmental mobility of the COIs is fundamental to the development of the Conceptual Source and Transport Model for potential DOD-related impact at the Project Site areas of interest. The mobility of COIs can be affected or controlled by both chemical and physical processes. Chemical processes include reaction between the COIs and various media (e.g., dissolution/precipitation reactions in water, sorption reactions with soil, volatilization in air). Other chemical processes include various biochemical reactions that transform the chemical structure or composition of a compound. Physical processes include natural infiltration and erosion, the latter including wind transport, surface water runoff, and mass wasting (e.g., soil creep, landslides). Anthropogenic activities, such as grading and discing of soil, can also affect mobility.

This section describes the general physial/chemial characteristics of the COIs in the context of the general principles affecting their mobility in the air-soil-groundwater system. For purposes of this characterization, the COIs are divided into organic and inorganic categories, below.

Organic Compounds

One of the most important parameters that allows a general assessment of an organic chemical's mobility in soil and groundwater is K_{oc}, which is the soil sorption coefficient normalized for a soil organic carbon content (Dragun, 1988). This value provides an indication of the tendency of a chemical to partition between solid particles containing organic carbon (i.e., soil) and groundwater. Compounds that adsorb strongly to organic carbon have characteristically low water solubilities, whereas compounds that do not adsorb readily to organic carbon have characteristically high water solubilities (Montgomery, 1996). Note that K_{oc} is calculated as milliliters per gram (mL/g), but is typically reported as a unitless log-transformed value (log K_{oc}).

Dragun (1988) reports that, in general, the following K_{oc}-mobility relationships are observed for organic chemicals:

- K_{oc} <50 mL/g (log K_{oc}<1.7) = very mobile
- K_{oc} 50 to 150 mL/g (log K_{oc} 1.7 to 2.2) = mobile
- K_{oc} 150 to 500 mL/g (log K_{oc} 2.2 to 2.7) = moderately mobile
- K_{oc} 500 to 2000 mL/g (log K_{oc} 2.7 to 3.3) = low mobility
- K_{oc} >2000 mL/g (log K_{oc} >3.3) = immobile.

These K_{OC}-mobility relationships should be viewed as general guidelines, as K_{OC} values can vary as a function of soil type and soil pH.

Vapor pressure is another important parameter to be considered in the assessment of mobility of organic chemicals. Vapor pressure allows an assessment of a chemical's tendency to exist in vapor form versus liquid or solid form. In general, chemicals with a vapor pressure of less than 10^{-7} mm mercury (Hg) should be present in the atmosphere or soil gas in negligible amounts; chemicals with a vapor pressure greater than 10^{-2} mm Hg should be present primarily in the atmosphere or soil air, instead of solid or liquid phases (Dragun, 1988). Chemicals with vapor pressures of less than approximately 10^{-2} mm Hg are generally regarded as non-volatile.

A description and general assessment of the mobility of organic COIs are presented below. A compilation of K_{OC} and vapor pressure values relevant to the discussions below is provided in Table 4-8.

Explosives. Explosives identified as COIs at the Project Site include TNT and its associated compounds and breakdown products (nitroaromatics and nitroamines on the EPA Method SW8330 list), RDX, octahydro-1,3,5,7-tetranitro-1,3,5-triazine (HMX), nitroglycerin, and pentaerythritol tetranitrate (PETN).

Other COIs that are typically associated with TNT in soil include the following TNT-related impurities and breakdown products: 1,3,5-trinitrobenzene (TNB), 1,3-dinitrobenzene (DNB), 2,4-dinitrotoluene (2,4-DNT), 2,6-dinitrotoluene (2,6-DNT), 2-amino-4,6-dinitrotoluene (2amDNT), and 4-amino-2,6-dinitrotoluene (4amDNT) (Layton et al., 1987). Numerous other nitrotoluenes may also be present, either as impurities or as a result of biotransformation, but generally in lesser quantities (U.S. Environmental Protection Agency, 2000). Note that 2amDNT and 4amDNT are sometimes reported by the analytical laboratory as "amDNTs," which would include either/or both 2amDNT and 4amDNT.

RDX, which is known by the trade name Cyclonite, is a form of high explosive prepared from the nitration of hexamine. The main co-contaminant of RDX is HMX, which is a high-melting explosive. Nitroglycerin is the major component of dynamite, which is a mixture of liquid nitroglycerin with an absorbent substance, such as diatomaceous earth. PETN is a compound that, when mixed with TNT, forms the high-explosive Pentolite.

Under ambient environmental conditions, TNT and other explosives are typically highly persistent in soil, exhibiting a resistance to volatilization, biodegradation, and hydrolysis. Where biodegradation of TNT occurs, 2amDNT and 4amDNT (collectively referred to as amDNTs) are the most commonly identified transformation products. Photochemical decomposition of TNT and TNB occurs in the presence of sunlight and water, with TNB being generally resistant to further photodegradation. Investigations at other munitions facilities (Crockett et al., 1996) indicate that TNT is the least mobile of the explosives and most frequently

impacts soil. HMX and RDX are the most mobile explosives and, therefore, present the largest potential for groundwater impact. 2amDNT, 4amDNT, and TNB are of intermediate mobility and frequently occur as co-contaminants in soil and/or groundwater.

Laboratory studies of the sorption of explosives by soils indicate that sorption occurs fairly rapidly in soils with high clay/silt content and/or high organic carbon content (U.S. Environmental Protection Agency, 2000). Based on the log K_{oc} values presented in Table 4-8, TNT and associated compounds and degradation products range from mobile to moderately mobile in soil, with the degradation products being the most mobile. Vapor pressures indicate that the chemicals tend not to evaporate and are present in the soil air in negligible amounts. Because of its relative water insolubility, TNT is very persistent in soil.

Based on the above characteristics, any occurrence of TNT at the Project Site is expected to be confined to shallow to moderately deep soils, with most transport via physical movement of soil including transport as a result of erosion and surface water runoff. Degradation products, such as TNB, would be expected to exhibit somewhat more mobility. There is potential for leaching of TNT and, in particular, TNT degradation products through the soil zone to shallow groundwater. However, due to the relative insolubility of these compounds, any detections would be expected to be at extremely low concentrations.

Polynuclear Aromatic Hydrocarbons. PAHs occur naturally as components of crude oil, car tar, and other natural hydrocarbons. Their presence in the environment, however, is typically the result of the incomplete combustion of solid and liquid hydrocarbon fuels such as coal, wood, kerosene, and fuel oil. Industrial activities such as petroleum refining, waste incineration, and iron and steel smelting also are sources of PAHs. Asphalt, due to its hydrocarbon content, also contains PAHs. Similarly, refined petroleum hydrocarbon fuels such as diesel and kerosene typically contain PAHs.

PAHs are generally of limited mobility in the air-soil-water system. Vapor pressures are relatively very low, ranging from approximately 8×10^{-2} mm Hg to 4×10^{-10} mm Hg (see Table 4-8). Log K_{oc} values, which range from 3.1 to 7.5, with most greater than 4, indicate that PAHs are relatively immobile (see Table 4-8). PAHs produced from combustion of organic matter are predominantly adsorbed onto soot and other organic/particulate matter in soil.

Based on the above characteristics, any occurrence of PAHs due to burning activities at the Project Site would be expected to be confined to the near-surface soil with transport via physical movement of soil including transport as a result of erosion and surface water runoff. Deeper occurrence of PAHs in soil could occur as a result of a point-source release of petroleum hydrocarbon fuels from an underground source such as a UST. From a deeper source, there is potential for leaching through the soil zone to shallow groundwater. However, due to the

relative insolubility of PAHs, any detection of such compounds would be expected to be at extremely low concentrations.

Petroleum Hydrocarbons. Petroleum hydrocarbons were analyzed at the Project Site using broad-scale measures of "total petroleum hydrocarbons," quantified against diesel, kerosene, and motor oil standards. Diesel, kerosene, and motor oil represent the "heavier" (i.e., higher molecular weight) end of the fuel hydrocarbon spectrum. Diesel, kerosene, and motor oil typically contain significant proportions of PAHs (e.g., naphthalene) and aliphatic hydrocarbons comprised of ten or more carbon atoms (e.g., dodecane), and, particularly in the case of kerosene, minor proportions of monoaromatic hydrocarbons (e.g., benzene, toluene, ethylbenzene, and xylenes [BTEX]). The mobility of petroleum hydrocarbons is based on the mobility of the individual chemical constituents of which they are comprised. For the heavier fuels, PAHs (see above) can be used to describe general mobility in the air-soil-water system. For lighter fuels such as gasoline, monoaromatic hydrocarbons measured as VOCs (see below) can be used to describe general mobility in the air-soil-water system.

Volatile Organic Compounds. VOCs include the monoaromatic hydrocarbons, chlorobenzenes, halogenated hydrocarbons, and ketones on the EPA Method SW8260B list. This list of VOCs includes the most commonly used organic chemicals for industrial and household purposes, as well as the components of lighter hydrocarbon fuel (e.g., gasoline). VOCs are classified as "volatile" due to their relatively high vapor pressures, which range from approximately 0.3 mm Hg to 455 mm Hg (see Table 4-8). More than the other organic chemicals of environmental concern, the VOCs can rapidly dissipate to the atmosphere in the vapor phase with only a small fraction of the mass available for adsorption and dissolution processes. High water solubilities (and correspondingly low log K_{OC} values) are a characteristic of many VOCs, particularly ketones such as acetone and 2-butanone. Table 4-8 shows that log K_{OC} values for VOCs range from less than 1 to 4. Rates of biodegradation of VOCs vary significantly, but are most rapid for the monoaromatic hydrocarbons such as benzene.

Based on the above characteristics, any VOCs at the Project Site originating at the surface could be detected in the deeper soil zone or groundwater, provided sufficient mass was available to support subsurface chemical migration. Volatilization from the near surface soil and aeration of soil stockpiles due to soil movement would preclude detection of VOCs in these locations unless extraordinary masses were initially present. Deeper occurrence of certain VOCs (i.e., monoaromatic hydrocarbons) in soil could occur as a result of a point-source release of petroleum hydrocarbon fuels from an underground source such as a UST; however, such compounds would be subject to biodegradation processes and would not be expected to persist for a prolonged period of time. From a deeper source, there is the potential for leaching through the soil zone to shallow groundwater, given the relatively low log K_{OC} values of VOCs. Water solubilities of VOCs vary greatly, with some being characterized as insoluble in water (e.g., 1,2,4-trichlorobenzene), while others exhibit near miscibility with water (e.g.,

acetone). If VOCs become dissolved in groundwater, transport can occur via advection and dispersion.

Dioxins/Furans. Dioxin is a family of 210 compounds having either a dioxin structure or a furan structure. There are 75 possible forms of dioxin, with 2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD) being the most notable form. Dioxins do not occur naturally but are ubiquitous in the environment, particularly in urban soils, as a result of airborne transport from industrial activities. Dioxin is associated with fly ash and has been detected in air and soil surrounding pulp and paper manufacturing plants, incineration of municipal and industrial wastes, transformer or capacitor fires, and low-temperature combustion of organic material such as wood and petroleum hydrocarbons (U.S. Environmental Protection Agency, 1992b; Academy of Natural Sciences, 1989). Dioxin is also present in some herbicides, in wood preservatives prepared from chlorophenols, and is often associated with PCBs. Power plants, smelters, steel mills, oil refineries, and automobiles (via emissions) all have been documented to produce dioxins.

Dioxins/furans are non-volatile and exhibit a strong tendency for adsorption to organic matter. The vapor pressure and log K_{oc} for 2,3,7,8-TCDD are 1.5×10^{-9} mm Hg and 6.6, respectively, indicating that dioxins/furans can be expected to be immobile in the air-soil-water system (see Table 4-8). Based on these characteristics, any occurrence of dioxins/furans at the Project Site would be expected to be confined to the near-surface soil with potential transport via physical movement of soil including transport as a result of erosion and surface water runoff. Given their extremely high log K_{oc} values and expected minimal mass, impact to groundwater would not be expected.

Organochlorine Pesticides. Organochlorine pesticides include many of the most commonly used agricultural and household insecticides and fumigants, some of which have been banned in the U.S. (e.g., 4,4'-dichlorodiphenyltrichloroethane [DDT]). The organochlorine pesticides are persistent in the environment and relatively immobile. They are characterized by low vapor pressures and high log K_{oc} values (see Table 4-8).

Based on the above characteristics, any occurrence of organochlorine pesticides at the Project Site would be expected to be confined to the near-surface soil with any transport via physical movement of soil including transport as a result of erosion surface water runoff. Given their extremely high K_{oc} values, impact to groundwater would not be expected.

Chloropicrin. Chloropicrin is an extensively used industrial chemical often used as a fumigant and fungicide (Montgomery, 1996). It is a powerful chemical irritant that was formerly stockpiled by the United States military as a chemical agent used to fill Livens projectiles, Stokes mortar rounds, and artillery projectiles (NSCMP, 2000). Chloropicrin was also produced in the form of small ampules with a 50 percent mixture of chloroform as part of a chemical agent identification set

used by the United States military. The Russian Federation still uses chloropicrin as a qualitative fit-testing substance for air-purifying respirators (NSCMP, 2000).

Chloropicrin is an oily liquid characterized by a relatively high vapor pressure and an extremely low log K_{OC} (see Table 4-8). The low log K_{OC} indicates the potential for relatively rapid leaching through the soil zone to shallow groundwater, providing sufficient mass is present after volatilization. If chloropicrin becomes dissolved in groundwater, transport can occur via advection and dispersion.

Pentachlorophenol. Pentachlorophenol is a commonly used wood preservative. Until the mid-1980's, when manufacturing limits were imposed by the federal government, dioxins/furans were associated with the production of pentachlorophenol and its presence in wood products such as utility poles (AWPI, 2000). Pentachlorophenol is relatively immobile in the air-soil-water system; it is relatively insoluble in water and exhibits a low vapor pressure and high log K_{OC} (see Table 4-8). Based on these characteristics, any occurrence of pentachlorophenol at the Project Site would be expected to be confined to the near-surface soil in contact with discarded wood products, with potential transport via physical movement of soil including transport as a result of erosion and surface water runoff. The limited mass of pentachlorophenol associated with wood wastes, as well as the relative water insolubility of pentachlorophenol, would preclude its presence in groundwater at the Project Site.

Hydrazine. Hydrazine is a colorless, oily, and flammable liquid. It is a powerful reducing agent currently used as a chemical intermediate for the production of pesticides and herbicides; however, it is more commonly known for its first large-scale use, beginning in World War II, as rocket fuel. Hydrazine is extremely volatile, exploding on contact with many substances. It exhibits a relatively high vapor pressure, producing fumes at room temperature, and is water soluble; no log K_{OC} value was identified in the literature (see Table 4-8), but the value is expected to be relatively low based on observations regarding high water solubility.

Based on the above characteristics, any hydrazine at the Project Site potentially originating at the ground surface could be detected in the deeper soil zone or groundwater, provided sufficient mass was available to support subsurface chemical migration. The volatility of hydrazine would preclude detection in the near-surface soil. If hydrazine was to reach groundwater, it would be expected to readily dissolve and be transported via advection and dispersion.

Polychlorinated Biphenyls. PCBs are common industrial chemicals known in the United States by their trademarked name "Arochlor," followed by a four-digit number (e.g., Arochlor 1221). The first two numbers indicate the type of molecule and the last two numbers indicate the percent, by weight, of chlorine in the compound. For example, Arochlor 1221 is a biphenyl with 21 percent chlorine (Hounslow, 1995).

PCBs are chemically and thermally stable, extremely inert, and have excellent dielectric properties; because of these properties, PCBs are associated with high-power electrical transformers and capacitors as a heat-transfer agent or insulator fluid. PCBs are also used as plasticizers in paint, plastics, and sealants, and can be present as an additive in lubricants and hydraulic fluids. PCBs are sometimes associated with waste oil, via impact from industrial operations.

PCBs are characterized by low volatility and low water solubility, and high resistance to chemical and biological breakdown (Hounslow, 1995). Vapor pressures for the Arochlors are extremely low and log K_{oc} values are extremely high, indicating that PCBs can be expected to be immobile in the air-soil-water system (see Table 4-8). Based on these characteristics, any occurrence of PCBs at the Project Site would be expected to be confined to the near-surface soil with potential transport via physical movement of soil including transport as a result of erosion and surface water runoff. Given their extremely high K_{oc} values and expected minimal mass, impact to groundwater would not be expected.

Inorganic Compounds and Elements

The inorganics compounds and elements characterized in this section consist primarily of the metallic elements that occur naturally in the soil-groundwater system. In addition, nitrate, nitrite, elemental phosphorus, and perchlorate are addressed, the latter not occurring naturally in the soil-groundwater system.

Elements (Metals + Phosphorus). The following 11 elements, along with carbon, hydrogen, and oxygen, constitute over 99 percent of the total elemental content of soil: aluminum (Al), calcium (Ca), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), phosphorus (P), sulphur, (S), silicon (Si), and titanium (Ti); the remaining 1 percent is comprised of the elements commonly known as "trace elements" (Dragun, 1988). Metallic ions falling in the trace elements category are collectively referred to as "trace metals." Trace metals include the following 17 metals on the CAM list: antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (total) (Cr), cobalt (Co), copper (Cu), Hg, lead (Pb), molybdenum (Mo), nickel (Ni), selenium (Se), silver (Ag), thallium (Tl), vanadium (V), and zinc (Zn).

The mobility of metals in the environment is a complex subject; however, there are some general principles governing the mobility of metals in the environment, described herein, that are used to characterize the potential for the transport of metals at the Project Site.

Several processes interact to influence the transport of metals in the soil-groundwater system, including complexation reactions, reduction/oxidation related processes, and reactions that result in the removal of metal ions from water, such as adsorption and precipitation (Davis et al., 1993). It is widely recognized that, due to the positive charge of metal ion species, adsorption of metals onto negatively charged clay minerals or organic matter is an important limiting process

with respect to metals mobility in the environment. A cation with a greater valence state is adsorbed more strongly than a cation of a lower valence state and, for a given valence state, the cation with the smallest radius is more strongly adsorbed than a cation with a larger radius (Hounslow, 1995). Trace metals, therefore, can be expected to be adsorbed more strongly than the major metals, such as sodium, potassium, calcium, and magnesium, all of which possess relatively large atomic radii and relatively low valence states. Dragun (1988) notes that as the surface area and the clay content of soils increase, a soil's ability to retain cations generally will increase.

With respect to the major metals comprising the inorganic fraction of soil, several reactive minerals (listed below) can control mobility through solubility/precipitation and ion exchange reactions; weathering of these minerals at the surface can cause significant concentration variations:

- Sodium: halite, sodium-montmorillonite clay, and weathered albite
- Calcium: calcite, aragonite, dolomite, gypsum, and weathered plagioclase, pyroxenes, and amphiboles
- Magnesium: dolomite and weathered pyroxenes, amphiboles, and micas
- Potassium: weathered potash, feldspar, and mica.

Elemental phosphorus is a soft waxy solid that ignites spontaneously in air. Because it is so chemically active, it is never found free in nature, instead forming various phosphorus-bearing compounds and minerals. The most common anthropogenic source of phosphorous-bearing compounds are phosphate, commonly used as fertilizer. The mobility of phosphorus-bearing compounds is generally extremely low due to the rapid formation of precipitates with the major mineral-forming elements. The lack of phosphate mobility has been demonstrated by the widespread use of phosphate fertilizers. These fertilizers tend to remain within the upper few inches of the soil zone; movement is associated with the erosion of topsoil containing adsorbed phosphate compounds.

Based on the above characteristics, the anthropogenic component of metals and phosphorus can be expected to strongly adsorb to the clay/silt-rich soil at the Project Site and, therefore, would be expected to be confined to the near-surface soil with any transport via physical movement of soil including transport as a result of surface water runoff. Detection of metals and phosphorus-bearing compounds in groundwater above natural ambient concentrations is not considered likely given their limited mobility.

Nitrate and Nitrite. The primary source of all nitrates in the environment is atmospheric nitrogen gas which is converted to organic nitrogen by plants.

Nitrate compounds are formed through a series of ammonification and nitrification reactions of plant matter. Nitrite is an intermediate reaction product that is generally short lived and seldom accumulates in significant quantities in the environment (Hounslow, 1995). Common anthropogenic sources of nitrate and nitrite include fertilizers, livestock waste, and septic systems, and, as noted for this investigation, nitrate can be associated with explosives. Nitrate ions are not readily adsorbed by clay minerals and, therefore, tend to move relatively freely through the soil zone to groundwater, unless active vegetation causes uptake.

Based on the above characteristics, anthropogenic nitrate potentially originating at the surface could be detected in the soil zone and/or groundwater, provided sufficient mass was available to support subsurface chemical migration. Deeper occurrence of anthropogenic nitrate in soil could occur as a result of a point-source release (e.g., from an underground septic system). From such a source, there is the potential for leaching through the soil zone to shallow groundwater, given the mobility and solubility of the nitrate ion. If nitrate becomes dissolved in groundwater, transport can occur via advection and dispersion.

Perchlorate. Perchlorate is the anion ClO_4^- associated with certain inorganic explosives and solid rocket fuel. Perchlorates are highly water soluble and tend to move freely through most soils due to their anionic property. Therefore, where widespread impact from perchlorate compounds has occurred, the detection of perchlorate in groundwater can be expected due to its relatively high mobility and solubility.

4.1.3 Conceptual Source and Transport Model for Areas of Interest

A Conceptual Source and Transport Model was developed for the areas of interest based on the available information (obtained from, and prior to, the interim investigation [see Section 4.2.1]) regarding the types of activities and potential sources at each area of interest, COIs, and an understanding of the geologic/hydrogeologic conditions at the Project Site. The Conceptual Source and Transport Model was used to help determine the types of media likely to be affected at each area of interest and the potential fate and transport mechanisms of those COIs identified as COIs within a particular media.

As part of the development of the Conceptual Source and Transport Model, this section presents the potential sources and migration pathways for each of the areas of interest. Specific COIs are further discussed in Section 4.1.2. The Conceptual Source and Transport Model presented herein was used to determine the information necessary to adequately define the extent of site impact and to evaluate potential remedial action alternatives.

4.1.3.1 North Valley Areas of Interest.

As summarized below, the areas of interest within the North Valley include the TNT Strips, the Howitzer Test Facility, the North Valley Military Landfill, and the

Ammunition Renovation/Primer Destruction Site. These areas were subject to a variety of DOD-related activities that may have resulted in impact to the soil/bedrock and groundwater. Common to all the areas of interest are the potential migration pathways of the COIs, as controlled by the topography/ drainage patterns, geology, and hydrogeology (see Figure 4-1). In general, the mechanisms for surface migration of the COIs are as follows:

- Local downslope gravity movement of soil
- Surface runoff of precipitation
- Erosion from wind, water, and vehicle traffic.

Typically, the migration pathway is down the north-facing or south-facing slopes of the North Valley and downgradient either northwest, within the northwest-sloping valley, or more likely southeast, within the southeast-sloping valley.

In addition, the North Valley has been subject to past grading activities associated with construction of the Howitzer Test Facility and the Ammunition Renovation/Primer Destruction Site. Such activities may have disturbed the surface soil, thus providing another transport mechanism or may have predated DOD-related activities involving chemical usage.

The subsurface migration of COIs is limited by the low-permeability soil and bedrock and the limited occurrence of groundwater. The primary mechanism for subsurface migration of COIs is infiltration of precipitation that may leach those chemicals into the subsurface. Infiltration of precipitation is expected to be shallow along the side slopes of the valley due to the relatively thin fine-grained residual soil/colluvium and low-permeability bedrock. Infiltration is expected to be more significant near the valley floor, where surface water runoff accumulates, thus allowing infiltration through the alluvium. The presence of a small wetland area in the North Valley suggests that infiltration into the alluvium along the valley floor may be limited in areas by the permeability of the alluvium (predominantly a fat clay with minor sand and gravel near the contact with the underlying weathered bedrock). Groundwater movement within the bedrock is via fractures/shear zones, and is thought to be limited within the uppermost weathered bedrock zone. At depth, the fractures/shear zones are anticipated to become "tight" as a result of overburden, less weathering, and infilling, effectively limiting groundwater movement at depth.

TNT Strips

The TNT Strips area is situated on the south-facing slope/crest of the North Valley. This area was reportedly used for burning TNT. The burning activities were confined to the ground surface. The burning activities are believed to generally correspond to the areas that currently lack vegetation.

The TNT Strips are underlain by a thin veneer of surficial residual soil or colluvium that is prone to raveling, especially on the steeper valley slopes. The residual

soil/colluvium is typically a fat clay with varying amounts of sand and gravel, which grades with depth from severely to moderately weathered shale/siltstone bedrock.

Potential Sources. The following lists the COIs for the TNT Strips and the potential source(s) of occurrence:

- Explosives: burning TNT
- PAHs, dioxins/furans: burning of organic matter or organic chemicals (including explosives)
- Metals: residue from explosives and ash from burning TNT
- Kerosene: fuel for burning TNT.

The TNT Strips (i.e., areas currently lacking vegetation) are considered to be the primary source area for the COIs, although the source area may have been disturbed where the strips cross a firebreak, via discing of the surficial soil, or where disturbed by trails.

The majority of the soil samples collected at the TNT Strips during investigations prior to the RI were collected within the strips themselves in the areas where vegetation is lacking. TNT was the most prevalent of the explosive compounds detected, followed by its breakdown product, and/or impurity TNB. A few samples were collected in the vegetated areas adjacent to the strips. Data collected from these adjacent locations indicated that the TNT concentrations in the subsurface soil along the strips (up to 2 feet bgs) attenuated significantly at relatively short lateral distances from the strips.

Potential Pathways. The following potential transport pathways have been identified for TNT Strips, given that the locations of the TNT Strips are on the crest and south-facing slope of the North Valley:

- Precipitation runoff
- Precipitation infiltration into subsurface soil/bedrock and groundwater
- Transport of surficial soil via mass wasting, discing of firebreaks, site grading activities, and erosion
- Aerial transport of dust generated by grading/erosion.

These potential transport pathways may have resulted in migration of the COIs away from the source areas. Figure 4-1 presents a schematic depiction of the conceptual model for sources and groundwater migration pathways at the TNT Strips.

Data obtained prior to the RI showed that the shallow soil has probably been affected through precipitation infiltration, which has caused COIs originating at the surface to leach into the subsurface soil/bedrock. The data also indicated that the TNT concentrations, for the most part, appeared to attenuate significantly with depth. However, the extent to which explosives had leached into the subsurface soil beyond 4 feet bgs, the maximum depth explored was unknown.

Based on information in Section 4.1.2.2, explosive compounds can typically be characterized as being highly persistent in the soil environment. Explosive compounds tend not to evaporate and are present in the soil air in negligible amounts. Therefore, migration into the ambient air was not considered to be a potential transport pathway for the TNT Strips, except during grading activities. Because of its relative insolubility, TNT is very persistent in the soils. There is the potential for leaching of TNT through the soil/bedrock zone to the shallow groundwater. However, due to the relative insolubility of explosives, any detections would be expected to be at extremely low concentrations. If groundwater were to become affected by the TNT, it could migrate to the southwest toward the valley floor, then to the southeast down the North Valley. The potential exists also for migration to the Ammunition Renovation/Primer Destruction Site area, then northwest to the Sulphur Springs Creek drainage (see Figure 4-1).

Howitzer Test Facility

The Howitzer Test Facility is situated on the east portion of the North Valley drainage divide, where the natural topography was graded to accommodate both the Howitzer Test Facility and the adjacent Ammunition Renovation/Primer Destruction Site (see Figure 4-1). The Howitzer Test Facility was used to test howitzer barrels and propellants. Building 540 may have been used for a variety of activities, including the laboratory soil testing. With the exception of excavating into the hillside in order to construct the test pad and tunnels, activities at the Howitzer Test Facility were confined to the surface. Structures within the Howitzer Test Facility were dismantled during the initial site preparation activities in late 1996. Excavated soil from OE clearance activities in this area, gravel, some OE fragments, and wood debris are currently stockpiled (Stockpile #3) along the east boundary of the Howitzer Test Facility.

Portions of the Howitzer Test Facility are underlain by artificial fill from grading activities associated with construction of the test pads/tunnels. Alluvium is present beneath portions of the artificial fill material, and grades with depth from severely to moderately weathered shale/siltstone bedrock.

Potential Sources. The following lists the COIs for the Howitzer Test Facility and the potential sources of occurrence:

- Explosives: propellants and burning of primer at the adjacent Ammunition Renovation/Primer Destruction Site.

- Solvents (VOCs): cleaning, general maintenance, and painting activities
- PAHs, dioxins/furans: burning of organic matter and organic chemicals (including explosives and propellants), heavy fuel hydrocarbons, asphalt
- Metals: scrap from casings, residue from explosives
- Diesel/motor oil: vehicles parked at facility, heating, dust control
- Kerosene: fuel for burning, heating
- PCBs: waste oil
- Nitrate: propellant for artillery shells
- Organochlorine pesticides: soil test laboratory (Building 540).

In addition to the compounds listed above, consideration was given to perchlorate and hydrazine, as requested by DTSC. However, no analytical test were performed for either chemical because the likelihood of detection was extremely remote. Perchlorate is very soluble in water; therefore, the shallow groundwater at the site, combined with abundant rainfall in wet years, made detection unlikely. Hydrazine is very volatile and not likely to persist in soils for any length of time; therefore, detecting hydrazine in soils is very difficult.

Sources of COIs may occur as either a point source release (i.e., a concentrated pile of metal scrap from casings) or a non-point source release (i.e., widely disseminated metal residue from explosives). This can result in characteristic occurrences and migration pathways (see below), which are potentially significant in understanding the nature and extent of the COIs for this area.

Surface/near-surface soil has been disturbed through past construction grading and more recent excavation activities at the Howitzer Test Facility during the 1996 initial site preparation activities. The excavated soils and debris stored within the area in Stockpile #3 is representative of the surficial soils and can be considered a "secondary" source of the COIs.

Potential Pathways. The following potential transport pathways have been identified in the Howitzer Test Facility:

- Precipitation infiltration into subsurface soil/bedrock and groundwater
- Precipitation runoff (including from stockpiled soil)

- Grading
- Erosion.

The potential transport pathways may have resulted in migration of the COIs away from the source area. Figure 4-1 presents a schematic depiction of the conceptual model for sources and migration pathways of the COIs.

With the exception of the VOCs, most of the COIs associated with the Howitzer Test Facility are very persistent in soils. Heavy fuels, PAHs, and metals all tend to be relatively immobile. Explosives also tend to be highly persistent in soil (as previously discussed) and are relatively insoluble, while solvents (VOCs) are considered to be mostly readily soluble and highly mobile. Volatilizations from near-surface soil and aeration of the soil stockpiles would generally preclude detection of VOCs in these locations. VOCs potentially originating at the surface could be present in the deeper soil or groundwater, provided sufficient mass was available to support subsurface migration. Perchlorate and hydrazine are both highly soluble and relatively mobile in soil. Therefore, only trace amounts of perchlorate/hydrazine would be expected in soil if a release occurred. Pesticides in soil are relatively insoluble and tend to be persistent.

Most of the sources of the COIs in the Howitzer Test Facility area are likely to be point-source releases associated with the facility structures (e.g., solvents, lubricants, associated with machine maintenance). A point-source release of a COI would likely result in a relatively high concentration in a small area and significant attenuation of the concentration laterally away from the area. There is higher potential for vertical migration of the COI and threat to groundwater from a point-source release than from a non-point-source release.

There is also the potential for non-point-source releases of COIs in the Howitzer Test Facility (i.e., petroleum hydrocarbons used for dust control). The resulting extent of a non-point-source release can be characterized by: (1) absence of a small area with a high concentration; (2) disseminated and relatively low concentrations of the COI in near-surface soil; (3) limited downward migration in the soil zone; and, (4) absence of groundwater impact due to insufficient mass.

Activities at the Howitzer Test Facility may have affected the subsurface soil/ bedrock and groundwater. Since the Howitzer Test Facility is near the upper reaches of the North Valley, any groundwater that may have been affected by the Howitzer Test Facility would predominantly migrate to the southeast down the North Valley.

North Valley Military Landfill

The North Valley Military Landfill is situated immediately adjacent to and northeast of the Howitzer Test Facility. There is little historical information available on this site. Information obtained from the site history (see Section 2.3.1.3) indicates that

a poorly defined drainage pathway was gradually filled to a maximum depth of approximately 12 feet with shell casings, shrapnel, and debris dug out from the test tunnels after artillery testing. During the 1996 initial site preparation activities at the Howitzer Test Facility (see Section 2.3.1.2), an area of debris was encountered east of the Howitzer Test Facility disposal area (Earth Tech, 2000f) to a depth of no more than 5 feet bgs. However, the debris uncovered in this area was mainly wood crates, pallets, and packing materials. Some inert ordnance, including 155mm howitzer practice rounds (gravel- or plaster-filled), was also recovered and removed from this area during the OE clearance of the Howitzer Test Facility. The wood debris and packing materials were added to Stockpile #3.

The North Valley Military Landfill is directly underlain by valley alluvium, which grades with depth from severely to moderately weathered shale/siltstone bedrock.

Potential Sources. The COIs for the North Valley Military Landfill are identical to those of the Howitzer Test Facility (with the addition of pentachlorophenol due to the potential presence of this wood preservative related to wood wastes), since the Howitzer Test Facility is the likely source for the material thought to have been placed in this disposal area.

Potential Pathways. The following potential transport pathways have been identified for the North Valley Military Landfill:

- Precipitation infiltration into subsurface soil/bedrock and groundwater
- Precipitation runoff (including from the stockpiled soil).

Figure 4-1 presents a schematic depiction of the conceptual model for sources and migration pathways of the COIs.

With the exception of VOCs, most of the COIs associated with the North Valley Military Landfill are very persistent in soils. Heavy fuels, PAHs, pentachlorophenol, and metals all tend to be relatively immobile. Explosives also tend to be highly persistent in soil and are relatively insoluble (as previously discussed), while solvents and paints are considered to be readily soluble and relatively highly mobile.

Activities at the North Valley Military Landfill may have affected the subsurface soil/bedrock and groundwater. Since the North Valley Military Landfill is near the upper reaches of the North Valley, if groundwater were to become affected, it would predominantly migrate to the southeast down the North Valley, as described for the Howitzer Test Facility.

Ammunition Renovation/Primer Destruction Site

The Ammunition Renovation/Primer Destruction Site is situated on the North Valley drainage divide, where the natural topography was graded to accommodate

both the Ammunition Renovation/Primer Destruction Site and the adjacent Howitzer Test Facility. The Ammunition Renovation/Primer Destruction Site was used to refurbish ordnance and to burn primers in a "squirrel cage." With the exception of potential USTs in the area of buildings (based on interpretation of geophysical anomalies), activities at the Ammunition Renovation/Primer Destruction Site were confined to the surface. Structures within the Ammunition Renovation/Primer Destruction Site were dismantled during the initial site preparation activities in late 1996. The excavated asphalt and shallow soil are currently stockpiled (Stockpiles #1 and #2) along the north boundary of the Ammunition Renovation/Primer Destruction Site.

The Ammunition Renovation/Primer Destruction Site is underlain by artificial fill from grading activities associated with facilities and area activities. Alluvium is present beneath the artificial fill material, and grades with depth from severely to moderately weathered shale/siltstone bedrock.

Potential Sources. The following lists the COIs for the Ammunition Renovation/Primer Destruction Site and the potential sources of occurrence:

- Explosives: burning of primers and residues from ammunition renovation activities
- Solvents (VOCs): cleaning, general maintenance, and painting activities
- PAHs, dioxins/furans: burning of organic matter or organic chemicals (including explosives and propellants), heavy fuel hydrocarbons, asphalt
- Metals: scrap from casings, residue from explosives, painting and machine shop activities
- Diesel/motor oil: vehicle maintenance, vehicles parked at facility, UST(s), dust control
- Kerosene: fuel for burning related to primer destruction activities, heating
- Nitrate: propellant for ammunition renovation activities, latrine, or septic tank
- PCBs: waste oil, transformers.

Sources of the COIs may occur as either point source releases (i.e., fuel release from UST, solvents and lubricants associated with machine maintenance) or non-point source releases (i.e., widely disseminated petroleum hydrocarbons used for dust control). This can result in characteristic occurrences and migration

pathways (see below), which are potentially significant in understanding the nature and extent of the COIs for this area.

Surface/near-surface soil has been disturbed through past construction grading and more recent excavation activities at the Ammunition Renovation/Primer Destruction Site during the 1996 initial site preparation activities. The excavated soils and debris stored within the area in Stockpiles #1 and #2 are representative of the surficial soils, and can be considered a "secondary" source of the COIs.

Potential Pathways. The following potential transport pathways have been identified for the Ammunition Renovation/Primer Destruction Site:

- Precipitation infiltration into subsurface soil/bedrock and groundwater
- Precipitation runoff (including from the stockpiled soil)
- Grading
- Erosion
- Aerial.

The potential transport pathways may have resulted in migration of the COIs away from the source areas. Figure 4-1 presents a schematic depiction of the conceptual model for sources and groundwater migration pathways of the COIs.

With the exception of VOCs, most of the potential COIs associated with the Ammunition Renovation/Primer Destruction Site are very persistent in soils. Heavy fuels, PAHs, and metals all tend to be relatively immobile. Explosives also tend to be highly persistent in soil and are relatively insoluble (as previously discussed).

Sources of the COIs from the Ammunition Renovation/Primer Destruction Site are likely to be point-source releases associated with the facility structures. A point-source release of a COIs would likely result in a small area of relatively high concentration and significant attenuation of the concentration laterally away from the area. There is higher potential for vertical migration of the COIs and a threat to groundwater from a point-source release than from a non-point-source release.

There is also the potential for non-point-source releases of COIs in the Ammunition Renovation/Primer Destruction Site (i.e., petroleum hydrocarbons used for dust control). The resulting extent of a non-point-source release can be characterized by (1) absence of a small area with a high concentration; (2) disseminated and relatively low concentrations of the COI in near-surface soil; (3) limited downward migration in the soil zone; and, (4) absence of groundwater impact due to insufficient mass.

Activities at the Ammunition Renovation/Primer Destruction Site may, therefore, have affected the subsurface soil/bedrock and groundwater. Since the Ammunition Renovation/Primer Destruction Site is situated at the drainage divide between the North Valley (to the southeast) and an unnamed valley (to the northwest), surface and groundwater from this area of interest could flow in either direction. The aerial transport pathway also must be considered at the Ammunition Renovation/Primer Destruction Site because the nature of the work performed there allowed combustion by-products to become airborne particles. Prevailing winds are likely to transport such particles from the west to the east, although topographic influences could deflect the pathway toward the southeast, down the North Valley.

4.1.3.2 Ridge Areas of Interest.

Dynamite Burn Site

The Dynamite Burn Site was identified as an area of interest associated with the Ridge where DOD-related activities may have resulted in impact to bedrock and groundwater. Common to all the areas of interest are the potential migration pathways of the COIs, as controlled by the topography/drainage patterns, geology, and hydrogeology (see Figure 4-1).

However, the portion of the Ridge where the Dynamite Burn Site was situated, approximately 600 feet south of the howitzer test tunnels, was removed as part of the initial site grading activities (see Section 2.3.3). Surface soil potentially affected by past activities appear to have been used in the construction the McAllister Drive Land Bridge based on the analysis presented in Section 2.3.3. Furthermore, if the Ridge material was transported to the land bridge, it would most likely be near its base, since the upper portions of the Ridge would have been excavated first and the material that had been removed would have been the early fill placed.

However, in the period prior to the excavation activities, subsurface migration of the COIs may have occurred to a depth or distance beyond the limit of the excavation. Therefore, since the soil directly below the Dynamite Burn Site may have been impacted, three potential source areas exist: (1) the bedrock remaining beneath the Dynamite Burn Site after excavation on the Ridge, (2) downgradient soil not removed by excavation, and (3) the lower portion of the land bridge.

Potential Sources. The following lists the COIs for the Dynamite Burn Site and the possible sources of occurrence:

- Nitroglycerin: burning of dynamite
- Nitrate: residue/breakdown of dynamite.

PAHs and dioxins/furans, if present, would be expected to occur near the surface as the result of burning of organic material. However, since approximately 20 to

40 feet was cut from the original grade of the Ridge, these were no longer considered COIs for the Dynamite Burn Site.

Potential Pathways. The following potential transport pathways have been identified for the Dynamite Burn Site:

- Precipitation runoff
- Precipitation infiltration into subsurface soil/bedrock and groundwater
- Transport of surficial soil via grading activities to the McAllister Drive Land Bridge
- Grading
- Erosion
- Aerial.

Figure 4-1 presents a schematic depiction of the conceptual model for sources and groundwater migration pathways of the COIs. The migration pathway from the Ridge can be both to the north toward the North Valley, or to the south toward the South Valley. The subsurface migration of the COIs is limited by the low-permeability soil and bedrock, and limited groundwater occurrence especially on the Ridge, where the depth to shallow groundwater is greater than in the adjacent valley floors. The aerial transport pathway also must be considered at the Dynamite Burn Site, not only because of the potential for combustion by-products to become airborne, but also because the previous grading activities could have caused dust particles to become airborne. Prevailing winds are likely to transport such particles from the west to the east, although topographic influences could deflect the pathway over the Ridge and down the North Valley toward the southeast.

Explosives tend to be highly persistent in soil and are relatively insoluble (as previously discussed). Nitrate tends to move relatively freely through the soils zone to groundwater, unless active vegetation causes uptake, provided sufficient mass is available to support subsurface migration.

Surficial soil at the site may have been affected and transported to the McAllister Drive Land Bridge. Because potentially affected soil has been moved to the land bridge, which spans the South Valley, the groundwater and the surface water in the wetland area may have been affected as a result of the transport pathways previously listed.

A mobile, truck-mounted communication tower may also have been situated on the Ridge (see Figure 2-9). Since the aerial photographs do not reveal evidence of ground disturbance that could have been caused by this facility, this feature was

not designated as an area of interest requiring targeted exploration. Additional investigation downgradient of the Dynamite Burn Site and additional investigation of the McAllister Drive Land Bridge are planned after the OE point clearance for COIs possibly associated with a mobile communications tower (see Table 8-1).

4.1.3.3 South Valley Areas of Interest.

As summarized below, the areas of interest situated within the South Valley include the Flare Site and Demolition Sites #1, #2, and #3. These sites, except Demolition Site #2 where no evidence of DOD-related activities was found, experienced a variety of DOD-related activities that may have resulted in impact to the surface and subsurface soils. Common to all the areas of interest are the potential migration pathways of the COIs, as controlled by the topography/ drainage patterns, geology, and hydrogeology (see Figure 4-1). As with the North Valley, the mechanisms for surface migration of COIs in the South Valley are as follows:

- Local downslope gravity movement of soil
- Surface runoff of precipitation
- Erosion from wind, water, and vehicle traffic.

Typically, the migration pathway is down the south-facing or north-facing slope of the South Valley and downgradient toward the east within the east-sloping valley. Surface water movement along the South Valley has been impeded during heavy peak flows by the construction of the McAllister Drive Land Bridge that is designed to restrict flow and prevent flooding downstream.

Subsurface migration of the COIs is limited by the low-permeability soil and bedrock, and the limited occurrence of groundwater. The primary mechanism for subsurface migration of COIs is infiltration of precipitation that may leach those chemicals into the subsurface. Infiltration of precipitation is expected to be very limited along the side slopes of the valley due to the relatively thin fine-grained residual soil/colluvium and low-permeability bedrock. Infiltration is expected to be more significant near the valley floor, where surface water runoff accumulates and infiltrates through the alluvium.

However, the presence of a significant wetland area in the South Valley suggests that infiltration into the alluvium along the valley floor may be limited in areas by the permeability of the alluvium (predominately a fat clay with minor sand and gravel toward the contact with the underlying weathered bedrock).

Flare Site

The Flare Site is on the north-facing slope of the South Valley immediately above the wetland; therefore, COIs from the Flare Site may have affected wetland sediments and surface waters. The Flare Site was used to burn and dispose of flares. Flare Site activities were confined to the surface. In the field, the center of

the Flare Site is readily discernible as a small, flat area covered by residual gray ash and pieces of burnt flares.

The Flare Site is underlain by approximately 10 feet of landslide materials consisting of colluvial deposits, typically fat clays with varying amounts of sand and gravel overlying severely to moderately weathered shale/siltstone bedrock.

Potential Sources. The following lists the COIs for the Flare Site and the possible sources of occurrence:

- Explosives: burning of flares
- PAHs, dioxins/furans: burning of organic matter or organic chemicals (including explosives)
- Metals (including phosphorus): flare residue.

Potential Pathways. The following potential transport pathways have been identified for the Flare Site:

- Precipitation runoff
- Transport of surficial soil via gravity downslope toward the wetland
- Precipitation infiltration into subsurface soil/bedrock and groundwater
- Transport downgradient by wetland surface water/groundwater
- Aerial pathway.

Most of the COIs associated with the Flare Site are very persistent in soils. Metals and PAHs all tend to be relatively immobile. Explosives tend to be highly persistent and are relatively insoluble (as previously discussed).

Precipitation results in surface water runoff from the Flare Site toward the topographic low of the wetland. Precipitation that infiltrates into the side slopes may have leached the COIs into the subsurface soil/bedrock. Given the proximity of the Flare Site to the wetland, it is likely that the depth to groundwater in this area is relatively shallow. If groundwater became affected by the Flare Site, it would migrate north toward the wetland, then tend to migrate east down the South Valley beneath the McAllister Drive Land Bridge. The aerial transport pathway also must be considered at the Flare Site because the nature of the flare destruction activities there allowed combustion by-products to become airborne particles. Prevailing winds are likely to transport such particles from the west to the east, although topographic influences could deflect the pathway toward the south of east, and down the South Valley.

Figure 4-1 presents a schematic depiction of the conceptual model for sources and groundwater migration pathways of COIs.

Demolition Sites

Three demolition sites (Demolition Sites #1, #2, and #3) were identified in the area of the South Valley and are further described below.

Demolition Site #1 is situated within a drainage channel running down the north-facing slope of the South Valley. No live ordnance items have been recovered from this site during previous investigations. However, OE scrap and fragments have been recovered around and near the site, and a large magnetic anomaly is present within this area (see Figure 9-1).

Demolition Site #2 is a suspected demolition site that does not show evidence of use. This site is also on the north-facing slope of the South Valley between the Flare Site and Demolition Site #1. Review of geophysical data (see Figure 9-1) does not indicate that the site has a high anomaly count similar to those of Demolition Sites #1 and #3, no field evidence of OE scrap or fragments has been observed during site visits, and non-OE affected soil has not been found at this site. The site was subsequently removed from further consideration.

Demolition Site #3 is situated along the south-facing slope of the South Valley, immediately above the wetland. Demolition Site #3 is a confirmed ordnance demolition area where out-of-service munitions were placed in a pit and detonated. A half-track armored personnel vehicle was reportedly removed from the site in the mid-1990s, and the resulting depression was backfilled.

Demolition Sites #1 and #2 are underlain by a thin veneer of surficial residual soil or colluvium, typically a fat clay with varying amounts of sand and gravel that grades into severely to moderately weathered shale/siltstone bedrock. It is thought that at Demolition Site #3, approximately 10 feet of fill exists and overlies bedrock.

Potential Sources. The following lists the COIs for the demolition sites and the potential sources of occurrence:

- Explosives: demolition activities
- PAHs: burning of organic matter or chemicals (including explosives)
- Metals: explosives residue, destroyed ordnance.

Potential Pathways. The following potential transport pathways have been identified for Demolition Sites #1 and #3:

- Precipitation runoff
- Precipitation infiltration into subsurface soil/bedrock and groundwater
- Transport of surficial soil via gravity downslope toward the wetland
- Transport downgradient by wetland surface water/groundwater
- Aerial pathway.

Figure 4-1 presents a schematic depiction of the conceptual model for sources and groundwater migration pathways of the COIs.

Most of the COIs are very persistent in soils. Metals and PAHs all tend to be relatively immobile. Explosives tend to be highly persistent in soil and are relatively insoluble (as previously discussed).

Precipitation will result in surface water runoff from the demolition sites toward the topographic low of the wetland. Precipitation that infiltrates into the sideslopes may have leached the compounds into the subsurface soil/bedrock. Given the proximity of the demolition sites to the wetland, it is likely that the depth to groundwater in this area is relatively shallow. If groundwater became affected by the demolition sites, it would migrate south toward the wetland, then tend to migrate east down the South Valley beneath the McAllister Drive Land Bridge. The aerial transport pathway also must be considered at the Demolition Sites because the nature of the demolition activities there allowed combustion by-products to become airborne particles. Prevailing winds are likely to transport such particles from the west to the east, although topographic influences could deflect the pathway toward the south of east, and down the South Valley.

4.2 INVESTIGATIVE PHASES

As previously stated, an iterative and focused approach was used for the non-OE RI at the Project Site that resulted in four phases of fieldwork:

- **Interim Investigation** - Conducted in May through July 1999 prior to preparation of a formal work plan. Data from the interim investigation were used in the development of DQOs for the non-OE RI. As described in Section 1.1, the final product of the DQO process is a work plan that includes an SAP and associated QAPP; together they present a data collection design that meets the quantitative and qualitative needs of the study. The interim data were also used in the development of the Conceptual Source and Transport Model (see Section 4.1.3), a tool used along with the DQOs to determine the scope and rationale for the non-OE field sampling programs.

- **Remedial Investigation** - Conducted in December 1999, after preparation of the Draft Final Work Plan (Earth Tech, 1999c). The SAP and QAPP presented in the Draft Final Work Plan (Earth Tech, 1999c), and ultimately the Final Work Plan (Earth Tech, 2000b), formed the basis for the RI and subsequent follow-on investigations at the Project Site. The RI was designed to evaluate the nature and extent of COIs at the Project Site to the extent necessary to adequately evaluate remedial action alternatives in the FS.

- **Data Gaps Investigation** - Conducted in several phases starting in February through August 2000. The initial phase, conducted in February 2000, was essentially a continuation of the RI. During the RI, several boreholes were advanced for the installation of groundwater monitoring wells; however, groundwater was encountered at only three of the designated locations. DTSC subsequently requested that monitoring wells be installed at all designated well locations in order to monitor seasonal groundwater fluctuations. This work was conducted in accordance with the Final Work Plan (Earth Tech, 2000b). Upon review of the RI preliminary (i.e., unverified and unvalidated) data, a number of "data gaps" were identified that would need to be filled prior to completion of the non-OE RI. The data gaps investigation SAP was outlined in the Tech Memo (Earth Tech, 2000c), which served as an addendum to the Final Work Plan (Earth Tech, 2000b). This stage of the data gaps investigation was conducted March 2000 through May 2000, after preparation of the Tech Memo. Additional phases of work to the data gaps investigation were conducted in June 2000 and August 2000 after the scope of the supplemental work was submitted to DTSC in three letters dated June 5, July 31, and August 21, 2000, respectively. These letters served as addenda to the Final Work Plan (Earth Tech, 2000b) and the Tech Memo (Earth Tech, 2000c). These later phases of work included additional sampling in the vicinity of the TNT Strips, additional sampling of the South Valley wetland sediment and another round of groundwater sampling, and field permeability testing. Off-site sampling to the north and east of the Project Site boundary was also conducted in August 2000.

- **Removal Action Investigation** - Conducted in May and June 2000. The removal action investigation focused on the North Valley Military Landfill, which was not included in any of the previous investigations since investigation of this site would require potential "OE removal" to complete the fieldwork, as opposed to potential "OE avoidance," which was practiced during the interim, remedial, and data gaps investigations. The removal action investigation SAP was outlined in the RAW (Earth Tech,

2000f). Initially, two trenches were to be excavated through the landfill; however, the trenches were replaced in the field by a series of 30 test pits excavated along the approximate trench alignments.

Each of the investigative phases is presented in the following sections and summarized in Tables 4-4 through 4-7. With the exception of the interim investigation, all fieldwork was performed in accordance with the protocols and procedures presented in the Final Work Plan (Earth Tech, 2000b), the Tech Memo (Earth Tech, 2000c) and associated letter addenda, and the RAW (Earth Tech, 2000f), respectively, as described in Appendix C. As previously stated, the interim investigation was conducted prior to the development of a formal work plan. However, samples collected during the interim investigation were collected in accordance with the procedures presented in the Final Work Plan (Earth Tech, 2000b), unless otherwise stated in Appendix C. All data collected from the non-OE RI (including the interim investigation data), except as noted below, have been validated according to the QAPP and associated addenda, and are considered to represent definitive-level data as discussed in the QCSRs presented in Volume IV of this document and summarized in Chapter 5.0.

Geological and hydrogeological data obtained from all the exploratory boreholes, test pits, and seismic refraction survey are discussed as part of the site-specific geology (see Section 4.3). Soil, sediment, surface water, and groundwater analytical results from the four investigation sampling programs, which have been fully verified and validated, are presented in Chapter 5.0. It should be noted that during the following discussion of the various investigation programs, reference is made to preliminary (i.e., unverified and unvalidated) analytical data. These data are referenced only in the context of how the preliminary results were used in the development of the various sampling programs. The reader is directed to Chapter 5.0 for all final definitive-level analytical results. Reference is also made in the following sections to data that may be "rejected" during the data verification/ validation process. These data are also referenced only in the context of how the preliminary analytical results were used in the development of the various sampling programs. The reader is directed to the Chapter 5.0 for a summary of the final rejected data and to the QCSRs in Volume IV of this document for a complete discussion on the completeness of the non-OE RI analytical dataset.

4.2.1 Interim Investigation Program

The interim investigation was conducted in June/July 1999, immediately after the Order was issued, with the exception of the test pits, which were excavated in May 1999. The primary objective of the interim investigation was to obtain analytical data that could be used in the development of a work plan for the non-OE RI/FS activities at the Project Site, since the only available analytical data at the time of the Order were unverified and unvalidated screening-level data collected by SECOR in late 1998 (see Section 3.2). The interim investigation focused on those areas of interest where screening-level data showed detectable

concentrations of some of the COIs, in particular, the TNT Strips in the North Valley and the Flare Site in the South Valley. Additional sampling of Demolition Sites #1 through #3 was also included in the interim investigation. The interim investigation focused on three "core" COIs "groups": explosives, PAHs (by-product of burning organic materials), and metals.

Interim investigation borehole locations are shown on Figure 4-2 and summarized in Table 4-4. Details of the work performed during the interim investigation are presented in Appendix C. Copies of the Test Borehole Logs are included in Attachment C-3 of Appendix C. It should be noted that final borehole locations were subject to, and dependent on, OE avoidance.

A minimum of 10 percent replicate soil samples was collected during the interim investigation, as described in the QCSRs (see Volume IV of this document). Additional split soil samples were also collected for use by DTSC and/or USACE. Soil samples from the interim investigation were submitted to one of the following off-site analytical laboratories for chemical analysis: Quanterra, Inc. (Quanterra), of West Sacramento, California, or CalTest of Napa, California. It should be noted that Quanterra has since been acquired by Severn Trent Laboratories (STL).

4.2.1.1 TNT Strips.

During the 1998 SECOR investigation, five surface soil samples (SS-1 through SS-5) were collected along the axis of the TNT Strips (i.e., areas lacking vegetation). TNT was detected in the surface soil at concentrations up to 72,400 mg/kg. The objective of the interim investigation sampling program at the TNT Strips was to collect soil samples below the ground surface along the axis of the TNT Strips and at selected step-out locations (vegetated area immediately adjacent to the strip). The analytical data would then be used in a preliminary evaluation of the nature and extent of COIs in the soil at the TNT Strips so that an effective data collection program could be established for the follow-on RI.

During the interim investigation, one shallow borehole was advanced toward both ends of each TNT strip (e.g., TNT-1A and -1C, -2A and -2C). Soil samples were collected at 1 foot and 2 feet bgs, unless bedrock was encountered. One additional borehole was advanced toward the center of each TNT Strip (e.g., TNT-1B, TNT-2B). Soil samples from the center borehole were collected at 1 foot, 2 feet, and 4 feet bgs, unless bedrock was encountered. Two additional boreholes at each strip (TNT-2D, -2E and -5D, -5E) were advanced in adjacent vegetated areas near each of the two associated strips (TNT Strip #2 and TNT Strip #5, respectively). Soil samples from these boreholes were collected at 1 foot and 2 feet bgs, unless bedrock was encountered. All interim investigation samples collected from the TNT Strips were analyzed for the following COIs:

- Explosives by EPA Method SW8330
- PAHs by EPA Method SW8310

- CAM 17 Metals (antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc) by EPA Methods SW6010B/7470A/7471A.

In addition, one sample collected from borehole TNT-2A on TNT Strip #2 at 1 foot bgs and one sample collected from borehole TNT-5A on TNT Strip #5 at 1 foot bgs were also analyzed for dioxins/furans by EPA Method SW8290. After submittal of the soil samples to the analytical laboratory, it was determined that the soil at the TNT Strips should also be analyzed for nitroglycerin and PETN by EPA Method SW8330. Since replicate soil samples had been collected at most locations for quality control (QC) purposes and for use by DTSC and/or USACE, these replicate samples were used for the nitroglycerin and PETN analyses.

4.2.1.2 North Valley Stockpiles.

Three stockpiles containing soil and various types of debris are situated in the North Valley. Stockpiles #1 and #2 are situated in the Ammunition Renovation/ Primer Destruction Site and contain asphalt paving and soil resulting from the dismantling of this site in late 1996. Stockpile #3 is situated in the Howitzer Test Facility and contains soil, gravel, and OE scrap resulting from the dismantling of structures/facilities at the Howitzer Test Facility, also in late 1996. These stockpiles were not sampled during the SECOR investigation. The objective of the interim sampling program at the stockpiles was to obtain analytical data from the soil matrix in the stockpiles that could be used to assist in the eventual disposition of the stockpile material.

During the interim investigation, two discrete soil samples were collected from Stockpile #1 (SP1-A1, -B1) and Stockpile #2 (SP2-A1, -B1), respectively, at 2 feet below the stockpile surface. Four discrete soil samples were also collected from Stockpile #3 (SP3-1, SP3-2, SP3-3, and SP3-4) at 2 feet below the stockpile surface. All interim investigation samples collected from the North Valley stockpiles were analyzed for the following COIs:

- Explosives by EPA Method SW8330
- PAHs by EPA Method SW8310
- CAM 17 Metals by EPA Methods SW6010B/7470A/7471A.

Due to matrix interference during analysis of a number of the stockpile samples by EPA Method SW8310, the samples had to be diluted to such a degree that PAHs would not be detected, if present, at the higher RLs. The analytical laboratory suggested reanalyzing the affected samples by EPA Method SW8270C in order to get lower RLs.

4.2.1.3 Flare Site.

During the SECOR investigation, one surface soil sample (SS-22) and one surface soil field sample (FSS-29) were collected at the Flare Site. One explosive compound (RDX) was detected at a low concentration of 2.6 mg/kg in the field screening sample, while elevated concentrations of various metals (including antimony, barium, copper, lead, and zinc) were detected in the SS sample. The objective of the interim sampling program at the Flare Site was to collect soil samples below the ground surface toward the center and periphery of the surface expression of the burn area (i.e., area of residual ash). The analytical data would then be used in a preliminary evaluation of the nature and extent of COIs in the soil at the Flare Site so that an effective data collection program could be established for the follow-on RI.

During the interim investigation, one shallow borehole (FA-3) was to be advanced near the center of the Flare Site. However, only a near-surface sample was collected from the residual ash covered area during the interim investigation based on OE avoidance. Two additional boreholes (FA-1 and -2) were advanced toward the periphery of the residual ash-covered area. Soil samples were collected at 1 foot and 2 feet bgs, unless bedrock was first encountered. All interim investigation samples collected from the Flare Site were analyzed for the following COI:

- Explosives by EPA Method SW8330
- PAHs by EPA Method SW8310
- CAM 17 Metals by EPA Methods SW6010B/7470A/7471A.

In addition, the near-surface sample collected at 0.5 foot bgs was analyzed for dioxins/furans by EPA Method SW8290.

4.2.1.4 Demolition Sites.

Demolition Sites #1, #2, and #3 were included as part of the 1998 SECOR investigation. One explosive compound (RDX) was detected at a low concentration of 1.4 mg/kg in one of the field screening samples collected in the vicinity of Demolition Site #1. The objective of the interim sampling program at the demolition sites was to collect soil samples below the ground surface. The analytical data would then be used in a preliminary evaluation of the nature and extent of COIs in the soil at the demolition sites so that an effective data collection program could be established for the follow-on RI.

During the interim investigation, two boreholes were advanced at each demolition site (DA1-1 and DA1-2, DA2-1 and DA2-2, DA3-1 and DA3-2). Soil samples were collected at 1 foot, 2 feet, and 4 feet bgs, unless bedrock was encountered. All interim investigation samples collected from the demolition sites were analyzed for the following COIs:

- Explosives by EPA Method SW8330
- PAHs by EPA Method SW8310
- CAM 17 Metals by EPA Methods SW6010B/7470A/7471A.

4.2.1.5 South Valley Wetland.

No sediment samples were collected from the South Valley wetland area during the 1998 SECOR investigation. The objective of sampling the wetland sediment was to obtain analytical data that could be used in an initial assessment of potential impact of the areas of interest in the South Valley so that an effective data collection program could be established for the follow-on RI.

During the interim investigation, one sample (WET-1B) was collected from the wetland sediment and analyzed for the following COIs:

- Explosives by EPA Method SW8330
- PAHs by EPA Method SW8310
- CAM 17 Metals by EPA Methods SW6010B/7470A/7471A.

4.2.1.6 Other Activities

In addition to the collection of soil/sediment samples for chemical analysis, the interim investigation also included conducting a shallow seismic refraction survey and excavating a series of test pits to evaluate the depth to bedrock in the South Valley in the vicinity of the flare and demolition sites.

Twelve test pits were excavated in the South Valley in May 1999 to assist in the characterization of the depth to weathered/unweathered bedrock. Locations of

the test pits are shown on Figure 4-2. The maximum depth of the test pits ranged from 4.5 feet to 12 feet bgs.

The purpose of the geophysical survey was to further define the thickness of overburden and highly weathered bedrock overlying the less weathered bedrock to assist in an evaluation of the approximate volume of overburden material that may need to be excavated as part of any removal action alternative evaluated in the FS. The seismic refraction survey was conducted by NORCAL in June 1999. Seismic refraction data were obtained from a series of traverses situated perpendicular to the east-west drainage of the South Valley.

Locations of the seismic refraction survey traverses are shown on Figure 4-2. Seismic refraction data from the South Valley appeared to resolve the shallow subsurface into two or three seismic velocity layers as follows:

- V1 (surficial layer) - typical seismic velocity below 1,500 feet per second (fps), which has been interpreted as representing the thickness of residual soil and possible colluvium in localized areas

- V2 (intermediate layer) - typical seismic velocity in the range of 2,000 to 2,900 fps, which has been interpreted as representing highly weathered bedrock material

- V3 (deepest layer) - typical seismic velocity greater than 3,000 fps, which has been interpreted as representing less weathered bedrock material.

The interpreted thickness of the surficial material and depth to less weathered bedrock along each seismic line are summarized in Table 1 of NORCAL's report presented in Attachment C-2 of Appendix C. Interpreted thickness of surficial material is also summarized on Figure 4-5.

The results of the shallow seismic refraction survey and the test pit data are discussed as part of the site-specific geology (see Section 4.3).

4.2.2 Remedial Investigation Program

Preliminary analytical data (i.e., unverified and unvalidated) from the interim investigation were used to develop a work plan for the non-OE RI. The RI was conducted after preparation of the Draft Final Work Plan (Earth Tech, 1999c). In a DTSC letter dated November 24, 1999, it was requested that the following be incorporated into the RI field program:

- Collection of additional soil samples along the southeastern extension of TNT Strip #1 and collection of additional soil samples along the slope wash emanating from TNT Strip #5

- Analysis of soil samples from the TNT Strips, starting from the top and continuing downwards, until two consecutive non-detects for explosive compounds are obtained

- No compositing of bedrock samples collected from the Dynamite Burn Site

- Collection of soil samples outside the areas of interest to assist in the determination of ambient metals concentrations

- Collection of soil samples from the upslope and downslope toe of the McAllister Drive Land Bridge

- Installation of a permanent monitoring well at the downgradient toe of the McAllister Drive Land Bridge

- Analysis of all groundwater samples from the North Valley for perchlorate
- Collection of stockpile samples in accordance with the sampling frequencies contained in EPA SW846
- Advancement of boreholes in the North Valley to coincide with historical buildings
- Collection of split soil samples for DTSC and USACE at a frequency of 10 percent and 5 percent, respectively
- Acquisition of well permits from Solano County Department of Environmental Management (DEM) prior to monitoring well installations.

These additional requirements were subsequently incorporated into the Final Work Plan (Earth Tech, 2000b).

The primary objective of the RI was to obtain definitive-level data that would provide information on the nature and extent of those COIs that have impacted soil, sediment, surface water, or groundwater (i.e., COIs) in order to adequately evaluate potential human health and ecological risks and remedial action alternatives in the FS.

RI sampling locations are shown on Figure 4-2 and summarized in Table 4-5. Details of the work performed during the RI are presented in Appendix C. Copies of the Test Borehole Logs are included in Attachment C-3 of Appendix C. It should be noted that final borehole locations were subject to, and dependent on, OE avoidance.

A minimum of 10 percent replicate soil and duplicate water samples (see QCSRs in Volume IV of this document) were collected during the RI, as required by the QAPP. Additional split soil samples were also collected for use by DTSC and/or USACE at a minimum frequency of 10 percent and 5 percent, respectively. Soil samples for explosives, PAHs, TEPHs, and VOCs were analyzed by ONSITE Environmental Laboratories (ONSITE) of Fremont, California, using a mobile laboratory at the Project Site, while metals, dioxins/furans, and general water chemistry were analyzed off site by Quanterra. Quanterra also performed confirmation analyses on a select number of samples analyzed for explosives by the ONSITE mobile laboratory. Water samples requiring analysis for perchlorate were analyzed by E.S. Babcock & Sons (Babcock) of Riverside, California. Due to the need to submit samples to both an on- and off-site analytical laboratory, as well as the number of replicate and split soil samples required to fulfill the DQOs, replicate and split samples within the uppermost 3 feet of soil were generally collected from boreholes advanced within 6 inches of each other center-to-center (as close as the sampling method would allow), while replicate and split soil

samples collected at greater than 3 feet were generally taken at consecutive depths. Boreholes used for replicate and split sample collection were identified with an "A" (e.g., TNT-1C represents the borehole for primary sample collection, whereas TNT-1CA represents the borehole for replicate and split sample collection). It should be noted that "A" boreholes are not shown on the figures since they are considered to represent the same location as the primary borehole.

4.2.2.1 TNT Strips.

Preliminary (i.e., unverified and unvalidated) analytical data from the interim investigation indicated that elevated concentrations of explosive compounds exist in the uppermost soil along the axis of the TNT Strips where vegetation is lacking. However, the concentrations appeared to decrease significantly with depth beneath the strip and laterally off the strips within the vegetated areas. The highest concentration of explosive compounds detected at the TNT Strips during the interim investigation was 380,000 mg/kg of TNT at 1 foot bgs at borehole location TNT-1C. It should be noted that soil impacted by TNT at concentrations of greater than 100,000 mg/kg (i.e., 10 percent) falls into the category of OE (see Chapter 9.0) and will be handled as such during removal action activities. However, since the vast majority of the TNT concentrations were below 10 percent, TNT was grouped with the non-OE COIs for the purposes of Project Site investigations. Additional data were required to confirm the trends observed during the interim investigation and to better delineate the vertical and lateral extent of explosive compounds in soil (in particular TNT and its breakdown products TNB and amDNTs) at the TNT Strips.

Three of the strips (TNT Strips #1, #4, and #5) were chosen for additional focused investigation to obtain definitive-level analytical data to further define the vertical and lateral extent of explosive compounds by advancing a series of step-out boreholes at distances of 5 feet, 10 feet, and at 10-foot intervals thereafter, from the center axis of the TNT Strips. The TNT-1C series step-out boreholes (nine total) were centered on the previous high concentration sampling location and across the strip in an upslope and downslope direction, intersecting previous borehole location TNT-1C. Given the high concentration of TNT detected at TNT-1C, the potential for lateral and vertical migration of TNT was considered to be greatest at this location. One borehole (TNT-1C2) was advanced adjacent to previous borehole location TNT-1C to confirm the elevated levels of TNT detected at this location and to evaluate the maximum depth of impact associated with the elevated TNT concentrations.

The TNT-1F series step-out boreholes (nine total) were oriented along a firebreak, which is observed to cross TNT Strip #1 on historical aerial photographs, and represents an area where near-surface soils have been disturbed and spread via discing. One additional borehole (TNT-1F) was advanced on the center axis of the strip, since this location was not previously sampled.

The TNT-4C series step-out boreholes (13 total) were advanced beyond the end of TNT Strip #4 and across the strip in an upslope and downslope direction, intersecting previous borehole location TNT-4C.

The TNT-5A series step-out boreholes (nine total) were advanced across TNT Strip #5 in an upslope and downslope direction, offset from previous borehole location TNT-5A, approximately 10 feet to the east. One additional borehole (TNT-5F) was proposed in the Draft Final Work Plan (Earth Tech, 1999c), three additional boreholes (TNT-5I, -5M, and -5N) were advanced at the request of DTSC downslope from surface expressions of slope wash emanating from the west end of TNT Strip #5, as presented in the Final Work Plan (Earth Tech, 2000b). It should be noted that these borehole locations were actually identified in the field as TNT-5G, -5H, and -5I, respectively.

Boreholes in close proximity to the TNT Strips were generally advanced to bedrock or to hand auger/rig refusal, whichever was encountered first. Soil samples were collected at the surface, 1 foot, 2 feet, and at 2-foot depth intervals thereafter to the total depth of the borehole. The objective of the step-out program was to analyze soil samples, starting at the top of the borehole and continuing downwards until the sample results indicated two consecutive non-detects for explosive compounds. Consequently, boreholes farther from the TNT Strips were typically only advanced 2.5 feet to 4.5 feet bgs.

In order to obtain the rapid turn-around of analytical results required to direct the step-out program at the TNT Strips, an on-site mobile laboratory was used. The soil samples were tested in sequence to determine the extent of the step-out program (i.e., shallowest to deepest soil samples, starting with those boreholes nearest to the TNT Strip center axis). Soil samples were tested until explosive compounds were non-detect. If the non-detect field testing criterion was met, any remaining deeper samples from a particular borehole were typically not analyzed. It should be noted that at the request of DTSC and for safety concerns, all boreholes located within the axis of the TNT Strips were advanced with a hand auger, which was the limiting factor in the maximum depth of sample collection on the TNT Strips.

All soil samples collected from the TNT Strips during the RI were analyzed by the mobile laboratory for explosives by EPA Method SW8330. Approximately 10 percent of the samples were also submitted to an off-site analytical laboratory for confirmation analysis by EPA Method SW8330.

In addition, selected soil samples from the TNT-1C series step-out boreholes, in the vicinity of the highest TNT concentration, were also analyzed for the following COIs:

- PAHs by EPA Method SW8310

- CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium by EPA Methods SW6010B, SW7470A, and SW7471A.

Seven additional boreholes (TNT-1D, -1E, -1G, -1H, -1J, -1K, and -1L) were advanced along the suspected extension of TNT Strip #1 toward the southeast. Boreholes (TNT-1D, -1E, -1G, and -1H) were proposed in the Draft Final Work Plan (Earth Tech, 1999c); three additional boreholes were added at the request of DTSC, as presented in the Final Work Plan (Earth Tech, 2000b). Boreholes were advanced to bedrock or to hand auger/rig refusal, whichever was encountered first. Soil samples were collected at the surface, 1 foot, 2 feet, and at 2-foot depth intervals thereafter to the total depth of the borehole. Soil samples from these boreholes were analyzed for explosives by EPA Method SW8330.

Supplemental Activities Not Included in Draft Final/Final Work Plans. In addition to the samples outlined in the Draft and Final Work Plans, the following supplemental field activities were conducted during the RI:

- Three shallow boreholes (TNT-1I, -1M, and -1N) up to 2 feet bgs were advanced approximately 140 feet northeast of TNT Strip #1 over the ridgeline; soil samples were collected at the surface, 1 foot, and 2 feet bgs

- Two additional boreholes (TNT-5J and -5L) were advanced downslope of TNT-5F, because TNT was detected in the samples collected at borehole TNT-5F. Boreholes were advanced to bedrock, or to hand auger/rig refusal, whichever was encountered first. Soil samples were collected at the surface, 1 foot, 2 feet, and at 2-foot depth intervals thereafter to the total depth of the borehole.

All soil samples from the supplemental investigation locations were analyzed for explosives by EPA Method SW8330.

Two additional boreholes, TNT-1C2Y (for primary samples) and TNT-1C2AY (replicate/split samples), were advanced by hand auger in close proximity to borehole TNT-1C2. Soil samples from these two boreholes were collected from the soil cuttings as opposed to using the slide hammer or direct push sampling method used to collect all other samples during the RI. Soil cuttings represent a disturbed (or homogenized) sample, while samples collected with a slide hammer or direct push rig represent an undisturbed sample.

Activities Proposed in Draft Final/Final Work Plans But Not Completed

The RI called for the collection of a sample from borehole TNT-1C2 at 1 foot bgs for analysis of dioxins/furans by EPA Method SW88290. This sample was

inadvertently omitted; however, additional sampling of the TNT Strips for dioxins/furans was included in the data gaps investigation (see Section 4.2.3).

4.2.2.2 Howitzer Test Facility and Stockpile #3.

Preliminary (i.e., unverified and unvalidated) analytical data from the interim investigation indicated low levels of PAHs (chrysene and pyrene) in the soil samples collected from Stockpile #3. The matrix interference encountered during analysis of some of the stockpile samples collected during the interim investigation may have been caused by petroleum hydrocarbons in the sample. Since the material in the stockpiles was from the dismantling of structures at the Howitzer Test Facility, the possibility exists for these COIs as well as other COIs to be present within the subsurface soil/bedrock at this site.

The objective of the RI soil sampling program at the Howitzer Test Facility was to collect definitive-level analytical data of in situ subsurface soil, with borehole locations primarily focused in the vicinity of former buildings and facilities at the site (i.e., point-source) and access roads and vehicle parking areas (i.e., non-point-source). Although the specific design of the sampling program at this site was not based on a random sampling plan for non-point-sources, the sampling locations provide a reasonable distribution for characterization of both potential point-source and non-point-source occurrences, especially when evaluated with respect to the physical characteristics of the site as defined by topography, structures, access roads, and paved areas, which define where vehicular activity would most likely be associated. Six boreholes (HF-1, -2, -3, and TW-4, -5, and -6) were proposed in the Draft Final Work Plan (Earth Tech, 1999c) within and adjacent to the Howitzer Test Facility. One additional borehole (HF-4) was added at the request of DTSC in the vicinity of former Building 540, as presented in the Final Work Plan (Earth Tech, 2000b). Three of the boreholes (HF-1 through -3) were advanced toward the north end of the Howitzer Test Facility approximately at the location of the former test firing butts, while a fourth borehole (HF-4) was advanced near former Building 540. Boreholes were advanced to bedrock or to rig refusal, whichever was encountered first. Soil samples were collected at 0.5 foot, 4 feet, 10 feet, and at 5-foot depth intervals thereafter to the total depth of the borehole and analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330
- PAHs by EPA Method SW8310
- TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California Leaking Underground Fuel Tank (LUFT) Modified EPA Method SW8015B
- VOCs by EPA Method SW8260B

- CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium, by EPA Methods SW6010B, SW7470A, and SW7471A

- Nitrate and nitrite as nitrogen by EPA Method 300.0.

The remaining three boreholes (TW-4, -5, and -6) were to be advanced to first encountered groundwater for possible temporary monitoring well installation. Borehole TW-4 was advanced immediately adjacent and downgradient of the Howitzer Test Facility. Borehole TW-6 was advanced in the vicinity of the former howitzer test tunnels, while borehole TW-5 was advanced to provide spatial coverage of the site as a whole. Groundwater was encountered during drilling at only one location, TW-4 at 22 feet bgs; therefore, only one single-cased shallow monitoring well was installed at the Howitzer Test Facility during the RI. Boreholes were advanced to bedrock or to rig refusal, whichever was encountered first. Soil samples from the "TW" boreholes were collected at 0.5 foot, 4 feet, 10 feet, and at 5-foot depth intervals thereafter to the total depth of the borehole and analyzed for the COIs listed above.

No additional sampling of Stockpile #3 was conducted during the RI.

Supplemental Activities Not Included in Draft Final/Final Work Plans

Two of the samples collected from borehole TW-5 at 5.5 feet and 10.5 feet bgs were analyzed for dioxins/furans by EPA Method SW8290.

4.2.2.3 Ammunition Renovation/Primer Destruction Site and Stockpiles #1 and #2 .

Preliminary (i.e., unverified and unvalidated) analytical data from the interim investigation indicated low levels of nine PAHs and one explosive compound (TNT) in the soil samples collected from Stockpiles #1 and #2. The matrix interference encountered during analysis of some of the stockpile samples collected during the interim investigation may have been caused by petroleum hydrocarbons in the sample. Since the material in the stockpiles was from the dismantling of the Ammunition Renovation/Primer Destruction Site, the possibility exists for these COIs and other COIs to be present within the subsurface soil/bedrock at this site.

The objective of the RI soil sampling program at the Ammunition Renovation/ Primer Destruction Site was to collect definitive-level analytical data of in situ subsurface soil, with borehole locations primarily focused in the vicinity of former buildings/structures at the site and a suspected UST (i.e., point-source), as well as providing spatial coverage of the entire site (i.e., non-point-source). Although the specific design of the sampling program at this site was not based on a random sampling plan for non-point-sources, the sampling locations provide a reasonable distribution for characterization of both potential point-source and non-point-source occurrences. This is especially true when evaluated with respect to

the physical characteristics of the site as defined by topography, structures, access roads, and paved areas, which define where vehicular activity would most likely be associated. Six boreholes were advanced within the Ammunition Renovation/Primer Destruction Site. Four of the boreholes (AR-1 through -4) were advanced to bedrock or to rig refusal, whichever was encountered first. Soil samples were collected at 0.5 foot, 4 feet, 10 feet, and at 5-foot depth intervals thereafter to the total depth of the borehole. Soil samples were analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330
- PAHs by EPA Method SW8310
- TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B
- VOCs by EPA Method SW8260B
- CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium by EPA Methods SW6010B, SW7470A, and SW7471A
- Nitrate and nitrite as nitrogen by EPA Method 300.0.

The remaining two boreholes (TW-1 and -7) were to be advanced to first encountered groundwater for possible temporary monitoring well installation. Since groundwater was not encountered at either of these two borehole locations, no monitoring wells were installed at the Ammunition Renovation/ Primer Destruction Site during the RI. Soil samples were collected at the same interval as the "AR" boreholes and analyzed for those COIs listed above.

Since preliminary (i.e., unverified and unvalidated) analytical data from the interim investigation indicated several COIs in all but one of the samples collected from the stockpiles at Ammunition Renovation/Primer Destruction Site, one additional soil sample was collected from each of the stockpiles, from 2 feet below the stockpile surface. Stockpile soil samples were analyzed for those COIs listed above with the exception of VOCs, since it was assumed that any VOCs that may have been present in the stockpile soil would have long since volatilized. It should be noted that, because soil samples had been previously collected from the stockpiles, the additional samples were not collected at the sampling frequency outlined in EPA SW846.

4.2.2.4 North Valley Groundwater and Seeps.

No groundwater samples were collected from the North Valley in any of the previous investigations conducted at the Project Site. The objective of the RI

hydrogeologic program was to determine the existence and quality of groundwater in the North Valley. Nine boreholes (TW-1 through TW-9) were advanced in the North Valley for possible temporary monitoring well installations. The boreholes were advanced to either first encountered groundwater, or to bedrock, or to rig refusal, whichever was encountered first. First groundwater was anticipated to be encountered in the alluvium (if sufficient thickness present) and/or the underlying weathered bedrock zone. Groundwater was encountered at only two borehole locations in the North Valley, TW-3 and TW-4. Groundwater was encountered during borehole advancement at 22.1 feet and 22 feet bgs, respectively. Single-cased shallow temporary groundwater monitoring wells were installed at these two locations. The wells were considered "temporary" because they did not have a cement grout sanitary seal installed at the time of well construction. These wells were subsequently converted into "permanent" wells during the data gaps investigation (see Section 4.2.3) by adding a cement grout sanitary seal, the placement of which was observed by a Solano County DEM inspector. The temporary wells were renamed MW-3 (TW-3) and MW-4 (TW-4) in the data gaps investigation when additional permanent monitoring wells were installed. Copies of the well construction logs are included in Attachment C-4 of Appendix C. Well construction details are summarized in Table 4-9.

Soil samples were collected from the boreholes installed in and around the Howitzer Test Facility (TW-4, -5, and -6), and analyzed as described in Section 4.2.2.2. Soil samples were collected from the boreholes advanced in the Ammunition Renovation/Primer Destruction Site (TW-1 and -7) and analyzed as described in Section 4.2.2.3. One soil sample was collected from the bottom of boreholes TW-8 and TW-9 and analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330
- PAHs by EPA Method SW8310
- TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B
- VOCs by EPA Method SW8260B.

In addition to the discrete soil samples collected from each borehole in the North Valley, bulk soil samples were also collected of the major lithologies encountered and analyzed for the following:

- Total organic carbon by EPA Method SW9060
- Grain size by American Society of Testing and Materials (ASTM) Standard D422.

The bulk samples for grain size analysis were collected from boreholes TW-1 and TW-2. Bulk samples for total organic carbon were collected from boreholes TW-1 and TW-8. Total organic carbon analysis results are included in the analytical summary tables. The results of the grain size analyses are presented in Attachment C-5 of Appendix C.

Grab groundwater samples were collected from temporary wells TW-3 and TW-4 and analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330
- PAHs by EPA Method SW8310
- TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B
- Dissolved CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium, by EPA Methods SW6010B, SW7470A, and SW7471A
- Perchlorate by California Department of Health Services (CADHS) Method 300.0 Modified
- General water chemistry (chloride, nitrate/nitrite, sulfate by EPA Method 365.2; total organic carbon by EPA Method 415.1; TDS by EPA Method 160.1; and TSS by EPA Method 160.2)
- Field parameters (temperature by EPA Method 170.1, pH by EPA Method 150.1, electrical conductivity by EPA Method 120.1, and turbidity by EPA Method 180.1).

Perchlorate was not proposed in the Draft Final Work Plan (Earth Tech, 1999c), but was included as a COI at the request of DTSC, as presented in the Final Work Plan (Earth Tech, 2000b).

No seeps were encountered in the North Valley during the RI sampling activities.

4.2.2.5 Dynamite Burn Site

No soil samples were collected from the Dynamite Burn Site during previous investigations at the Project Site. The Dynamite Burn Site was situated on the Ridge between the North and South Valleys. The Ridge has been graded, as discussed in Section 2.3.3. The area of the Dynamite Burn Site is at a current elevation of approximately 235 feet above MSL, approximately 20 feet to 40 feet below the elevation when the Dynamite Burn Site was operational.

During the RI, four near-surface bedrock samples were collected from that portion of the Ridge believed to have been immediately below the Dynamite Burn Site location. Ridge samples were analyzed for nitroglycerin and PETN by EPA Method SW8330 and for nitrate and nitrite as nitrogen by EPA Method 300.0.

4.2.2.6 Flare Site.

Preliminary (i.e., unverified and unvalidated) analytical data from the interim investigation confirmed the elevated metals concentrations previously observed at the Flare Site. The objective of the RI soil sampling program at the Flare Site was to collect definitive-level analytical data at depth within and toward the upslope and downslope periphery of the residual ash-covered area to better delineate the lateral and vertical extent of metals impact.

Three additional boreholes were advanced at the Flare Site during the RI. Two of the boreholes (FA-4 and-5) were advanced toward the periphery of the Flare Site in an upslope and downslope direction, respectively. Based on OE avoidance, the remaining borehole (FA-6) was advanced as close to the center of the Flare Site as possible. The boreholes were advanced to bedrock or to rig refusal, whichever was encountered first. Soil samples were collected from the central borehole location at 1 foot, 2 feet, and 5 feet bgs. Soil samples were collected from the peripheral borehole locations at the surface, 1 foot, 2 feet, and 3 feet bgs. Soil samples from the Flare Site were analyzed for the following COIs:

- CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium, by EPA Methods SW6010B, SW7470A, and SW7471A.

In addition, the sample collected from the central borehole (FA-6) at 1 foot bgs was also analyzed for explosives, including nitroglycerin and PETN by EPA Method SW8330, PAHs by EPA Method SW8310, dioxins/furans by EPA Method SW8290, and nitrate and nitrite as nitrogen by EPA Method 300.0.

4.2.2.7 Demolition Site #1.

Of the COIs analyzed during the interim investigation, only metals were detected in soil samples from Demolition Site #1. Based on discussions between the Project Team and DTSC, an additional investigation was performed to evaluate the sidewalls of the incised channel that passes through Demolition Site #1 in an area where OE fragments have been reported. Further subsurface investigation within Demolition Site #1 is limited by the presence of a large geophysical anomaly. Two soil samples (DA1-3W1 and DA1-3W2) were collected from the sidewall of the incised channel that passes through Demolition Site #1. The samples were analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330

- PAHs by EPA Method SW8310
- CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, and sodium, by EPA Methods SW6010B, SW7470A, AND SW7471A
- Nitrate and nitrite as nitrogen by EPA Method 300.0.

4.2.2.8 Demolition Site #2.

Of the COIs analyzed during the interim investigation, only metals were detected in soil samples from Demolition Site #2. Since no physical evidence (i.e., live ordnance, magnetic anomalies) or ordnance-related activities have been found at Demolition Site #2, the site was eliminated from further investigation; consequently, no additional sampling of Demolition Site #2 was conducted as part of the RI.

4.2.2.9 Demolition Site #3.

Of the COIs analyzed during the interim investigation, only metals were detected in soil samples from Demolition Site #3.

The objective of the RI soil sampling program at Demolition Site #3 was to collect definitive-level analytical data at depth toward the center of the site, in particular from the soil underlying the area known to have been backfilled.

Four additional boreholes (DA3-3, -4, -5, and -6) were advanced at Demolition Site #3 during the RI. Two of the boreholes (DA3-3 and DA3-4) were advanced toward the downslope periphery of the demolition area. The remaining two boreholes (DA3-5 and -6) were advanced toward the center of the demolition area. Previously disturbed soils (i.e., backfill material) were encountered at all borehole locations, immediately overlying the bedrock. The boreholes were advanced to bedrock, or rig refusal, whichever was encountered first. Bedrock samples were collected immediately below the fill material and analyzed for following COIs:

- Explosives by EPA Method SW8330
- PAHs by EPA Method SW8310
- CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium by EPA Methods SW6010B, SW7470A, AND SW7471A.

In addition, samples collected from bedrock immediately below the fill material at the central borehole locations (DA3-5 and DA3-6) were also analyzed for nitroglycerin and PETN by EPA Method SW8330, and nitrate/nitrite as nitrogen by EPA Method 300.0.

4.2.2.10 South Valley Wetland Sediment and Surface Water

Of the COIs analyzed during the interim investigation, only metals were detected in the sediment sample collected from the wetland area. The sediment sample from the interim investigation was, however, collected upgradient of the Flare Site, an area with high concentrations of metals. Surface water samples were collected by SECOR (see Section 3.2.1); however, no surface water samples were collected during the interim investigation.

The objective of the RI sediment and surface water sampling program was to obtain definitive-level analytical data upgradient of the South Valley areas of interest, which would be compared to analytical data downgradient of the areas of interest, in particular the Flare Site, to evaluate whether the sediment and surface water have been impacted by DOD-related activities.

Two sets of sediment and surface water samples were collected during the RI, upgradient (WET-1 and SW-1) and downgradient (WET-2 and SW-2), respectively, of Demolition Sites #1, #2, and #3, and the Flare Site. Sediment samples were analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330
- PAHs by EPA Method SW8310
- CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium, by EPA Methods SW6010B, SW7470A, and SW7471A
- Nitrate and nitrite as nitrogen by EPA Method 300.0.

Surface water samples were analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330
- PAHs by EPA Method SW8310
- Total and dissolved CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium, by EPA Methods SW6010B, SW7470A, and SW7471A
- General water chemistry (chloride, nitrate/nitrite, sulfate by EPA Method 300.0; TDS by EPA Method 160.1; and TSS by EPA Method 160.2)

- Field parameters (temperature by EPA Method 170.1, pH by EPA Method 150.1, electrical conductivity by EPA Method 120.1, and turbidity by EPA Method 180.1).

Activities Proposed in Draft Final/Final Work Plans But Not Completed

The RI called for the downgradient sediment sample to be analyzed for dioxins/furans by EPA Method SW8290. This sample was inadvertently omitted. However, additional sampling of the sediment for dioxins/furans was included in the data gaps investigation (see Section 4.2.3).

4.2.2.11 South Valley Groundwater and Seeps.

No groundwater samples were collected from the South Valley in any of the previous investigations conducted at the Project Site. The objective of the RI hydrogeologic program was to determine the existence and quality of shallow groundwater in the South Valley. Three boreholes (TW-10 through -12) were proposed in the South Valley for possible temporary monitoring well installations in the Draft Final Work Plan (Earth Tech, 1999c). However, DTSC requested that the well located at the downgradient toe of the land bridge be installed as a permanent well for possible long-term monitoring, as presented in the Final Work Plan (Earth Tech, 2000b).

Only two of the boreholes (TW-11 and -12) were able to be advanced at the time of the RI due to the lack of rig availability and access. The two boreholes were advanced to either first encountered groundwater, or to rig refusal, whichever was encountered first. First groundwater was anticipated to be encountered in the alluvium and/or the underlying weathered bedrock zone. Groundwater was encountered at only one location during borehole advancement, TW-12, at 23 feet bgs. A single-cased shallow permanent groundwater monitoring well was installed at this location. As discussed in Section 4.2.2.4, permanent wells were constructed with cement grout sanitary seals, the placement of which was observed by a Solano County DEM inspector. This well was renamed MW-12 (TW-12) in the data gaps investigation, when additional permanent monitoring wells were installed. A copy of the well construction log is included in Attachment C-4 of Appendix C. Well construction details are summarized in Table 4-9.

No soil samples were collected during advancement of borehole TW-12. A grab groundwater sample was collected and analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330
- PAHs by EPA Method SW8310

- Dissolved CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium, by EPA Methods SW6010B, SW7470A, and SW7471A

- VOCs by EPA Method SW8260B

- General water chemistry (chloride, nitrate/nitrite, sulfate ; total organic carbon by EPA Method 415.1; TDS by EPA Method 160.1; and TSS by EPA Method 160.2)

- Field parameters (temperature by EPA Method 170.1, pH by EPA Method 150.1, electrical conductivity by EPA Method 120.1, and turbidity by EPA Method 180.1).

No seeps were encountered in the South Valley during the RI.

Activities Proposed in Draft Final/Final Work Plans But Not Completed

As mentioned above, only two (TW-11 and -12) of the three proposed boreholes were advanced during the RI. The third borehole (TW-10) was advanced during the data gaps investigation when additional permanent groundwater monitoring wells were installed (see Section 4.2.3), at which time the borehole/well was identified as MW-10.

Supplemental Activities Not Included in Draft Final/Final Work Plans

No soil samples were to be collected from the boreholes of well installations in the South Valley. Since no groundwater was encountered during advancement of borehole TW-11, soil samples were collected from the bottom of the borehole and analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330

- PAHs by EPA Method SW8310

- TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B

- VOCs by EPA Method SW8260B

- CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium, by EPA Methods SW6010B, SW7470A, and SW7471A.

4.2.2.12 Other Activities Outside Areas of Interest.

The following activities were also conducted as part of the RI: the collection of soil samples from nine soil stockpiles situated on the Ridge between the North and South Valleys to assist in evaluating potential site impact and disposal options; the collection of soil samples from the McAllister Drive Land Bridge fill material to see if the land bridge is affected by soil from the Dynamite Burn Site (see Section 2.3.3); the collection of surface soil samples from outside the areas of interest to help evaluate concentrations of naturally occurring metals; and additional geologic mapping to supplement site-specific geological information.

Ridge Stockpiles

Nine stockpile areas are located on the Ridge between the North and South Valleys. The stockpiles had not been previously sampled. The stockpile material was generated from construction activities associated with the adjacent Southampton development (see Section 1.1), and is not related to DOD activities at the Project Site. The objective of the RI stockpile soil sampling program was to evaluate potential site impact and to provide information to assist in the eventual disposition of the stockpile materials.

Soil samples were collected from nine stockpile areas (RSP-1 through -9) on the Ridge between the North and South Valleys during the RI. Four soil samples were collected from each of the larger stockpiles (RSP-1 through -5), while two soil samples were collected from each of the smaller stockpiles (RSP-6 through -9). Soil samples were collected from 2 feet below the stockpile surface. Soil samples from each stockpile were composited into one sample by the analytical laboratory and analyzed for the following COIs:

- Explosives by EPA Method SW8330
- TEPHs quantified against a diesel and motor oil standard, respectively, by California LUFT Modified EPA Method SW8015B
- CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium, by EPA Methods SW6010B, SW7470A, and SW7471A.

McAllister Drive Land Bridge

Soil samples were collected from three borehole locations on each side of the McAllister Drive Land Bridge, near the toe of the fill during the RI. Soil samples were collected from an approximate depth of 5 feet bgs at five of the six borehole locations (LB-1, -3, -4, -5, and -6) and from approximately 15 feet bgs at one borehole location (LB-2). The samples were analyzed for nitroglycerin and PETN by EPA Method SW8330, and for nitrate/nitrite as nitrogen by EPA Method 300.0. The sample from borehole LB-3 was also analyzed for CAM 17 metals plus

aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium, by EPA Methods SW6010B, SW7470A, and SW7471A.

Ambient Soil Samples

Twenty surface samples (NO-19, -27, -38, -44, -50, -68, -89, -99, -100, -118, -129, -132, -146, -170, -173, -179, -184, -210, -238, -241) were collected from outside the areas of interest during the RI as follows: the Ridge area northeast of the McAllister Drive Land Bridge; areas northwest and southwest of the TNT Strips; and the west end of the South Valley. Samples were analyzed for CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium, by EPA Methods SW6010B, SW7470A, and SW7471A. Each of the aforementioned areas was gridded and sample locations within the grid were chosen by a random number generator, as discussed in Section 5.1.4.

Geologic Mapping

To supplement existing geological data, the Project Site was inspected by a state of California-registered geologist who identified bedrock outcrops, and in particular, bedrock exposures in the graded Ridge area between the North and South Valleys. Results of the geologic field mapping have been incorporated into the site geology (see Section 4.3).

4.2.3 Data Gaps Investigation Program

Preliminary (i.e., unverified and unvalidated) analytical data from the RI were reviewed to determine if any data gaps existed that would prevent adequate evaluation of remedial action alternatives in the FS. Several data gaps were identified particularly with respect to the areas of interest in the North Valley, as outlined in the Tech Memo (Earth Tech, 2000c), and three letter addenda dated June 5, 2000, July 31, 2000, and August 21, 2000.

The primary objective of the data gaps investigation was to obtain additional definitive-level data on the nature and extent of COIs, to adequately evaluate remedial action alternatives in the FS.

Other activities conducted in the data gaps investigation included the advancement of geotechnical boreholes to supplement existing data on the depth to bedrock in both the North and South Valleys.

Data gaps investigation sampling locations are shown on Figure 4-2 and summarized in Table 4-6. Details of the work performed during the data gaps investigation are presented in Appendix C. Copies of the Test Borehole Logs are included in Attachment C-3 of Appendix C. It should be noted that final borehole locations were subject to, and dependent on, OE avoidance.

A minimum of 10 percent replicate soil samples were collected during the data gaps investigation, as described in the QCSRs (see Volume IV of this document).

No additional split soil samples were collected for use by DTSC and/or USACE during this phase of the non-OE RI.

All soil samples were analyzed by Quanterra. Sediment samples requiring analysis for methyl mercury were analyzed by Frontier GeoSciences of Seattle, Washington. Water samples requiring analysis for perchlorate were analyzed by Babcock. Water samples requiring analysis for hydrazine were analyzed by Truesdail Laboratories of Tustin, California.

4.2.3.1 TNT Strips.

Evaluation of the preliminary (i.e., unverified and unvalidated) analytical data collected during the interim investigation and RI indicated that the lateral extent of the high concentrations of explosive compounds in the immediate vicinity of the TNT Strips was relatively well understood such that the lateral boundaries of the explosives impact associated with the TNT Strips could be drawn or estimated. The vertical extent of the explosive compounds along the axis of the TNT Strips was, however, not as well defined. Results from the interim investigation indicated that very high concentrations of explosives were present along the axis of the TNT Strips. Consequently, due to safety concerns, all boreholes along the axis of the TNT Strips were advanced using a hand auger during the RI. The use of a hand auger limited the depth of sample collection along the axis of the strips, since refusal using the hand auger method was encountered at shallower depths than via the direct-push, drill rig method used on the step-out boreholes. While the data suggested there was a significant decrease in the explosives concentrations beyond 2 feet to 3 feet bgs, samples with no detectable levels of explosives were not obtained during the RI along the axis of the strips. Consequently, this was considered to be a data gap.

During the RI, a low concentration of TNT (0.6 mg/kg) was detected in the surface soil in the sample (TNT-1I) collected over the ridgeline to the northeast of TNT Strips area. TNT was not detected in either of the associated step-out samples (TNT-1M and -1N). Based on the TNT step-out data, explosives were not detected in the surface soil beyond 10 feet in the upslope direction. However, since a low concentration of explosives were detected, additional surface soil sampling along the ridgeline was recommended.

Soil samples collected along the axis of the TNT Strips during the interim investigation were analyzed for PAHs. Low levels of PAHs were detected along the axis of the strip. Samples from the TNT-1C series step-outs were also analyzed for PAHs during the RI. No PAHs were detected in those samples; therefore, the lack of testing for PAHs in one of the step-out boreholes (TNT-1C9) during the RI, was not considered to represent a significant data gap. The types of PAHs detected along the axis of the at the TNT Strips are consistent with fuel products. While there is no evidence in the records research that fuels were used as an ignition source at the TNT Strips, the lack of testing for fuel products was considered to be a data gap.

Two samples collected from the TNT Strips were analyzed for dioxins/furans in the interim investigation. Dioxins/furans were detected in both samples. Since dioxins/furans can be associated with combustion of fuel products and low-temperature burning, additional sampling for dioxins/furans along the TNT Strips was recommended.

Three additional deep boreholes (TNT-1P, -1Q, and -2F) were advanced along the axis of the TNT Strips during the data gaps investigation to a greater depth, using a combination of hand augering and conventional drilling methods. Two of the boreholes (TNT-1P and -1Q) were advanced along the axis of TNT Strip #1, and one of the boreholes (TNT-2F) was advanced along the axis of TNT Strip #2. Soil samples were collected at the surface, 1 foot, 2 feet, and at 2-foot depth intervals thereafter to a maximum depth of 10 feet bgs, after which continuous bedrock cores were collected from 44 feet to 46.5 feet into the bedrock. The continuous bedrock cores were used for supplemental lithological interpretation (see Section 4.3). Soil/bedrock samples from these boreholes were homogenized by the analytical laboratory prior to analysis.

Soil samples collected within the upper 3 feet bgs were initially tested for explosives in the field using a soil test kit (see Attachment C-8 of Appendix C). The soil test kit provided a quantitative result by EPA Method SW8515, which was used to determine if samples from the TNT Strips could be shipped off-site for analysis by an analytical laboratory. If the field soil test kit indicated concentrations of explosives in excess of 100,000 mg/kg (10 percent), the sample <u>was not</u> shipped off-site per the Tech Memo (Earth Tech, 2000c). Soil samples that were shipped off-site were analyzed for the following COIs:

- Explosives by EPA Method SW8330
- TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B.

In addition, the 1-foot samples from one of the boreholes (TNT-2F) was analyzed for dioxins/furans by EPA Method SW8290. A 4-foot sample from borehole TNT-1P was also analyzed for dioxins/furans.

Surface soil samples were collected at five locations (TNT-R1 through -R5) approximately 75 feet to 100 feet from TNT Strip #1, along the ridgeline. The surface samples were analyzed for explosives by EPA Method SW8330.

Supplemental Activities Not Proposed In Tech Memo

In addition to the samples outlined in the Tech Memo, the surface sample collected at borehole location TNT-1P was submitted for analysis of PCBs by EPA Method SW8082 based on preliminary (i.e., unverified and unvalidated) analytical data obtained during the performance of the data gaps investigation. Preliminary

data from the TNT Strips indicated the presence of TEPHs. Since preliminary data from the Ammunition Renovation/Primer Destruction Site indicated PCBs may be associated with detections of TEPHs, it was decided to analyze one of the samples from the TNT Strips for PCBs.

Preliminary analytical data from the surface samples locations TNT-R1 through TNT-R5, indicated concentrations of TNT in the surface soil along the ridgeline. Twenty additional surface samples (TNT-R6A and -R6B through -R15A and -R15B) were collected from ten locations throughout the TNT Strips area to further assess the lateral extent of the explosives impacted soil associated with the TNT Strips and to assess the effects of sample homogenization. The surface soil samples were analyzed for explosives, including nitroglycerin and PETN, by EPA Method SW8330. Although each set of "A" and "B" samples were collected from the same location, the laboratory was requested to homogenize the "A" samples before analysis and to analyze the "B" samples without homogenization.

Preliminary analytical data also indicated that the soil/bedrock in the bottom of the North Valley, downgradient of the TNT Strips, was impacted by low levels of explosives. Five additional boreholes (TNT-R16 through -R20) were advanced along the south-facing slope between the TNT Strips and the toe of the slope, as outlined in the letter addendum dated June 5, 2000. Soil samples were collected at the surface, 1 foot, 2 feet, and every 2 feet thereafter to the base of the soil, at the soil/bedrock interface, and every 2 feet to a depth of 10 feet into the bedrock. All soil samples were initially analyzed in the field for explosives using the soil test kit (see Attachment C-8 of Appendix C). All samples were then shipped to an off-site analytical laboratory for confirmation analysis of explosives, including nitroglycerin and PETN, by EPA Method SW8330.

In addition, sample soils were collected at the surface and 1 foot bgs from nine locations (TNT-R21 through -R29) north and east of the Project Site boundary where off-site access was obtained. All soil samples were initially analyzed in the field for explosives using the soil test kit (see Attachment C-8 of Appendix C). All samples were then shipped to an off-site analytical laboratory for confirmation analysis of explosives, including nitroglycerin and PETN, by EPA Method SW8330.

All additional surface/near-surface sample and borehole locations are shown on Figure 4-2.

4.2.3.2 Howitzer Test Facility and Stockpile #3.

Evaluation of preliminary (i.e., unverified and unvalidated) analytical data collected during the RI indicated low levels of petroleum hydrocarbons in the motor oil range in the surface soil at two borehole locations (HF-2 and -3) and at another borehole location (TW-5) at 5 feet and 10 feet bgs. A low concentration (1.7 mg/kg) of TNT was also detected at one borehole location (HF-4) at 10 feet bgs. TNT was not detected in the shallower samples at the same location or at any other locations

sampled at the Howitzer Test Facility. One nitroglycerin/ PETN result (HF-1 at 1 foot bgs) could not be analyzed because there was insufficient sample. Nitroglycerin and PETN were not detected in the samples collected above or below the missing sample, nor were they detected in any of the other samples collected at the Howitzer Test Facility; therefore, this was not considered to be a significant data gap. However, additional sampling was recommended to confirm the isolated detection of TNT.

Borehole HF-4 was situated very close to a former building (Building 540). During the RI, samples from this location were analyzed for a wide suite of compounds including explosives and nitroglycerin/PETN, PAHs, TEPHs, VOCs, metals, and nitrate/nitrite. Other COIs that may have been associated with activities at this building include:

- Pesticides - associated with soils testing
- Perchlorate and hydrazine - at the request of DTSC
- Chloropicrin - at the request of DTSC.

Pesticides are relatively insoluble and tend to be persistent in the soil environment; therefore, the lack of testing for this COI in the soil was considered to be a data gap. The DTSC also recommended analyzing for perchlorate and hydrazine in the groundwater and chloropicrin in both the soil and groundwater.

During the RI, two samples collected from borehole TW-5 at 5.5 feet and 10.5 feet bgs were analyzed for dioxins/furans. No dioxins/furans were detected in the shallower sample, but 2,3,7,8-tetrachlorodibenzo furan (TCDF) was detected at an estimated concentration of 0.78 picograms per gram (pg/g) in the deeper sample. The detection of dioxins/furans at depth is considered unusual since they tend to be immobile in the soil environment. It was recommended that additional sampling be conducted in order to confirm this detection.

Two VOCs, methylene chloride and 2-butanone, were also detected in some of the soil samples collected during the RI at the Howitzer Test Facility. A preliminary review of the QC data indicated that the methylene chloride results were likely laboratory contaminants. However, the 2-butanone result (0.034 mg/kg) was noted to be possibly too high to be considered a laboratory contaminant and there was concern that it might represent an actual detection, although VOCs would not be expected to be present in shallow soil (0.5 foot bgs) due to their volatility. Additional sampling for VOCs was, therefore, recommended to avoid a potential future data gap.

Five additional boreholes (HF-5 through HF-9) were advanced at the Howitzer Test Facility in the vicinity of Building 540 during the data gaps investigation. One of the boreholes (HF-5) was situated adjacent to borehole HF-4, the remaining four boreholes were radial step-outs, approximately 10 feet to 15 feet from this central borehole location. Soil samples were collected at 0.5 foot, 4 feet, 10 feet, and at

5-foot depth intervals thereafter to the total depth of the borehole. Soil samples collected from borehole HF-8 were analyzed for the following COIs:

- Pesticides by EPA Method SW8081A
- Chloropicrin by EPA Method SW8270C.

The sampling program described in the Tech Memo (Earth Tech, 2000c) required that the sample collected at 0.5 foot and 10 feet bgs at borehole HF-5 also be analyzed for VOCs by EPA Method SW8260B and explosives by EPA Method SW8330, respectively. If either VOCs or explosives were detected, additional samples from the same borehole and the step-out boreholes would be analyzed for the same compounds to evaluate lateral and vertical extent. However, due to time constraints and holding times, it was decided to analyze selected soil samples from boreholes HF-5 through HF-8 for VOCs and explosives.

Two additional boreholes were advanced in the Howitzer Test Facility for the installation of groundwater monitoring wells (MW-5 and -6). One borehole was advanced immediately adjacent to borehole TW-5 for the installation of groundwater monitoring well MW-5. Groundwater was not encountered during advancement of the borehole at this location; however, a groundwater monitoring well was installed. One soil sample was collected from the borehole to support data gaps in this area at 10.5 feet bgs and submitted for analysis of dioxins/furans by EPA Method SW8290. Another borehole was advanced approximately 40 feet northwest of borehole TW-6, within the footprint of a former building, for the installation of groundwater monitoring well MW-6. Groundwater was encountered at 14 feet bgs during advancement of the borehole. Soil samples were collected at 0.5 foot, 4 feet, 10 feet, and at 5-foot depth intervals thereafter to the total depth of the borehole. The soil samples from MW-6 were analyzed for the following COIs:

- Explosives by EPA Method SW8330
- CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium by EPA Methods SW6010B, SW7470A, and SW7471A
- Nitrate/nitrite as nitrogen by EPA Method 300.0.

It should be noted that groundwater was encountered at two other borehole locations (HF-5 and -8) at the Howitzer Test Facility at 18 feet and 13 feet bgs, respectively; groundwater monitoring wells were not installed at these locations.

Supplemental Activities Conducted But Not Proposed In Tech Memo

While the data gaps investigation was on-going, preliminary (i.e., unverified and unvalidated) analytical data from the RI at the Howitzer Test Facility indicated that some of the TEPH data for the "HF" boreholes may be qualified or rejected. It was therefore decided to advance a replacement borehole (HF-3R) and collect

additional samples to avoid a potential future data gap. Soil samples were collected at 0.5 foot, 4 feet, 10 feet, and at 5-foot depth intervals thereafter to the total depth of the borehole. All the soil samples were analyzed for TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B.

The preliminary data from the interim investigation and RI also indicated that the majority of the stockpile sample results for PAHs may be qualified or rejected; consequently, Stockpile #3 was resampled. The stockpile was divided into quarters; four samples were then collected from each quarter from 2 feet below the stockpile surface. The four samples from each quarter (SP3-R1[A, B, C, D], SP3-R2[A, B, C, D], SP3-R3[A, B, C, D], SP3-R4[A, B, C, D]) were then composited by the analytical laboratory into a single sample. The samples were analyzed for TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B and for PAHs by EPA Method SW8270C (SVOCs), since based on previous experience with samples from the stockpiles, analysis of PAHs by EPA Method SW8310 would not be appropriate due to fuel interference.

Since preliminary data obtained from the data gaps investigation at the Ammunition Renovation/Primer Destruction Site indicated PCBs may be associated with detections of TEPHs, it was decided to analyze the near-surface sample from borehole HF-3R for PCBs by EPA Method SW8082. Another near-surface sample (HF-2R) was collected immediately adjacent to borehole HF-2 and analyzed for both TEPHs and PCBs to further evaluate a potential correlation between petroleum hydrocarbons and PCBs.

4.2.3.3 Ammunition Renovation/Primer Destruction Site and Stockpiles #1 and #2.

Evaluation of preliminary (i.e., unverified and unvalidated) analytical data collected during the RI indicated low levels of petroleum hydrocarbons in the motor oil and diesel ranges throughout the soil column at the Ammunition Renovation/Primer Destruction Site. Since PCBs can be associated with heavy fuels, the lack of testing for these COIs was considered to be a data gap.

Two elevated concentrations of petroleum hydrocarbons in the diesel range were detected at depth at boreholes AR-3 (630 mg/kg) and TW-1 (222 mg/kg) at 17.5 feet and 22 feet bgs, respectively. No hydrocarbons were reported in the soil samples collected from the same boreholes at shallower depths. Two VOCs that can be associated with fuel, naphthalene and sec-butylbenzene, were also detected at borehole AR-3 at the same depth as the petroleum hydrocarbons. Two other VOCs, methylene chloride and acetone, were also detected in some of the soil samples collected from the Ammunition Renovation/Primer Destruction Site.

The levels of petroleum hydrocarbons in the diesel range indicate a possible source within the Ammunition Renovation/Primer Destruction Site. Possible sources of the hydrocarbons include: a leaking UST and associated piping; "squirrel cage" spillages; use of petroleum hydrocarbons for dust control; or other surface spillages. Identification and delineation of the source was considered to be a data gap.

No samples from the Ammunition Renovation/Primer Destruction Site were analyzed for dioxins/furans during any of the previous investigations. Since burning activities reportedly occurred in this area, the lack of testing for this COI was considered to be a data gap. In addition, further sampling in the vicinity of the former buildings and temporary structures within the Ammunition Renovation/Primer Destruction Site was recommended.

Eight additional boreholes (AR-5 through -12) were advanced at the Ammunition Renovation/Primer Destruction Site during the data gaps investigation primarily focused on defining the lateral and vertical extent of the diesel detected in the vicinity of boreholes AR-3 and TW-1, which appear to coincide with two geophysical anomalies in the area (see Figure 3-2). Soil samples were collected at the 0.5 foot, 4 feet, 10 feet, and at 5-foot depth intervals thereafter, until bedrock was encountered. One borehole (AR-7), adjacent to AR-3 where the highest petroleum hydrocarbon concentrations were detected during the RI, was advanced up to 30 feet into the bedrock. Shallow soil samples from AR-7 were collected as indicated above. Once bedrock was encountered, continuous bedrock cores were collected to the total depth of the borehole. The continuous bedrock cores were used for lithological interpretation (see Section 4.3). Soil samples collected from the "AR" boreholes were analyzed for the following COIs:

- TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B

- VOCs by EPA Method SW8260B (excluding surface samples).

In addition, a sample was also collected at 1 foot bgs during the advancement of borehole AR-7. This sample was analyzed for TEPHs and dioxins/furans by EPA Method SW8290.

Two additional boreholes were advanced in the Ammunition Renovation/Primer Destruction Site for the installation of groundwater monitoring wells MW-1 and MW-7. The borehole for well MW-1 was advanced immediately adjacent to borehole TW-1, downgradient of the borehole AR-7, while the borehole for well MW-7 was advanced approximately 20 feet north of TW-7, nearer the axis of the valley. No groundwater was encountered during advancement of these boreholes; however, monitoring wells were installed. Since these two boreholes are located within, or in close proximity to, the Ammunition Renovation/Primer Destruction Site, soil samples were collected during their advancement to support data gaps in

this area. During advancement of the borehole for well MW-1, soil samples were collected between 17.5 feet and 24 feet bgs at the alluvium/bedrock interface and analyzed for the following COIs:

- TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B
- VOCs by EPA Method SW8260B
- Dioxins/furans by EPA Method SW8290.

During advancement of the borehole for well MW-7, soil samples were collected at the 0.5 foot, 4 feet, 10 feet, and at 5-foot depth intervals thereafter, until bedrock was encountered. The 0.5 foot sample was analyzed for the following COIs:

- TEPHs quantified against a diesel, motor oil, and kerosene standard by California LUFT Modified EPA Method SW8015B
- PCBs by EPA Method SW8082.

The 0.5-foot sample was the initial sample chosen for analysis of PCBs because some of the highest concentrations of petroleum hydrocarbons in the motor oil range were detected in the vicinity of borehole TW-7 during the RI. When the preliminary (i.e., unverified and unvalidated) analytical results for this sample indicated a low concentration of one PCB (Archlor 1254 at 0.038 mg/kg), additional analysis for PCBs in soil was initiated as described below. All remaining samples for MW-7 were analyzed for TEPHs.

Supplemental Activities Conducted But Not Proposed In Tech Memo

While the data gaps investigation was being conducted, preliminary analytical data from the interim investigation and RI also indicated that the majority of the stockpile sample data for PAHs would be rejected. Consequently, Stockpiles #1 and #2 were resampled. The stockpiles were each divided into halves, four samples were then collected from each half from 2 feet below the stockpile surface. The four samples from each half (SP1-R1[A, B, C, D], SP1-R2[A, B, C, D] and SP2-R1[A, B, C, D], SP2-R2[A, B, C, D]) were then composited by the analytical laboratory into a single sample. The samples were analyzed for TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B and PAHs by EPA Method SW8270C (semivolatile organic compounds [SVOCs]), since based on previous experience with samples from the stockpiles, analysis of PAHs by EPA Method SW8310 would not be appropriate due to fuel interference.

Since preliminary data obtained from the data gaps investigation at the Ammunition Renovation/Primer Destruction Site indicated PCBs may be associated with detections of TEPHs, it was decided to analyze additional soil

samples for PCBs to evaluate their possible vertical and lateral extent. All soil samples from borehole AR-7 were analyzed for PCBs by EPA Method SW8082. Additional near-surface soil samples were collected immediately adjacent to existing boreholes AR-1R, AR-2R, AR-4R, AR-7R, AR-8R, AR-9R, AR-10R, and AR-12R and analyzed for both TEPHs and PCBs to further evaluate a potential correlation between petroleum hydrocarbons and PCBs.

4.2.3.4 North Valley Soil, Groundwater, and Seeps.

During the RI, nine boreholes (TW-1 through TW-9) were advanced in the North Valley for temporary well installations. Shallow groundwater was encountered at only two locations, TW-3 and TW-4. Temporary groundwater monitoring wells were, therefore, installed at these two locations. Since the RI field activities were conducted in December, after the summer dry period and before the winter rainstorms, there was a possibility that shallow seasonal groundwater may have existed and that it was missed due to the timing of the RI. Similarly, no seeps were encountered in the North Valley at that time. If seasonal fluctuations in the shallow groundwater exists, the lack of additional monitoring wells and sampling of seeps was considered to be a data gap.

During the RI, soil samples were collected from all boreholes within and in close proximity to the areas of interest. The soil samples were analyzed for a wide range of COIs. No soil samples were collected from boreholes TW-2 and TW-3 located outside the areas of interest (with the exception of a bulk soil sample collected from TW-2, which was analyzed for total organic carbon). Soil samples were only collected from near the bottom of boreholes TW-8 and TW-9 also situated outside the areas of interest and analyzed for COIs. A bulk sample was also collected from borehole TW-8 and analyzed for total organic carbon. Since preliminary (i.e., unverified and unvalidated) analytical data from the RI indicated both soil and groundwater impact at TW-4, and groundwater impact at TW-3, the lack of soil sample collection during advancement of boreholes TW-2 and TW-3 was considered to be a data gap. Similarly, the preliminary data indicated petroleum hydrocarbon impact in the shallow soil collected from borehole TW-7. The lack of soil sample collection during advancement of boreholes TW-8 and TW-9 was also considered to be a data gap.

Grab groundwater samples collected from temporary wells TW-3 and TW-4 during the RI were analyzed for a wide suite of COIs including explosives and nitroglycerin/PETN, dissolved metals, PAHs, VOCs, TEPHs, perchlorate, and general water chemistry. However, a number of other COIs were identified in the data gap assessment of the various areas of interest in the North Valley, in particular hydrazine, pesticides, and chloropicrin at the Howitzer Test Facility (see Section 4.2.3.2). The lack of testing for these compounds in the groundwater was considered to be a data gap.

Preliminary groundwater data indicated estimated concentrations of two explosives in the grab groundwater sample collected from well TW-4. TNT and amDNT (total)

were detected at estimated concentrations of 0.9 micrograms per liter (µg/L) and 4.9 µg/L, respectively. A preliminary QA review of the RI groundwater data identified a QC issue that may cause the nitroglycerin/PETN data from wells TW-3 and TW-4 to be qualified or rejected during the data verification and validation. Resampling of the groundwater from these two wells for nitroglycerin/PETN was recommended to avoid a potential future data gap. It was also recommended that the groundwater be resampled for the remaining explosives to confirm the TNT and amDNT results.

Preliminary data from the RI indicated all of the petroleum hydrocarbons in the diesel range and the majority of the petroleum hydrocarbons in the motor oil range were encountered at the Ammunition Renovation/Primer Destruction Site. The remaining petroleum hydrocarbons in the motor oil range were detected in the surface soil at the Howitzer Test Facility, with very low concentrations encountered at depth at only one location (TW-5). No petroleum hydrocarbons in the diesel range were detected in any of the soil samples collected from the Howitzer Test Facility. Petroleum hydrocarbons in the diesel and motor oil ranges were detected in the grab groundwater sample collected from well TW-4, and petroleum hydrocarbons in the diesel range were detected in the groundwater sample collected from well TW-3. Explosives impact in soil appear to be confined to the area of the TNT Strips, with the exception of one detection of TNT at 10 feet bgs at the Howitzer Test Facility. Preliminary data also indicated low levels of explosives in the groundwater sample collected from well TW-4 downgradient of the TNT Strips and the Howitzer Test Facility. Given what appears to be a then current general lack of shallow groundwater, the relationship of the compounds detected in the groundwater with respect to their potential source areas was not well understood. A more complete understanding of the site groundwater flow regime was, therefore, considered to be a data gap.

During the data gaps investigation, the temporary wells discussed above (TW-3 and -4) were converted into "permanent" wells by adding a cement grout sanitary seal the placement of which was observed by a Solano County DEM inspector. These wells were then renamed MW-3 (TW-3) and MW-4 (TW-4). Seven additional permanent, single-cased, shallow groundwater monitoring wells (MW-1, -2, -5, -6, -7, -8, and -9) were installed adjacent to previously advanced boreholes (TW-1, -2, -5, -6, -7, -8, and -9) to assess potential seasonal fluctuations in shallow groundwater, except as follows. Groundwater monitoring well MW-6 was installed approximately 40 feet to the northwest of borehole TW-6, within the howitzer test tunnels footprint. Groundwater monitoring well MW-7 was installed approximately 20 feet north of borehole TW-7, closer to the axis of the valley. Groundwater monitoring well MW-2 was planned to be installed approximately 120 feet downgradient of borehole TW-2, immediately adjacent to the Project Site boundary; however, the well was inadvertently installed adjacent to borehole TW-2. It was decided to install an additional monitoring well (MW-14) at the Project Site boundary as discussed in the "Supplemental Activities" section below. One other single-cased shallow well (MW-13) was installed at the base of the slope, approximately half-way between well MW-4(TW-4) and the southeastern end of

TNT Strip #1. No groundwater was encountered during the advancement of these boreholes; however, monitoring wells were installed. Based on the lack of water it was decided to install another monitoring well (MW-15) at the base of the slope, approximately 130 feet southeast of well MW-13, as discussed in the "Supplemental Activities" section below.

Two additional double-cased, deep groundwater monitoring wells (MW-3A, and MW-4A) were installed immediately adjacent to existing shallow wells MW-3(TW-3) and MW-4(TW-4). The double-cased wells were installed in the bedrock to determine the existence of groundwater deeper within the bedrock and to assess potential vertical gradients. During installation of the conductor casing at well MW-3A, grout seeped into the conductor casing. Later, during development of well MW-3A (see Section C.8.3 in Appendix C), the pH of the water being removed from the well was 12.04. Since over-development of the well did not reduce the pH level, well MW-3A was declared a grout-impacted well for the purposes of the non-OE RI. A replacement well (MW-3B) was installed, approximately 15 feet upgradient (northwest) of MW-3A, as discussed in the "Supplemental Activities" section below. Well MW-3A has been appropriately abandoned in accordance with the Final Work Plan (Earth Tech, 2000b) and the requirements of the Solano County DEM.

Copies of the well construction logs are included in Attachment C-4 of Appendix C. Well construction details are summarized in Table 4-9.

Other deep boreholes were used to assess the nature of the bedrock, as previously discussed. Three deep boreholes (TNT-1P, -1Q, and -2F) were installed at the TNT Strips (see Section 4.2.3.1) and one deep borehole (AR-7) was installed at the Ammunition Renovation/Primer Destruction Site (see Section 4.2.3.3).

Soil sample collection and analysis has already been discussed for those wells advanced in the Howitzer Test Facility (MW-5 and -6) and Ammunition Renovation/Primer Destruction Site (MW-1 and -7) (see Sections 4.2.3.2 and 4.2.3.3, respectively).

Soil samples were collected during advancement of the boreholes for wells MW-2, -8, -9, -13, -14, and -15 at the 0.5 foot, 4 feet, 10 feet, and at 5-foot depth intervals thereafter, until bedrock was encountered. Soil samples from these boreholes were analyzed for the following COIs:

- Explosives by EPA Method SW8330
- TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B
- VOCs by EPA Method SW8260B (excluding surface samples).

Since no soil samples were collected during advancement of borehole TW-3 during the RI, shallow samples were collected during advancement of the pilot borehole for deep well MW-3A. Samples were collected at the same intervals previously described and analyzed for the same COIs listed above. No shallow soil samples were collected during advancement of the borehole for well MW-4A, or during advancement of the borehole for replacement well MW-3B.

Once unweathered bedrock was encountered during double-cased monitoring well installation, a conductor casing was installed to seal the shallow groundwater-bearing zone from potential deeper groundwater-bearing zones within the underlying bedrock. After the conductor casing was installed, the boreholes were continuously cored up to 33.5 feet (MW-3A), 35 feet (MW-3B), and 24.6 feet (MW-4A) into the bedrock. The continuous cores were used for lithological interpretation (see Section 4.3).

Although no groundwater was encountered during advancement of the boreholes, groundwater was present in all the new wells after installation. Groundwater samples were collected from the new wells after development (see Section C.8.3 in Appendix C). Grab water samples were also collected from three seeps (NV-S1, -S2, and -S3), which were present within and to the west of the Howitzer Test Facility at the time of the data gaps investigation. The groundwater and seep water samples were analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330
- PAHs by EPA Method SW8310
- TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B
- VOCs by EPA Method SW8260B
- Dissolved CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium by EPA Methods SW6010B, SW7470A, and SW7471A
- Organochlorine pesticides by EPA Method SW8081A
- Perchlorate by CADOHS Method 300.0 Modified
- Hydrazine by Modified EPA Method SW8315
- General water chemistry (chloride, nitrate/nitrite, sulfate by EPA Method 300.0, total organic carbon by EPA Method 415.1, TDS by EPA Method 160.1, and TSS by EPA Method 160.2)

- Field parameters (temperature by EPA Method 170.1, pH by EPA Method 150.1, electrical conductivity by EPA Method 120.1, and turbidity by EPA Method 180.1).

In addition, existing wells MW-3 (TW-3) and MW-4 (TW-4) were resampled and analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330
- TEPHs quantified against a diesel, motor oil, and kerosene standard by California LUFT Modified EPA Method SW8015B
- Chloropicrin by EPA Method SW8270C
- Organochlorine pesticides by EPA Method SW8081A
- Hydrazine by Modified EPA Method SW8315
- General water chemistry (chloride, nitrate/nitrite, sulfate by EPA Method 300.0, total organic carbon by EPA Method 415.1, TDS by EPA Method 160.1, and TSS by EPA Method 160.2)
- Field parameters (temperature by EPA Method 170.1, pH by EPA Method 150.1, electrical conductivity by EPA Method 120.1, and turbidity by EPA Method 180.1).

This round of groundwater sampling represents the April 2000 monitoring event.

Supplemental Activities Conducted But Not Proposed In Tech Memo

As previously discussed, two additional single-cased monitoring wells (MW-14 and -15) were installed in order to fill potential future data gaps, and an additional double-cased well (MW-3B) was installed to replace well MW-3A, which was impacted by the cement grout used to seal the conductor casing. Well MW-3B was installed as a replacement well so groundwater data would not be lost by declaring well MW-3A as a grout-impacted groundwater monitoring well. Soil samples were collected during advancement of the pilot borehole for well MW-3A. Therefore, it was not considered necessary to collect additional soil samples during the advancement of the replacement well installed in close proximity to the original well.

Given that only grab groundwater samples were collected from wells MW-3 (TW-3) and MW-4 (TW-4) (i.e., the wells had not been fully developed) during the RI, it was decided to collect additional groundwater samples after well development for analysis of PAHs, VOCs, dissolved metals, and perchlorate to avoid potential future data gaps.

Since preliminary (i.e., unverified and unvalidated) analytical data obtained from the on-going data gaps investigation at the Ammunition Renovation/Primer Destruction Site indicated PCBs may be associated with detections of TEPHs, it was decided to analyze some of the groundwater samples for PCBs. Groundwater samples from wells MW-3 (TW-3), -4 (TW-4), and -7 were analyzed for PCBs by EPA Method SW8082.

Near-surface soil samples from boreholes advanced for the installation of wells MW-14 and MW-15 were also analyzed for both TEPHs and PCBs to further evaluate a potential correlation between petroleum hydrocarbons and PCBs in soil.

During preparation of this Draft RI/FS report, it was decided to conduct an additional round of groundwater sampling of all wells at the Project Site, to assist in the evaluation of the groundwater data already obtained during the various investigative phase, as outlined in the letter addendum dated July 31, 2000. During this supplemental groundwater monitoring event, the following groundwater wells in the North Valley were dry: MW-5, -13, and -15. All the seeps in the North Valley were also dry. Groundwater samples collected from those wells with sufficient water were the analyzed for the following COIs previously detected in the groundwater at the Project Site:

- Explosives (excluding nitroglycerin and PETN) by EPA Method SW 8330
- PAHs by EPA Method SW8310
- TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B
- VOCs by EPA Method SW8260B
- Total and dissolved CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus, and sodium by EPA Methods SW6010B, SW7470A, and SW7471A
- Strontium by EPA Method SW6010B
- Organochlorine pesticides by EPA Method SW8081
- Field parameters (temperature by EPA Method 170.1, pH by EPA Method 150.1, electrical conductivity by EPA Method 120.1, and turbidity by EPA Method 180.1.

This round of groundwater sampling represents the August 2000 monitoring event. It should be noted that both filtered and unfiltered samples were collected for metals analysis to provide additional data for the screening-level HRA (see Chapter 7.0). Strontium was also added to the list of metals analyzed during this

monitoring event. Initially, only well MW-11 in the South Valley downgradient of the Flare Site was to be analyzed for strontium; however, all wells in both the North and South Valleys (see Section 4.2.3.7) with sufficient water were analyzed for strontium to allow a comparison of any strontium detected at well MW-11 with other wells at the Project Site.

4.2.3.5 Dynamite Burn Site

Supplemental Activities Conducted but Not Proposed in Tech Memo

Based on an updated review of the historical aerial photographs (see Appendix A), the previously identified location of the former Dynamite Burn Site was revised. As a result, three additional surface samples (R1-E, -F, and -G) were collected from the Ridge during the data gaps investigation and analyzed for nitroglycerin and PETN by EPA Method SW8330, and nitrate and nitrite as nitrogen by EPA Method 300.0.

4.2.3.6 South Valley Wetland Sediment and Surface Water.

The sediment sample collected from the downgradient sediment location (WET-2) during the RI was not analyzed for dioxins/furans as specified in the Draft Final and Final Work Plans (Earth Tech, 1999c and Earth Tech, 2000b, respectively). The lack of testing for this COI was considered to be a data gap.

One sediment sample (WET-2R) was collected during the data gaps investigation from the same location as WET-2 and analyzed for dioxins/furans by EPA Method SW8290.

The preliminary QA review of the RI surface water data, identified one QC issue that may cause explosives and nitroglycerin/PETN data from surface water locations SW-1 and SW-2 to be qualified or rejected during data verification/validation. Resampling of the surface water at those locations for explosives and nitroglycerin/PETN was, therefore, recommended to avoid a potential future data gap.

Two surface water samples (SW-1R and -2R) were collected from the same locations as SW-1 and -2 during the data gaps investigation and analyzed explosives and nitroglycerin/PETN by EPA Method SW8330.

Supplemental Activities Conducted but Not Proposed in Tech Memo

During preparation of this Draft RI/FS report it appeared that the level of mercury in the wetland surface sediment exceeded ambient upslope concentrations. Therefore, sediment samples were collected from five additional boreholes (WET-3, WET-4, WET-5, WET-6, and WET-7) downgradient of Demolition Site #3, as outlined in the letter addendum dated July 31, 2000. Sediment samples were

collected at the surface, 1 foot, 3 feet, and 5 feet bgs. The wetland sediment samples were analyzed for the following COIs:

- Mercury (total) by EPA Method 7471A
- Methyl mercury by Frontier Geoscience proprietary Method FGS-070.1.

Methyl mercury was included in the data gaps program to assist in the screening ecological risk assessment (see Chapter 7.0). The additional borehole locations are shown on Figure 4-2.

4.2.3.7 South Valley Groundwater and Seeps.

During the RI, two boreholes (TW-11 and -12) were advanced in the South Valley for temporary, and in the case of TW-12 permanent, monitoring well installations. No shallow groundwater was encountered at borehole TW-11; therefore, no temporary well was installed. Groundwater was encountered at borehole TW-12 and a single-cased, shallow permanent monitoring well was installed (see Section 4.2.2.11). One other borehole, TW-10, was to be advanced during the RI at the west end of the South Valley, upgradient of the areas of interest. This borehole was not advanced during the RI. The lack of a borehole in this area was considered to be a data gap. Since the RI activities were conducted in December, after the summer dry period and before the winter rainstorms, there is a possibility that shallow seasonal groundwater may have been missed due to the timing of the RI. Similarly, no seeps were encountered in the South Valley during the RI activities. If seasonal fluctuations in the shallow groundwater exist, the lack of additional monitoring wells and sampling of seeps was considered to be a data gap.

During the RI, a grab groundwater sample was collected from permanent monitoring well TW-12 and analyzed for a wide suite of COIs including explosives and nitroglycerin/PETN, PAHs, VOCs, dissolved metals, and general water chemistry. The preliminary QA review of the RI groundwater data, identified one QC issue that may cause explosives and nitroglycerin/PETN data from well TW-12 to be qualified or rejected during data verification/validation. Resampling of the groundwater for explosives and nitroglycerin/PETN was recommended to avoid a potential future data gap.

During the data gaps investigation, well TW-12 was renamed MW-12 (TW-12) for consistency with other permanent monitoring wells installed at the Project Site. Two additional permanent, single-cased, shallow groundwater monitoring wells (MW-10 and -11) were installed in the South Valley. Groundwater was encountered at both locations during borehole advancement at 3.5 feet (MW-10) and 14 feet (MW-11) bgs, respectively. No soil samples were collected during the installation of well MW-10. Soil samples were collected from the bottom of the borehole for installation of well MW-11. The soil samples were analyzed for VOCs

by EPA Method SW8260B and CAM 17 metals, plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium by EPA Methods SW6010B, SW7470A, and SW7471A. Copies of the well construction logs are included in Attachment C-4 of Appendix C. Well construction details are summarized in Table 4-9.

Groundwater samples were collected from the new wells after development (see Section C.8.3 in Appendix C). Grab samples were also collected from one seep (SV-S1) on the south slope of the South Valley between Demolition Sites #1 and #2. The water samples were analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330
- PAHs by EPA Method SW8310
- VOCs by EPA Method SW8260B
- Dissolved CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium by EPA Methods SW6010B, SW7470A, and SW7471A
- Perchlorate by CADOHS Method 300.0 Modified
- Hydrazine by Modified EPA Method SW8315
- General water chemistry (chloride, nitrate/nitrite, sulfate by EPA Method 300.0, total organic carbon by EPA Method 415.1, TDS by EPA Method 160.1, and TSS by EPA Method 160.2)
- Field parameters (temperature by EPA Method 170.1, pH by EPA Method 150.1, electrical conductivity by EPA Method 120.1, and turbidity by EPA Method 180.1).

In addition, existing well MW-12(TW-12) was resampled and analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330
- Hydrazine by Modified EPA Method SW8315
- General water chemistry (chloride, nitrate/nitrite, sulfate by EPA Method 300.0, total organic carbon by EPA Method 415.1, TDS by EPA Method 160.1, and TSS by EPA Method 160.2)

- Field parameters (temperature by EPA Method 170.1, pH by EPA Method 150.1, electrical conductivity by EPA Method 120.1, and turbidity by EPA Method 180.1).

This round of groundwater sampling represents the April 2000 monitoring event.

Supplemental Activities Conducted but Not Proposed in Tech Memo

During preparation of this Draft RI/FS report, it was decided to conduct an additional round of groundwater sampling of all wells at the Project Site, to assist in the evaluation of the groundwater data already obtained during the various investigative phase, as outlined in the letter addendum dated July 31, 2000. During this supplemental groundwater monitoring event, all wells in the South Valley had sufficient water for sample collection. The previously sampled seep in the South Valley was dry. Groundwater samples were the analyzed for the following COIs previously detected in the groundwater at the Project Site:

- Explosives (excluding nitroglycerin and PETN) by EPA Method SW 8330
- PAHs by EPA Method SW8310
- TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B
- VOCs by EPA Method SW8260B
- Total and dissolved CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus, and sodium by EPA Methods SW6010B, SW7470A, and SW7471A
- Strontium by EPA Method SW6010B
- Organochlorine pesticides by EPA Method SW8081
- Field parameters (temperature by EPA Method 170.1, pH by EPA Method 150.1, electrical conductivity by EPA Method 120.1, and turbidity by EPA Method 180.1.

This round of groundwater sampling represents the August 2000 monitoring event. It should be noted that both filtered and unfiltered samples were collected for metals analysis to provide additional data for the screening-level HRA (see Chapter 7.0).

Strontium was also added to the list of metals analyzed during this monitoring event. Initially, only well MW-11 was to be analyzed for strontium; however, all wells in both the North (see Section 4.2.3.4) and South Valleys with sufficient

water were analyzed for strontium to allow a comparison of any strontium detected at well MW-11.

4.2.3.8 Field Permeability Testing

Supplemental Activities Conducted but Not Proposed in Tech Memo

During preparation of this Draft RI/FS report, it was decided to conduct falling head permeability tests in selected groundwater monitoring wells at the Project Site to assist in the understanding of the Conceptual Hydrogeological Model, as outlined in the letter addendum dated August 21, 2000. The falling head permeability tests were used to estimate site-specific "aquifer" parameters (hydraulic conductivity, transmissivity, and storativity) in the shallow water-bearing zone. The falling head permeability tests were conducted at wells MW-2, -3B, -4A, and -6 in the North Valley and wells MW-10 and -11 in the South Valley, as described in Section C.19 of Appendix C and Appendix D. Data obtained from the falling head permeability tests are discussed in Section 4.4.2.2.

4.2.3.9 Other Activities Outside Areas of Interest.

A geotechnical investigation was conducted at the same time as the data gaps investigation. No soil samples were retained from the geotechnical boreholes for chemical analysis. The objective of the geotechnical investigation was to provide additional information on the depth to bedrock, primarily a 500-foot radius of the Demolition and Flare sites in the South Valley.

Thirty geotechnical boreholes (GB-1 through -30) were advanced throughout the Project Site as part of the data gaps investigation. Four boreholes (GB-1, -2, -3, and -9) were advanced on the upper north-facing slope of the South Valley. Ten boreholes (GB-4 through -8 and GB-12 through -16) were advanced along the sewer bench situated approximately half way up the north-facing slope of the South Valley. Three boreholes (GB-10, -11, and -17) were advanced along the south edge of the South Valley wetland area. Four boreholes (GB-18 through -21) were advanced on the ridge area northeast of the McAllister Drive Land Bridge. Four boreholes (GB-27 through -30) were advanced on the south slope of the Ridge. Four boreholes (GB-22 through -25) were advanced on the north slope of the Ridge, and one borehole (GB-26) was advanced on the south-facing slope of the North Valley in the TNT Strips area.

Copies of the geotechnical investigation borehole logs are included in Attachment C-3 of Appendix C. The depth to bedrock data obtained from the geotechnical investigation boreholes are presented on Figure 4-4 and discussed in Section 4.3. These data allow a determination of the amount of soil overburden and an evaluation of the approximate volume of soil that may need to be excavated as part of any removal action alternative evaluated in the FS. In addition, the boreholes along the sewer bench were used to determine whether the sewer line was

installed in the bedrock or the overlying soil, since the presence of the sewer line will need to be taken into account in any removal action.

4.2.4 Removal Action Investigation Program

The North Valley Military Landfill was not included in any of the previous investigations since investigation of this site would require potential "OE removal" to complete the fieldwork, as opposed to potential "OE avoidance," which was practiced during the interim, remedial, and data gaps investigations.

The primary objective of the removal action investigation was to characterize the lateral and vertical extent of the suspected disposal area, referred to as the North Valley Military Landfill, and to identify whether soil within and/or immediately below the landfill is affected with non-OE COIs.

Removal action investigation sampling locations are shown on Figure 4-3 and summarized in Table 4-7. Details of the work performed during the removal action investigation are presented in Sections C.3.1 and C.4.2 of Appendix C. Test pit cross sections are presented on Figure 4-4.

A minimum of 10 percent replicate soil samples were collected during the removal action investigation, as described in the QCSRs (see Volume IV of this document). No additional split soil samples were collected for use by DTSC and/or USACE during this phase of the non-OE RI.

All soil samples, except those requiring analysis for perchlorate, were analyzed by Quanterra. Soil samples requiring analysis for perchlorate were analyzed by Babcock. All water samples were analyzed by Quanterra.

4.2.4.1 North Valley Military Landfill.

Two intersecting trenches bisecting the landfill were proposed in the RAW (Earth Tech, 2000f). Samples were to be collected at 25-foot intervals along each trench at the base of the landfill and 2 feet below the landfill base. However, exploratory test pits were substituted for the trenches in order to try and locate an area of wood debris suspected to be near the center of the disposal area. After a site visit by Tom Crosby of SECOR, it was determined that the wood debris had already been removed during the 1996 initial site preparation activities and was placed in Stockpile #3. Thirty exploratory test pits (LFP-1 through 30) were excavated along the approximate proposed trench alignments. Excavations extended 2 feet beyond the base of the landfill into native soil as was originally proposed. The depth to the base of the landfill varied from approximately 2 feet near the edges to approximately 8 feet toward the central portion of the landfill. Soil samples were collected from 15 pits at the base of the landfill and approximately 2 feet below the landfill base. Four additional soil samples (LFM-1 through -4) were collected from the landfill soil stockpiles. All soil samples, except LFM-1 were analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330
- PAHs by EPA Method SW8310
- TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B
- VOCs by EPA Method SW8260B
- SVOCs (chloropicrin and pentachlorophenol) by EPA Method SW8270C
- CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium by EPA Methods SW6010B, SW7470A, and SW7471A.
- Organochlorine pesticides by EPA Method SW8081
- PCBs by EPA Method SW8082
- Nitrate and nitrite as nitrogen by EPA Method 300.0
- Perchlorate by CADOHS Method 300.0 Modified.

Because of limited sample volume, LFM-1 was not analyzed for nitrate/nitrite or SVOCs (chloropicrin and pentachlorophenol). Soil samples from LFM-1, -2, -3, -4, and LFP-1, -7, -10, -12, -22, and -24 were also analyzed for dioxins/furans by EPA Method SW8290.

In two instances (LFP-9 and -24), shallow groundwater was encountered less than 2 feet below the landfill base. In each case, a grab groundwater sample was collected and analyzed for the following COIs:

- Explosives, including nitroglycerin and PETN, by EPA Method SW8330
- PAHs by EPA Method SW8310
- TEPHs quantified against a diesel, motor oil, and kerosene standard, respectively, by California LUFT Modified EPA Method SW8015B
- VOCs by EPA Method SW8260B
- SVOCs (chloropicrin and pentachlorophenol) by EPA Method SW8270C

- Dissolved CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium by EPA Methods SW6010B, SW7470A, and SW7471A.
- Organochlorine pesticides by EPA Method SW8081
- PCBs by EPA Method SW8082
- Nitrate and nitrite as nitrogen by EPA Method 300.0
- Dioxins/furans by EPA Method SW8290.

4.3 SITE GEOLOGY

The site geology is based on information obtained from previous site investigations (see Chapter 3.0) and the investigation programs discussed in the previous sections of this chapter.

Two previous investigations were conducted by ENGEO (see Section 3.1), which included advancement of 22 exploratory boreholes and excavation of 4 shallow trenches and 10 test pits. Copies of the ENGEO borehole logs and trench/test pit drawings are included in Attachments B-1 and B-2 of Appendix B.

A total of 162 exploratory boreholes were advanced as part of the non-OE RI (see Section 4.2). Twelve test pits were excavated and a shallow seismic refraction survey was conducted in the South Valley. Copies of the non-OE RI borehole logs and test pit logs are included in Attachments C-1 and C-3 of Appendix C. A copy of the shallow seismic refraction survey is included in Attachment C-2 of Appendix C. In addition, 30 test pits were excavated in the North Valley in the vicinity of the North Valley Military Landfill (see Figure 4-4).

Most of the site investigations have focused on the surficial deposits consisting of fill soil, shallow landslide deposits, alluvium, and colluvium, top soil, and the uppermost weathered bedrock zone, all typically within the upper 30 feet bgs. Seven deeper boreholes were advanced into the bedrock during the data gaps investigation to a maximum depth of approximately 54 feet bgs.

The Project Site is underlain by bedrock units of the Panoche Formation. The bedrock units are exposed in cut areas, but are generally overlain by surficial deposits consisting of fill, shallow landslide deposits, alluvium, and colluvium. The site geologic map presented on Figure 4-5 shows the distribution of bedrock and surficial deposits at the Project Site.

The Panoche Formation at the Project Site is primarily interbedded shale and siltstone with minor amounts of sandstone. These rock units have been deformed by folding and faulting; hence, the shale and siltstone are typically intensely fractured, crushed, and sheared, while the more resistant and hard sandstone is generally closely fractured. The physical characteristics of the bedrock units

persist to the depth explored. The upper portion of the bedrock is severely to moderately weathered and typically shows the yellowish-brown color of oxidized material, grading to slightly weathered to unweathered and unoxidized bedrock that is typically grayish in color. The shale and siltstone are soft to very soft, while the sandstone is soft to moderately hard. At depth, the bedrock becomes very dense to hard and is compact and tight. The change in the physical characteristics of the bedrock with depth is further supported by the seismic data that identified two seismic velocity layers within the bedrock. These layers were interpreted as an intermediate layer (V2) with typical seismic velocities in the range of 2,000 to 2,900 fps representing highly weathered bedrock material, and a deeper layer (V3) with typical seismic velocities greater than 3,000 fps representing less weathered, more dense, bedrock material.

Because of the folding and faulting, bedding orientation and inclination are variable; however, the general trend is a northwest-southeast strike and moderate dips to the southwest. Fractures are likewise oriented in various directions and clay derived from the weathering of the shale bedrock is found along fracture surfaces or infilling of weathered fractures. A fault mapped by ENGEO (ENGEO, Inc., 1989a) extends in an east-west direction along the north slope of the South Valley.

Fill consists both of engineered fill associated with grading and dumped fill of unknown quality associated with activities during the previous operation of the Benicia Arsenal. The engineered fill at the Project Site includes the McAllister Drive Land Bridge across the South Valley, fill placed to develop building pads, and fill placed along the sewer bench and to repair slide areas. Fill of unknown quality is found in the North Valley area as valley channel fill associated with previous Benicia Arsenal grading activities.

Shallow landslides located on ridge slopes were partially repaired as part of the site development (ENGEO, Inc., 1991). The slides appear to be confined to the colluvium or residual soil overlying the weathered bedrock on ridge slopes and in swale areas.

Alluvium in the valley floor consists of highly plastic (fat) clay with minor amounts of weathered shale, siltstone, and sandstone fragments.

Colluvial deposits are very similar in composition to the alluvium and include residual soils found on ridge slopes and slopes bounding the valley floor. They are generally thickest in the drainage swales and consist of fat clay with varying amounts of sand and fragments of weathered shale, siltstone, and sandstone. Similarities in the physical characteristics of the alluvium and colluvium are supported by the seismic data which identified a surficial layer (V1) consisting of alluvium and colluvium with typical seismic velocities of less than 1,500 fps.

4.3.1 TNT Strips

The TNT Strips are situated on the north slopes of the North Valley and consist of a series of mostly bare soil strips subparallel to the contours of the hillside (see Figure 4-6). Remnants of the strips are visible today based on linear topographic benches and intermittent segments of bare, unvegetated ground along the strip alignments. Exploration of the TNT Strips area consisted of shallow hand-augered boreholes, machine driven continuously pushed samples, and three deep boreholes advanced by hollow stem auger and coring, as described in Appendix C (Photographs 18 and 19). The deeper boreholes were intended to assess the bedrock materials at depth.

Based on the results of the exploration, the TNT Strips area is underlain entirely by residual soil or colluvium and bedrock units of the Panoche Formation. Depth to bedrock ranges from 1.5 feet to 7.5 feet bgs, although locally it attains depths of 10 feet in drainage swale areas. The average depth to bedrock is approximately 3.5 feet bgs. Depths to bedrock (or thickness of residual soil or colluvium) in the TNT Strips area are summarized in the site geologic map for the North Valley (see Figure 4-6). Interpretation of bedrock depth is shown in the geologic sections across the TNT Strips (see Figures 4-9, 4-10, and 4-11). The bedrock immediately beneath the residual soil or colluvium is severely to moderately weathered shale and siltstone. The weathered shale/siltstone is typically a mottled yellowish brown, olive gray, to grayish brown, soft to very soft in hardness, and crumbles readily to a sandy fat clay. It is heavily oxidized and exhibits the typical yellowish to reddish brown iron-oxide staining that is readily apparent along weathered fractures.

Most of the boreholes in the TNT Strips area were terminated within the residual soil or a few inches into bedrock. Three boreholes (TNT-1P, TNT-1Q and TNT-2F) were cored along TNT Strips #1 and #2 close to the ridgeline to assess the condition of the bedrock units at depth. Bedrock in these boreholes was encountered at depths of 3 feet to 3.5 feet bgs and the boreholes were advanced to total depths of 47 feet, 48 feet, and 50 feet bgs, respectively. Based on the results of the coring, the shale/siltstone bedrock can be described as severely to moderately weathered to the depths explored and oxidation is evident from the iron oxide staining along fracture surfaces (Photographs 20 to 22). The weathered shale/siltstone has the consistency of highly compacted gravelly fat clays. The bedrock is intensely fractured and locally sheared; cores remain intact, compact and solid in the core barrel but crumble easily when transferred to core boxes (Photographs 23 and 24). The presence of iron oxide staining along fractures at depth suggests that groundwater penetrated into the fracture zones during the geologic past. No free groundwater was encountered during the drilling of these boreholes to the depths explored. Bedding noted in the cores shows steep dip angles (50° to 75°).

The residual soil is typically a moderate yellowish-brown to moderate reddish brown, fat clay with occasional fragments of weathered shale and siltstone. In

most of the boreholes in the TNT Strips, irregular, angular fragments of soft, brittle whitish- to grayish-crystalline material occur as inclusions or seams in the fat clay soil. The fragments are found at the ground surface and in the soil to a depth of about 2 feet bgs, and were not found in the bedrock. This crystalline material is probably a by-product of the burning at the TNT Strips.

4.3.2 North Valley

The North Valley includes the following facilities associated with the former Benicia Arsenal: Howitzer Test Facility and associated Stockpile #3, North Valley Military Landfill, and Ammunition Renovation/Primer Destruction Site and associated Stockpiles #1 and #2 all located on the North Valley floor (see Figure 4-6; Photographs 10 through 14). Because several areas of interest associated with the former Benicia Arsenal exist in the North Valley, an extensive exploration program to sample soil and bedrock was conducted. This included boreholes advanced by direct push sampling, hollow stem augers, and coring. Several of these boreholes were converted to groundwater monitoring wells.

Figure 4-6 is a geologic map for the North Valley. Cross sections showing the subsurface geology are presented on Figures 4-8 through 4-11.

Based on the results of the exploration work, the North Valley area is underlain by bedrock units of the Panoche Formation. Overlying the bedrock units are colluvium and residual soil on the slopes adjoining the valley floor, and alluvium and fill in the valley floor. Localized landslide deposits are found on the south slope.

Fill occurs as two generic types: old fill associated with the Benicia Arsenal activities (i.e., fill placed to develop building pads in the valley floor and the North Valley Military Landfill); and, more recent fill represented by Stockpiles #1, #2, and #3 (see Figure 4-6). These stockpiles were derived from the demolition of existing structures associated with the Howitzer Test Facility and the Ammunition Renovation/Primer Destruction Site during the fall of 1996 and consist of mounds primarily of soil with mixed gravel, asphalt, concrete, and wood debris (Photograph 11). The extent of the old fill in the valley floor is shown on the geologic map (see Figure 4-6) and the geologic sections (see Figures 4-8, 4-9, and 4-10). The old fill attains a maximum thickness of 8 feet and consists of a fat clay with weathered shale, siltstone, and sandstone fragments. It was apparently derived from the excavation of colluvium and weathered bedrock units in adjoining areas.

The North Valley Military Landfill is located east of Stockpile #3 (Photograph 28). The extent of the North Valley Military Landfill was investigated by excavating several closely spaced backhoe test pits in May 2000. The locations of the test pits are shown in Figure 4-3. Test pit logs are shown on Figure 4-4. The vertical extent of the North Valley Military Landfill is also depicted on the geologic cross-sections shown on Figure 4-10. As exposed in the test pits, the landfill consists predominantly of sandy clay to clayey sand with gravel and minor amounts of man-

made debris that occur sporadically or as concentrated pockets within the soil materials. The debris is composed of wood, various types of metal fragments (e.g., cans, hinges, nails), concrete fragments, and OE scrap. Imported white sand and pea gravel were also found randomly within the landfill. The clay portion of the fill is highly plastic. Maximum thickness of the landfill materials is on the order of 4.5 feet. Thicker fill was encountered where the landfill transitions to the Stockpile #3 (Test Pit LFP-24). Highly plastic sandy clay or clay alluvium or colluvium lies directly beneath the landfill. Bedrock was encountered at shallow depth only in Test Pit LFP-23 beneath alluvium/colluvium and is not in contact with the landfill material.

Beneath the old fill and North Valley Military Landfill is alluvium, which attains a maximum thickness of 26 feet at well MW-4A. The alluvium is a firm to stiff, moderate yellowish-brown fat clay grading into a fat clay with sand and gravel consisting of weathered fragments of shale, siltstone, and sandstone.

Bedrock beneath the alluvium is predominantly sheared to intensely fractured and crushed shale and siltstone with minor sandstone. Most of the boreholes were terminated a few feet into bedrock; however, in order to assess the condition of the bedrock at depth, three boreholes (AR-7, MW-3A, and MW-4A) were continuously cored to depths of 44 feet, 53.5 feet, and 50.6 feet bgs, respectively. MW-3A and MW-4A were completed as bedrock groundwater monitoring wells. Conductor casings were installed in the monitoring wells to seal of the alluvium and the upper weathered portion of the bedrock. Generally, the upper few feet of the shale/siltstone at the contact with the alluvium is moderately weathered soil-like (gravelly fat clay) material, which is light olive brown to light olive gray and has iron oxide staining. At MW-3A and MW-4A, the penetrated extent of the weathered shale/siltstone is 4.5 feet and 9 feet, respectively. The unweathered shale/siltstone is typically dark gray, very dense but soft. Recovered cores of the unweathered bedrock appear compact and tight (see Photos 25, 26, and 27).

4.3.3 Ridge Stockpiles and Dynamite Burn Site

The Ridge area refers to the central ridge between the North and South Valleys (see Figure 4-5). The Ridge area was a designated borrow site during grading of Southampton Units D-1 through D-4 in 1990 (see Section 2.3.3). During the operation of the former Benicia Arsenal, a small portion of the then ungraded Ridge was designated as a "Dynamite Burn Site," where aged, out-of-service dynamite was reportedly disposed of through burning sometime in 1947 to 1948. The approximate location of the Dynamite Burn Site is shown on Figure 4-5 and is within the cut area for the 1990 grading operation. Comparison of pre-grading topography and the current topography indicates that the Dynamite Burn Site was excavated about 20 feet to 40 feet below original ground surface. Grading of the Ridge began in about June 1990 and the initial excavated material was used for the McAllister Drive Land Bridge. The McAllister Drive Land Bridge was completed in September 1990. After completion of the land bridge, the cut of the Ridge area continued and was expanded to its current extent at the end of 1990 and possibly

the beginning of 1991. The excavated area was subsequently used to stockpile soil and concrete debris (see Photos 16 and 17) referred to as the "Ridge Stockpiles."

The grading of the Ridge exposed severely to moderately weathered, interbedded shale, siltstone, and sandstone on the excavation pad. Bedding attitudes are variable due to deformation (folding) of the beds. It is interpreted that, prior to grading, the Dynamite Burn Site was underlain by a few feet of residual soil or colluvium overlying weathered bedrock similar to the ungraded portions of the Ridge and the TNT Strips area.

4.3.4 South Valley

Areas of interest in the South Valley include the Flare Site and Demolition Sites #1, #2, and #3. Also included in the South Valley area are the McAllister Drive Land Bridge, the sewer bench, the wetland area, fill areas, and the Kick-Out Area for the previous demolition sites (see Figure 4-7; Photos 1 through 9). Exploration in the South Valley consisted of test pits, seismic lines, and boreholes. The geology of the South Valley area is shown on Figure 4-7 and the subsurface geologic conditions are shown on several cross sections (see Figures 4-12 through 4-15).

As in the North Valley and the Ridge area, the surficial geologic units (residual soil, colluvium, landslide deposits, and alluvium) of the South Valley are underlain entirely by bedrock units of the Panoche Formation. The bedrock occurs generally at shallow depths, except in the valley floor, landslide, and fill areas. Depths to bedrock encountered during site exploration are shown on Figure 4-7.

Demolition Sites #1 and #2 and the Flare Site are situated near the base of the south slope of South Valley (see Photos 2, 3 and 6) and are underlain by colluvium in the lower portion of the swales, where the colluvium is generally thicker than at higher locations. The depth of colluvium in this area ranges from 8 feet to 10 feet. The colluvium is a fat clay with weathered shale and sandstone gravel. Demolition Site #3 located on the north side of the South Valley is a relatively larger area and has apparently been graded so that a bench has been created with a back cut slope exposing weathered shale/siltstone/sandstone (see Photos 8 and 9). Within the bench is a fill area that apparently represents a filled-in demolition crater, which likely includes fill pushed downslope to form the bench. The maximum fill thickness in this area is about 6 feet as determined from exploration boreholes. The fill material is a gravelly lean clay with gravel clasts consisting of weathered shale, siltstone, and sandstone fragments.

The sewer bench is situated along the upper part of the south slope of the South Valley and was constructed as part of the 1990 grading operations for the Southampton residential development (see Photos 1, 2, and 3). A portion of the sewer bench is shown on Figure 4-7. The full alignment of the sewer bench is shown on Figure 2-10. Several boreholes were advanced along the sewer bench to

define the extent of fill, colluvium, or slide debris that would require possible excavation and removal because of the potential existence of OE. Specific information along the sewer bench was necessary to assess the need for realigning the sewer line in certain segments where the sewer line invert foundation is in fill or colluvium and above the bedrock contact. As shown on Figure 4-7, the sewer bench traverses slide areas (ENGEO, Inc., 1989a; Bissell and Karn, 1990), which required repair work consisting of keyway fills and subdrains. Three areas of slide repair (keyway fills 4SK1, 4SK2, and 4SK3) are situated along the sewer bench (see Photos 1, 2, and 3). Construction of these keyway fill areas was performed in August 1990 when the McAllister Drive Land Bridge was being completed. Geotechnical boreholes drilled in these fill areas indicated fill depths of 23.5 feet in 4SK1, 8.5 feet in 4SK2, and 22 feet in 4SK3. Several boreholes were advanced along the sewer bench between Manholes No. 10 and No. 13 to define the extent of fill and other surficial deposits in a slide repair area designed by ENGEO (ENGEO, Inc., 1991). Depth to bedrock along this segment ranged from 2.2 feet to 11 feet bgs (see Figure 4-7).

The McAllister Drive Land Bridge is an engineered fill constructed in June-September, 1990 apparently from weathered bedrock material excavated from the adjoining central Ridge area to the northwest. Exploration of the land bridge consisted of soil boreholes drilled on the downstream and upstream toe of the embankment slope (see Figure 4-7). Based on the results of the exploration and review of field density tests (ENGEO, Inc., 1990b, 1990c, and 1991), the fill material is composed essentially of fat clay with weathered fragments of shale, siltstone, and sandstone. The McAllister Drive Land Bridge area was originally underlain by alluvial deposits, which in turn were underlain by bedrock. The exploratory borehole LB-2 and the borehole for monitoring well MW-12 (TW-12) drilled through the toes of the embankment indicate that fat clay, representing compacted fill materials, are at the base of the embankment. The fat clay in monitoring well MW-12 is underlain by bedrock at a depth of 27 feet bgs (approximate elevation of 39 feet above msl). A cross section depicting geologic conditions under the fill is shown on Figure 4-16. Figure 4-16 also shows that the soil samples collected from the toe of the land bridge from boreholes LB-1, -2, -3, -4, -5, and -6 were collected from the land bridge fill material.

Other areas of fill within the South Valley include engineered fill at the edge of cut building pads and the upper portions of slide areas constructed during site grading in 1990 (see Figure 4-7). These include fill keyways Nos. 3RK1, 5SK1, and 4RK3.

Along the valley floor is a designated wetland area within the alluvial materials found in the creek channel and flood plains (see Figure 4-7; Photographs 6 and 7). The alluvium in the valley floor is interpreted to attain depths of up to 15 feet and probably consists of fat clay with included weathered fragments of shale, siltstone, and sandstone.

Within most of the South Valley, excluding the wetland and the engineered fill areas, the surficial deposits consist of colluvium, alluvium, slide debris, and residual soil ranging in thickness from 0 to 10 feet.

4.4 SITE HYDROLOGY AND HYDROGEOLOGY

4.4.1 Site Hydrology

Surface water occurrences within the boundaries of the Project Site consist of ephemeral creeks, surface seeps, and man-made wetlands. There is a small area (0.08 acre) at the east end of the North Valley that has been identified as a wetland due to a shallow groundwater level and other indications that surface water is seasonal in this area. An unnamed creek flows intermittently through the South Valley from west to east, exiting the Project Site through a culvert under the McAllister Drive Land Bridge. This area is commonly referred to as the South Valley wetland. The west end of the wetland is very broad, and was enlarged as a mitigation measure during construction of the McAllister Drive Land Bridge, and has several beaver dams that create small ponds. The east end of the wetland is much narrower with little or no ponding. The land bridge at the east end of the wetland is designed to restrict flow during periods of heavy precipitation to prevent rain flooding downstream. The wetland receives runoff from the seeps and storm drains, both on and off site, as well as natural runoff from the valley slopes upstream and influx of excess irrigation water from the adjacent residential development. The majority of seeps generally flow only during or after major precipitation events.

Surface water from the Project Site flows down to the Sulphur Springs Creek Canal, which generally runs from north to south through the industrial park east of the Project Site, eventually exiting into the Carquinez Strait near the Benicia-Martinez Bridge.

4.4.2 Site Hydrogeology

Groundwater movement at the Project Site is limited to shallow depths through low-permeability alluvium, colluvium, and weathered bedrock. With depth and increased lithostatic pressure, fractures in the fine-grained bedrock close, forming a dense, tight medium with minimal groundwater flow. Flow is toward the topographic lows in the valleys and down the valleys toward their exit points from the Project Site. Abundant hydrogeologic data from nearby sites, in addition to data at the Project Site, support this conceptual model. Figure 4-17 presents the Conceptual Hydrogeologic Model of the site.

4.4.2.1 Groundwater Occurrence.

Determining the occurrence of groundwater is made difficult by the fact that the geologic materials are of so low-permeability that they yield water only very slowly to soil boreholes. This can be observed on the geologic log for borehole LB-2 (see

Attachment C-3 of Appendix C), where the materials were referred to as "moist" at 17.5 feet bgs; however, when the field crew returned after 1-1/2 hours, there were 6 inches of water standing in the borehole. Likewise, when the 11 TW-series boreholes were drilled during the RI, water was encountered in only 3 of the boreholes (TW-3, -4, and -12). However, when monitoring wells were installed adjacent to those other "dry" borehole locations, water was observed in all the monitoring wells. Water was likely present, but not observed. Since the majority of the boreholes were drilled at the Project Site for the purpose of soil sampling rather than the determination of the presence of groundwater, many were filled with grout immediately after soil sample collection, allowing no time for the entrance and observation of groundwater.

In those boreholes where water was encountered (see Table 4-10), it was present at shallow depths (3 feet to 23 feet bgs). It should be kept in mind that these depths are maximum depths to the water table, since if the boreholes had been left open longer it is likely that the water level would have risen. The soil borehole water levels are contoured on Figure 4-18. There are uncertainties of several feet in those elevations, but the water levels are reasonable as they are similar to those observed in monitoring wells. The figure indicates that groundwater occurrence is strongly controlled by topography. This is consistent with the Conceptual Hydrogeologic Model, where the tight, dense, unweathered bedrock at depths of 20 feet to 40 feet bgs acts as a surface upon which infiltrated water ponds.

The presence of perennial wetlands, particularly in the South Valley and to a lesser extent in the North Valley, indicates that the groundwater table is very shallow through the topographic lows. This further corroborates that groundwater from the surrounding hillslopes flows down the topographic gradient to accumulate in the topographic lows.

An analogous site with almost identical hydrogeologic characteristics is the Main Refinery Area of the Valero Energy Corporation Refinery (formerly the Exxon Benicia Refinery), less than 1 mile to the southeast of the Project Site. Because of the similarities in geology and topography between the two sites, it is expected that the hydrogeologic characteristics of the sites will also be quite similar. An extensive site investigation has been carried out at the Refinery Site because of the presence of free-phase petroleum product atop the water table and of other refinery-related dissolved contaminants. The Refinery Site is also located on ridges and valleys of the Panoche Formation, with surficial deposits of fine-grained alluvium and colluvium derived from that formation. In spite of the valleys having been filled with local, Panoche-derived material prior to construction of the refinery, the groundwater occurrence at the Refinery Site closely follows the pre-existing topography (Radian International, 1999a). This reconfirms that the deeper, unweathered bedrock acts to limit downward migration of water.

A second, hydrogeologically similar site is the IT Corporation Panoche Facility located approximately 1.5 miles northeast of the Project Site. While the topography at the IT Facility consists of comparable ridges and valleys, the

geology is somewhat different. The main geologic unit at the IT Facility is the Panoche Formation, but there is also Domengine Sandstone present, which is significantly more permeable than the fine-grained siltstones/claystones of the Panoche Formation. In addition, the IT Facility is significantly more faulted and is located about 1/2 mile from the active Green Valley Fault. Six inactive, thrust faults have been identified (Jones and Stokes Associates, 1996). This is in contrast to a single thrust fault identified at the Project Site. Even with these differences, insights can be gained by examining the hydrogeology of the Panoche Formation at the IT Facility, which has been extensively studied. Results from the IT Facility investigations are discussed as a hydrogeologic analogy for the Project Site.

The surficial deposits at the Project Site consist of fine-grained colluvium and alluvium with their origin in the Panoche Formation. Depending on the thickness of these deposits above the bedrock and the timepoint in the rainfall cycle, these deposits may or may not be saturated. For instance, monitoring well MW-1 monitored 8 feet of saturated alluvium on May 3, 2000, and only 1 foot on August 2, 2000, due to water table decline.

Bedrock at the site grades from weathered to unweathered (i.e., fresh) over vertical distances of approximately 10 feet to 40 feet. The weathered bedrock shows clear evidence of the presence of water in the oxidation of minerals on the rock surfaces. All wells completed in the bedrock have contained water since exploration of the site was first performed, including on August 2, 2000, when several of the shallower, alluvial wells had gone dry. The unweathered bedrock shows little evidence of water movement (i.e., there is no mineral alteration on fracture surfaces) although water does enter wells completed in the less weathered bedrock (MW-3B and MW-4A). This indicates that some water is present at depth.

Groundwater was observed to be locally confined during drilling of monitoring well MW-4A (see Attachment C-3 of Appendix C), where the water level rose at least 8 feet from a gravelly, fat clay unit. Similar confined areas were observed at the Refinery Site, although much of the Refinery Site groundwater was under unconfined conditions (Radian International, 1999a). In general, however, the alluvium/colluvium and bedrock at the Project Site act as a single hydrogeologic unit. This is consistent with the observation at the Refinery Site that "the different lithological units act as a single hydrostratigraphic unit" (Radian International, 1999b) and similar conclusions at the IT Facility (IT Corporation, 1987a, 1987b, 1990).

Geologists at the IT Facility found moderate to severe weathering in the top 20 feet to 50 feet of bedrock, with much fracturing and shearing of the shale. Below that 50-foot zone, fracturing and shearing was only occasional "because shale tends to deform under pressure" (Jones and Stokes Associates, 1996). Fracture flow paths were considered to be short within the extensively folded and faulted bedrock, but to be generally longer along fault lines.

As at the other nearby sites, the water table at the IT Facility generally parallels the topographic surface. The ridges act as groundwater divides and flow converges on the stream channels in the valleys (IT Corporation, 1987a, 1987b). Investigators divided the subsurface into two principal water-bearing units: an upper flow zone consisting of alluvium and colluvium, weathered Panoche bedrock and some Domengine Sandstone; and a lower unit of unweathered Panoche bedrock. The two zones are believed to be in direct hydraulic connection. Depth to groundwater at the IT Facility is generally 15 feet to 30 feet (IT Corporation, 1987a, 1987b). As with the Project Site, flow through the upper zone is considered to be much greater than through the lower zone. Neither zone was considered to be a viable aquifer due to the very low well yields (typically 0.1 to 1 gallons per minute [gpm]).

4.4.2.2 Hydraulic Characteristics of Geologic Materials.

The low permeability of the geologic materials is attested to by the slow yield of water both to boreholes during drilling and to wells during well development. Some of the wells took hours to days of development to be able to remove the required ten casing volumes (e.g., wells MW-4 and -10 completed in the alluvium and wells MW-3B and -4A completed in the bedrock; see Attachment C-7 of Appendix C).

The alluvium and colluvium consist of dense, usually high-plasticity clay, which is generally recognized as a low-permeability geologic material. Even when coarser fragments are present (i.e., sand or gravel), the bulk of the matrix is clay giving the material a low permeability. Falling head slug tests were performed in August 2000 on the six wells at the Project Site that were suitable for testing (i.e., with sufficient diameter and sufficient depth of water). The results are presented in Table 4-12 (see Appendix D for supporting data). The log mean of the hydraulic conductivity values for the alluvial/interface wells is 0.52 foot per day; for the bedrock wells, this value is 0.28 foot per day. A log mean was used since hydraulic conductivity is generally found to be log-normally distributed (Fetter, 1988).

These hydraulic conductivity values are somewhat higher than the values found for nearby sites, as discussed below. This may, at least in part, be explained by the fact that the wells tested at the Project Site lie along the valley floor, whereas wells tested at the other sites are located along hillslopes in addition to along valleys. Also, the alluvial/interface wells at the Project Site are completed primarily in alluvium, whereas at the other sites many of the wells that were tested were completed in weathered bedrock. The bedrock wells at the Project Site had a log mean hydraulic conductivity about one-half of the value for the alluvium/interface wells. The fact that the hydraulic conductivity for the bedrock is only half that for the alluvium most likely results from the fact that the bedrock wells at the Project Site are relatively shallow (much shallower, for instance, than many bedrock wells at the IT Facility). Fractures present in this shallower bedrock are probably not as tight as they would be at greater depths, and thus the shallow bedrock is more permeable.

Hydraulic conductivities were determined for the Refinery Site on a number of wells, primarily by slug test on wells completed in alluvium-fill or at the alluvium-bedrock interface. The log mean hydraulic conductivity values for the five areas analyzed ranged from 0.038 to 0.53 foot per day (Radian International, 1999b).

The fine-grained shale and siltstone of the bedrock at the Project Site are low-permeability materials in themselves, but additional permeability may be contributed by the many fractures that are present due to uplift and deformation of the Panoche Formation. Much of the recovered bedrock core is described as pervasively fractured. While it appears dense and tight when still in the core barrel, it falls apart into many small fragments upon removal from the core barrel. These characteristics can be observed in photographs of some of the cores in the photograph section (see Photographs 20 through 27). The absence of any oxidation stains on the deeper cores indicates that minimal water movement has occurred at depth. Sheared zones were observed in the cores, but these were typically described as very soft with gravelly clay gouge. This low permeability material in the sheared zones most likely prevents them from acting as preferential conduits for groundwater flow.

The study at the Refinery Site concluded that the bedrock functioned "hydrogeologically as a fractured rock aquifer system" (Radian International, 1999a). The study also noted that where the bedrock was weathered, it was more permeable relative to the deeper bedrock, which was clearly less weathered with depth. They concluded that "this deeper bedrock probably acts as a barrier to the vertical migration of groundwater and constituents" (Radian International, 1999b). One slug test was performed on a well completed solely within the bedrock; a hydraulic conductivity of 1.6×10^{-3} foot per day was determined (Radian International, 1999b), which is two orders of magnitude less than the mean value determined above primarily for the alluvium. The study concluded that the low permeability of the bedrock indicated that the native alluvial/colluvial material was the primary conduit for groundwater flow, a statement that was supported by the configuration of the plumes on the Refinery Site (Radian International, 1999a).

At the IT Facility, the upper alluvial/weathered Panoche zone has an estimated hydraulic conductivity of 8.5×10^{-2} foot per day, as determined primarily by slug tests. The hydraulic conductivity of the lower zone (unweathered Panoche) is estimated to be 3×10^{-4} foo per day, based on packer testing of boreholes (IT Corporation, 1996). These values are lower than the values determined for the Refinery Site; however, there continues to be at least a two order of magnitude difference in permeability between the shallow and the deeper zones. The upper 10 feet to 25 feet of the unweathered Panoche contained many more fractures than the bedrock at depth and so was considered more permeable than deeper, unweathered bedrock (Jones and Stokes Associates, 1996).

4.4.2.3 Groundwater Flow Regime.

Water levels at the Project Site have been found to mimic topography (Section 4.4.2.1 and Figure 4-18), particularly the topography of the bedrock. This results from the fractures in the dense, fine-grained rock closing at depth because of increased overburden pressure and from water accumulating atop this low-permeability rock. This observation is consistent with findings and conclusions at the Refinery Site where water levels were found to follow the topography prior to grading and filling at the site (Radian International, 1999a). An additional investigation site, known as the former Solano County Sanitary Landfill, 2 miles to the west of the Project Site and with similar topography and geology, also showed water levels in the bedrock to follow the topography (Levine-Fricke-Recon, 2000). Furthermore, the water levels at the IT Facility in the shallow wells followed the surface topography fairly closely, while water levels in the deeper wells followed the topography in a more subdued manner (IT Corporation, 1987a, 1987b).

In order to evaluate the hydraulic gradient at the Project Site based on monitoring well water level data, the wells were divided into two groups: (1) wells screened in the alluvium or across the alluvium/bedrock interface, and (2) wells screened solely in the bedrock. Three double-cased, deeper bedrock wells were installed at the site: MW-3A, -3B, and -4A. One of the wells, MW-3A, was affected by grout intrusion into the sandpack. The presence of the grout created very high pH water conditions during development of the well, which made it unsuitable for sampling for water quality. It was decided not to utilize this well but replace it with another well, MW-3B, which was then installed nearby. Further data are not reported for well MW-3A. Water level data for these two sets of wells are presented in Table 4-11. Water levels have been contoured for the May 3, 2000, and August 2, 2000, measurements as shown on Figures 4-19 and 4-20, respectively.

In the South Valley, the water table surface slopes to the east-southeast, following the slope of the valley floor, with a hydraulic gradient of 0.034 for both May and August 2000. There is a groundwater divide in the North Valley that corresponds to the topographic divide in the vicinity of wells MW-7 and -8. The water table surface in the eastern portion of the valley, determined from the alluvial and interface wells, slopes to the east-southeast along the valley floor, with a hydraulic gradient of 0.047 in May 2000 and 0.040 in August 2000. At the western end of the valley, the water table surface slopes to the west-northwest, following the valley topography, with a hydraulic gradient of 0.053 in both May 2000 and August 2000. Hydraulic gradients determined for the Main Refinery Area at the Refinery Site ranged from 0.015 to 0.11 (Radian International, 1999b), presumably reflecting differences in the underlying bedrock topography. These values bracket the values observed at the Project Site. The hydraulic gradient in the uppermost water-bearing zone at the IT Facility ranged from 0.07 to 0.30 (IT Corporation, 1987a, 1987b). These values are somewhat higher than those observed in the valleys at the Project Site, but they include hydraulic gradients along the hillsides, which are generally greater because of the steeper topography.

Monitoring wells completed solely in the bedrock at the Project Site were installed only in the central portion of the North Valley. Water levels contoured for these wells are very similar to water levels contoured for the alluvial/interface wells, indicating that the alluvium and bedrock act as a single water-bearing unit. Flow occurs from the sides of the valley, in the vicinity of well MW-6, toward the center of the valley, and then down the valley to the east-southeast.

Vertical hydraulic gradients within the bedrock can be evaluated at well-pair MW-3/MW-3B. The gradient within the bedrock is upward with a magnitude of 0.10 in May 2000 and 0.09 in August 2000. The vertically upward hydraulic gradient is twice as large as the lateral hydraulic gradient, making flow predominantly upward, at least beneath the alluvium in the valley floor. This indicates that discharge is occurring into the alluvium from the bedrock. At well-pair MW-4/MW-4A, the upper well monitors alluvium and the lower well monitors deeper bedrock. Here there is a slight downward hydraulic gradient, with a magnitude of 0.018 in May 2000 and 0.013 in August 2000. The gradient determination is complicated by the presence of a confining layer at this location, a layer that does not appear to be present at other wells in either valley. This layer could, at least locally, create distinct water-bearing zones. While this local downward gradient could cause flow to occur from the alluvium into the bedrock, the presence of the very low-permeability confining layer would greatly minimize that flow. At the Refinery Site, the one location at the Waste Water Treatment Plant where vertical hydraulic gradients were evaluated, indicated an upward hydraulic gradient across a thick confining layer (Radian International, 1999a and 1999b). At the IT Facility, flow was thought to be upward beneath topographic lows, with discharge occurring from the deeper bedrock into stream channel deposits and at seeps. Elsewhere, the vertical hydraulic gradient appeared to be downward, since the depth to water in deeper wells ranged from 30 feet to 90 feet bgs (Jones and Stokes Associates, 1996).

The average linear pore water velocity (Vp) can be estimated for the alluvium at the Project Site using an averaged hydraulic gradient (dh/dl) of 0.043, a hydraulic conductivity (K) of 0.52 foot per day based on results of slug tests at the Project Site, and an estimated effective porosity (ne) of 0.30 (the same value used in the Refinery Site estimates, [Radian International, 1999b]). Utilizing these values in Darcy's Law:

$$Vp = K/ne\ dh/dl = [(0.52\ \text{foot/day})/0.30] \times 0.043 = 0.075\ \text{foot/day}.$$

A similar calculation for the shallow bedrock at the site, utilizing a hydraulic conductivity (K) of 0.28 foot/day and an estimated effective porosity (ne) of 0.20, yields a pore velocity value of 0.060 foot/day.

Velocities calculated for the Refinery Site ranged from 0.0019 foot per day (there is a typographical error in Table 4-3 of that report) to 0.070 foot per day (Radian International, 1999b). At the IT Facility, groundwater velocities at the shallow depths were calculated to be 0.015 to 0.12 foot per day. For the lower zone, the

velocity was calculated to be 3 x 10^{-4} foot per day (IT Corporation, 1996). Values of effective porosity utilized in the IT calculations were 0.20 for the weathered bedrock and 0.10 for the unweathered bedrock. The velocities calculated for the Project Site fall within those ranges. The pore velocity calculated for the lower zone at the IT Facility is significantly lower than that for the bedrock at the Project Site because the hydraulic conductivity used at the IT Facility was determined for wells that were completed at greater depths within the bedrock.

While there are significantly fractured and sheared zones in the bedrock, there is no evidence that these zones act as preferential pathways to groundwater flow. Within the deeper unweathered bedrock portion, these sheared zones do not exhibit mineral alteration as would occur with significant water movement. Rather, these sheared zones are clay-filled and soft, with highly plastic material that is likely to have low permeability. At the Refinery Site, fractures were observed in outcrop with a frequency on a scale of inches to 2 feet (Radian International, 1999a). No preferred orientation was noted for those fractures.

At the Project Site, a thrust fault mapped by ENGEO (ENGEO, Inc., 1989a) traverses the Ridge separating the two valleys, but there are no seeps present along its trace that would indicate that it is a barrier for groundwater migration. There are a number of seasonal seeps at the Project Site that appear during the rainy season and disappear during the summer. These seeps most likely reflect shallow water table conditions along the valley slopes and valley floor as infiltrated water ponds atop the low-permeability bedrock during prolonged wet periods.

4.4.2.4 Seasonal Variations.

Groundwater present at the Project Site results from infiltration of local precipitation. The fat clay present over most of the Project Site will tend to shrink as it dries out during the summer and to contain dessication cracks at the surface when the rainy season recommences in the fall. Thus, infiltration is likely to predominate over surface runoff during the early rains, but as the soils replenish their moisture and swell, more surface runoff will occur later in the winter. This infiltrated water is limited in downward percolation by the low permeability of the deeper bedrock, and so water builds up and moves downslope parallel to the surface topography. When water infiltrated over the watershed flows down to the valley floor, water levels in the monitoring wells installed along the valley floor rise. During the dry season, a combination of evapotranspiration of groundwater from the valley floor and outflow down the hydraulic gradient will cause the water table to drop.

Table 4-11 presents water level changes observed between May 3, 2000 and August 2, 2000. The changes in well water levels over this 3-month period ranged from 0.76 foot to 8.12 feet. While some of the water level changes are quite large, there was no change in the direction of groundwater flow and only minor changes in the magnitude of the hydraulic gradient (Section 4.4.2.3).

Over a longer period of record, seasonal groundwater fluctuations at the Refinery Site have ranged from 1.15 to 14.95 feet in individual wells in the Main Refinery Area. The amount of fluctuation was observed to be similar whether the well was completed in alluvium/fill or in bedrock (Radian International, 1999b). The range of fluctuations at the Refinery Site is likely to be similar to the magnitude of water level changes at the Project Site for data collected over an entire season.

Seasonal water level variations in the weathered bedrock at the IT Facility were on the order of 5 feet to 20 feet, while in the unweathered bedrock they ranged from 0 feet to 15 feet. Shallow wells (screened intervals above 50 feet bgs) completed in unweathered bedrock generally showed yearly seasonal fluctuations in water levels. Deeper wells in the unweathered bedrock (screened intervals below 50 feet bgs) only occasionally showed water level fluctuations, such as in 1993 when there were heavy rains after the end of the prolonged drought (IT Corporation, 1996, 2000, Appendix C). This further illustrates the low permeability and relative hydraulic isolation of the deeper, unweathered bedrock. Water level contours were not found to change significantly from one point in time to the next, so the flow regime is not expected to vary much on a seasonal basis.

The water level changes for the Project Site are plotted on Figure 4-21. Minimal water level changes occurred in the South Valley (range 0.76 foot to 1.23 feet). The small amount of water table decline in this area may in part be attributed to the influx of excess irrigation water from the adjacent residential development. On July 17, 2000, landscape irrigation runoff was observed to flow into the upper end of the wetland at a rate of about 0.2 to 0.5 cubic feet per second (HydroScience, 2000). In the North Valley, water levels changed to the greatest extent in the central portion of the valley. Within that central portion, water level changes in bedrock wells were very similar to water level changes in nearby alluvial/interface wells, supporting the statement that the two lithologies act as a single water-bearing unit. Water level changes in the North Valley ranged from 1.69 to 8.12 feet.

4.4.2.5 Groundwater Transport Pathways

Data from the Project Site, from the IT Facility, and from the adjacent Refinery Site indicate that groundwater in the bedrock flows downslope toward the valley bottoms and discharges into the alluvium. Shallow groundwater in the alluvium and weathered bedrock is the main pathway for dissolved chemicals to move in groundwater along the hillslopes. The alluvial deposits are the main pathway for any chemicals in groundwater to migrate down the valleys and off site. Evidence for deeper migration of chemicals through more permeable fracture zones does not exist at the Project Site nor at the adjacent Refinery Site or IT Facility. Such migration is contradicted by the upward gradient observed in the bedrock at the Project Site and the very low permeability material in fracture zones observed in the bedrock cores.

Analysis of chemical migration pathways at the IT Facility indicated that the shallow alluvium/weathered bedrock water-bearing zone was the predominant

migration pathway. Within that pathway, flow directions were controlled by topography. It was thought highly unlikely for there to be significant transport from the more permeable, weathered bedrock into the less permeable, unweathered bedrock (Jones and Stokes Associates, 1996). There may be some limited vertical transport, upward in the valley bottoms and downward elsewhere. Flow within the deep unweathered bedrock does not appear to be significant, with an apparent absence of high flow-rate zones at depth. This was further supported by radiometric age dating of deeper groundwater in the unweathered bedrock, which showed that the water had been isolated from the atmosphere for thousands of years (IT Corporation, 1987a, 1987b). Thus, only very small quantities of water could migrate at very slow rates from the near-surface into the deeper bedrock. The presence of seeps along fault traces at the IT Facility indicate that they act as barriers to lateral flow.

Based on the assessment of the hydrogeology of the Project Site and other nearby sites, it is concluded that the monitoring wells installed at the Project Site in the alluvium in the valley bottoms of both valleys are in the appropriate locations to permit detection of COIs moving through the groundwater flow pathway (see Figure 4-1). This is true for flow to the southeast in both the North and South Valleys and to the northwest in the North Valley.

Other potential source sites, such as the Flare Site and demolition sites in the South Valley or the Dynamite Burn Site along the Ridge, are monitored by downgradient monitoring wells situated along the valley floor.

The migration of COIs through the alluvium toward the drinking water source at Lake Herman is unlikely. This pathway is monitored by wells MW-8 and -9. Lake Herman is approximately 1,000 feet northwest of the westernmost boundary of the North Valley. There is no evidence of direct hydraulic connection between Lake Herman and the Project Site because of the presence of the intervening valley of Sulphur Springs Creek separating them. Groundwater flowing northwest in the alluvium and shallow weathered bedrock from the North Valley toward Lake Herman would most likely reach the alluvium of Sulphur Springs Creek and then flow through the alluvium beneath the creekbed to the east and then southeast around the Project Site. Groundwater exiting the North Valley would not flow upgradient after it reaches the floor of Sulphur Springs Creek and, therefore, could not reach Lake Herman.

Seasonal fluctuations in water levels could have two opposite effects on concentrations of COIs in groundwater, depending on the amount of residual impact in the soil. If there is still a significant amount of relatively mobile compounds retained within the zone of water table fluctuations, those compounds could become mobilized during periods of high water table. This could cause concentrations within the groundwater to increase. If there is little residual impact in the soil, then the increased inflow of water causing the water table to rise would serve to dilute any dissolved compounds already present, thus lowering the concentrations.

5.0 NON-OE REMEDIAL INVESTIGATION ANALYTICAL RESULTS

This section presents the chemical analytical results for the non-OE RI. All analytical data presented in this section have been verified and validated (definitive-level). Selected soil, sediment, surface water, and groundwater samples obtained from the Project Site during the non-OE RI were submitted for analysis of the following COIs, as discussed in the previous chapter:

- Explosives - nitroaromatics and nitroamines, including nitroglycerin and PETN, by EPA Method SW8330
- TEPHs quantified against a diesel, motor oil, and kerosene standard (TEPH-D/MO/K), respectively, by California LUFT Modified EPA Method SW8015B
- PAHs by EPA Method SW8310
- VOCs by EPA Method SW8260B
- SVOCs, including chloropicrin and pentachlorophenol, by EPA Method SW8270C
- CAM 17 metals plus aluminum, calcium, iron, manganese, magnesium, potassium, phosphorus (total), and sodium by EPA Methods SW6010B/SW7470A/SW7471A
- Strontium by EPA Method SW6010B
- Methyl mercury by Frontier GeoScience proprietary Method FGS-070.1
- Dioxins/furans by EPA Method SW8290
- Organochlorine pesticides by EPA Method SW8081A
- Perchlorate by CADOHS Method 300.0 Modified
- Hydrazine by Modified EPA Method SW8315
- PCBs by EPA Method SW8082
- Nitrate and nitrite as nitrogen by EPA Method 300.0
- General water chemistry (nitrate/nitrite, chloride, and sulfate by EPA Method 300.0; total phosphorus by EPA Method 6010B; total organic carbon by EPA Method 415.1; TDS by EPA Method 160.1; and TSS by EPA Method 160.2).

Verified and validated, definitive-level analytical results from the interim, remedial, data gaps, and removal action investigations are presented in Tables 5-1 through 5-23. These analytical summary tables include field replicate (soil) and field duplicate (water) sample results, as well as sample qualifiers and analytical practical quantitation limits (PQLs). Performance evaluation (PE), trip blank, source water, and equipment rinsate blank analytical results are presented in Tables 5-24A through 5-24E. All soil/sediment analytical results are reported on a dry weight basis. The analytical results are also summarized on Figures 5-1, 5-1A, 5-1B, 5-2, 5-3, 5-4, 5-4A, 5-5, 5-5A, 5-6, 5-6A, 5-8, 5-8A, 5-9, and 5-9A (soil), Figure 5-10 and 5-10A (surface water and sediment), and Figure 5-7, 5-7A, and 5-7B (groundwater).

Data collected during a previous investigation conducted by SECOR in late 1998 are presented in Section 3.2.1 and on Figure 3-1. The SECOR data cannot be verified or validated and are, therefore, treated as screening-level data. However, in those areas of interest where SECOR data are available, the screening-level data are consistent with the definitive-level analytical data obtained during the non-OE RI. The SECOR data are referenced in this section for comparison purposes only.

5.1 QUALITY ASSURANCE SUMMARY

QA/QC activities for field, sampling, analytical, and data management for this project were performed according to the SAP requirements specified in the Final Work Plan (Earth Tech, 2000b), the Tech Memo (Earth Tech, 2000c), and the RAW (Earth Tech, 2000f). The interim investigation was performed prior to the preparation of a formal work plan; however, samples collected during the interim investigation were collected in accordance with the procedures presented in the Final Work Plan (Earth Tech, 2000b), unless otherwise stated in Appendix C.

Data review and validation was performed on the entire (interim; remedial; data gaps; and removal action) definitive-level data set, including evaluation of results for PE samples analyzed by the laboratories receiving the samples for this investigation. The results indicate the definitive-level data collected during the non-OE RI meet project objectives except where specified as rejected. When project objectives were determined not to have been met for specific samples, additional sampling was performed. All samples with severely impacted (rejected) data were resampled or found not to be critical to the project objectives.

QCSRs summarizing the data validation and QA/QC review for this project were prepared in accordance with Section 5.8 of the *Environmental Data Quality Management Program Specifications*, Draft Version 1.08 (U.S. Army Corps of Engineers, Sacramento District, 1999) for each sampling event of the non-OE RI, and are presented in Volume IV of this document. The QCSRs discuss the quality and usability of the definitive-level analytical data for all samples collected as part of the non-OE RI, and include discussion of deviations from procedures specified in the SAPs outlined in Chapter 2.0 of the Final Work Plan (Earth Tech, 2000b), Section 5.0 of the Tech Memo (Earth Tech, 2000c), and, Chapter 8.0 of the RAW

(Earth Tech, 2000f); and the QAPP, Chapter 3.0 of the Final Work Plan (Earth Tech, 2000b), with Addendum to the QAPP, Appendix A of the Tech Memo (Earth Tech, 2000c), referred to collectively as "the QAPP."

All analyses were performed according to the requirements for the methods in *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (U.S. Environmental Protection Agency, 1996), *Methods for Chemical Analysis of Water and Wastes*, EPA Manual 600/4-79-020 (U.S. Environmental Protection Agency, 1983 with additions), or modifications to the specified methods presented in the QAPP. The testing methods used, parameters and analytes reported, and PQLs required for the analytical program are listed in Table 3.1-1 of the QAPP. Holding time and sample container and preservation requirements are specified in Table 3.1-2 of the QAPP. QA/QC requirements, control limits, and corrective actions are specified in Tables 3.2-1 through 3.2-5 of the QAPP. Data validation flagging conventions are specified in Table 3.4-1 of the QAPP.

5.1.1 Data Validation

Data validation is a systematic and independent process of reviewing and qualifying the definitive-level analytical data presented against an established set of criteria. Validation is performed to ensure the quality of the definitive-level data collected and to assess limitations on usability based on the accuracy, precision, completeness, representativeness, comparability, and sensitivity parameters defined in the QAPP, as well as to evaluate laboratory compliance with specified methods and protocols.

The definitive-level analytical data for all samples collected at the Project Site were validated according to the QC requirements and control limits specified in the QAPP consistent with guidelines and procedures outlined in the *EPA Contract Laboratory Program National Functional Guidelines For Organic Data Review* (EPA-540/R-94/012), (U.S. Environmental Protection Agency, 1994b) and *National Functional Guidelines For Inorganic Data Review* (EPA-540/R-94-013) (U.S. Environmental Protection Agency, 1994c). The reviewer's professional judgment was used to evaluate data quality when called for in the Functional Guidelines and in instances with no clear policy or conflicting guidance on how the data should be qualified. The data validation process was performed on the interim investigation data by an Earth Tech chemist in San Jose, California. Data validation was performed on the remedial, data gaps, and removal action investigation data by Laboratory Data Consultants (LDC) in Carlsbad, California. The data were validated at EPA Level IV for a minimum of 10 percent of the samples for each matrix for each method for the non-OE RI as a whole. The remainder were validated at EPA Level III.

5.1.1.1 Data Qualifiers.

Qualifiers were assigned by the reviewer to all definitive-level data that failed to meet specified analytical and QC criteria. Data qualified as "R" are rejected and

considered unusable. Data qualified with the "J" qualifier are considered estimated and usable for limited purposes. "J+" indicates the possibility that the result may be biased high, and that the actual chemical level may be lower than the reported result. "J-" indicates the possibility that the result may be biased low, and that the actual chemical level may be higher than the reported result or detection limit reported for a non-detected result. The remaining data met the data QA objectives for accuracy, precision, sensitivity, and completeness specified in the QAPP. The "U" qualifier indicates that the result is non-detected at or above the detection limit specified, and is applied to all non-detected results.

All analytical results and reporting limits for the samples collected in this project were adjusted for dilutions resulting from the preparation procedures required by the method or to get the result for a compound or analyte within the calibration range of the instrument. The PQLs and MDLs were raised by the dilution factor when reported for diluted analyses. The laboratory reported analytical results that were above the MDL but below the PQL. Such results are considered "trace" detections and were qualified as estimated ("J") due to possible quantitative or qualitative uncertainty near the limits of detection. Data qualified with the "J" qualifier solely for reported values less than the PQL but greater than the MDL do not indicate analytical problems related to the QC parameters, do not affect project objectives or the usability of the data, and are not included in the completeness calculations.

With respect to project objectives, usable results are defined in the QAPP as results that are not rejected. Results qualified as estimated are considered usable unless the qualification compromises the ability of the result to be used for decision making purposes. Unless qualified as rejected, estimated results have been evaluated in the QCSRs as acceptable for project objectives and decision-making.

5.1.2 Data Validation Results and QA/QC Review Summaries

The data review includes assessment for compliance with the data quality assurance objectives for accuracy, precision, completeness, representativeness, comparability, and sensitivity specified throughout the QAPP. This includes achievement of quality assurance objectives related to sample collection, handling, labeling, and custody; analytical methods and procedures; laboratory data reduction, validation, reporting, and management; data package and electronic deliverables verification, validation, and assessment; and documentation and reporting. PE results demonstrated acceptable accuracy for each method. The completeness goals were acceptable. Each of these QA/QC parameters are discussed for each sampling event in the respective QCSRs. The compliance with the quality assurance elements of the DQOs indicates a high level of confidence in the data, allowing the data to be used for its intended purposes within the constraints of the data qualifiers.

5.1.2.1 Data Validation Results and QA/QC Review Summary for the Interim Investigation.

For the interim investigation, approximately 2 percent of the definitive-level data were qualified as rejected and 9.3 percent of the definitive-level data were qualified as estimated for exceeding data quality criteria. The remaining definitive-level data met the data quality criteria. A summary of all rejected data for this sampling event is presented in Table 5-25. For complete explanation of all data qualifications, refer to the QCSRs, Section 1.0 of Volume IV of this document.

All of the rejected data for the interim investigation were the result of seven samples that were initially analyzed for PAHs by EPA Method SW8310, but which required reanalysis by EPA Method SW8270C due to severe interference in the original analyses. All of the non-detected SW8270C results were rejected as the reanalyses were grossly out of holding time. The samples were all from the stockpiles, which were subsequently resampled for analysis by SW8270C during the data gaps investigation.

All of the rejected data were resampled and reanalyzed for the analytes of interest. Of the estimated data, in general, data qualifications were not severe, and the resultant data are usable for decision-making purposes. The data are considered to meet project objectives.

5.1.2.2 Data Validation Results and QA/QC Review Summary for the Remedial Investigation.

For the RI, approximately 0.5 percent of the definitive-level data were qualified as rejected and 12.4 percent of the definitive-level data were qualified as estimated for exceeding data quality criteria. The remaining definitive-level data met the data quality criteria. A summary of all rejected data for this sampling event is presented in Table 5-26. For complete explanation of all data qualifications, refer to the QCSR, Chapter 2.0 of Volume IV of this document.

Of the rejected data for the RI, approximately one-third were for field blanks. Approximately half of the rejected results for non-blank field samples were resampled and analyzed for the rejected analytes. All of the water samples and some of the soil samples with rejected results were resampled and analyzed for the analytes of interest in the data gaps investigations.

Non-detected results for antimony by EPA Method SW6010B in seven soil samples and three sediment samples (less than 0.2 percent of the metals data) were rejected for low matrix spike/matrix spike duplicate (MS/MSD) recoveries. Antimony is subject to matrix interference in soils by this method.

For EPA Method SW8260B, data qualification for continuing calibrations resulted in the rejection ("R") of non-detected results for methylene chloride in 13 samples due to percent differences (%Ds) greater than two times the control limit. In addition, results for acetone in three samples and three field blanks were rejected

for relative response factors (RRFs) of 0.046, which is marginally below the 0.05-control limit. According to the Functional Guidelines and EPA Region IX validation protocols, these acetone results should be estimated not rejected. All of the samples in question for acetone and some of the samples for methylene chloride were resampled in the data gaps investigations. Methylene chloride is not considered to be a COI for this project.

For EPA Method SW8290, low recoveries of four labeled internal standard compounds in the continuing calibration verification (CCV) resulted in the rejection ("R") of non-detected results for nine analytes in two soil samples for temporary well TW-5. All of the qualified analytes have low toxicity equivalence factors (TEFs) and are, therefore, of relatively low importance compared to the unqualified compounds for these samples. Two additional soil samples were analyzed for this method when monitoring well MW-5 was installed during the data gaps investigations.

Results for explosives in one groundwater sample by EPA Method SW8330 were rejected ("R") due to low surrogate recoveries. Additional results for SW8330 and SW8330M for nitroglycerin and PETN were rejected, mostly in equipment blanks. All of the water field samples were resampled and analyzed for EPA Methods SW8330 and SW8330M during the data gaps investigations.

The results for five compounds by EPA Method SW8310 in one soil sample were rejected ("R") for low MS recoveries (approximately 0.2 percent of the PAH data). The sample was one of five samples in the soil column, and the project objectives are not considered to be adversely affected.

All of the rejected samples were either resampled and reanalyzed for the COIs, or were not considered to affect project objectives.

Of the estimated data, approximately one-third of the qualifications were for field blanks. In general, data qualifications were not severe, and the resulting data are usable for decision making purposes unless rejected. The data are considered to meet project objectives.

5.1.2.3 Data Validation Results and QA/QC Review Summary for the Data Gaps 1 and 2 Investigation.

For the data gaps 1 and 2 investigation (i.e., data collected from February through July 2000), approximately 1.1 percent of the definitive-level data were qualified as rejected and 9.7 percent of the definitive-level data were qualified as estimated for exceeding data quality criteria. The remaining definitive-level data met the data quality criteria. A summary of all rejected data for this sampling event is presented in Table 5-27. For a complete explanation of all data qualifications, refer to the QCSR, Chapter 3.0 of Volume IV of this document.

Of the rejected data, approximately 80 percent were for 2-chloroethyl vinyl ether in soils; for 2-chloroethyl vinyl ether and dibromo-3-chloropropane in waters, of which

most were field blanks; and for several ketones in several field blanks. These small numbers of rejections are not expected to significantly affect the project objectives.

One result for nitrate-N and six results for nitrite-N by EPA Method 300.0 were rejected ("R") in soil samples due to holding time exceedance. The small numbers of qualifications do not significantly affect the project objectives for this method.

Results for TEPH by EPA Method SW8015B in three soil samples were rejected ("R") due to exceedance of extraction holding time criteria. Non-detected results for TEPH in two soil samples were rejected due to low surrogate recoveries caused by significant interference from high concentrations of TNT. The locations are known to have high concentrations of TNT so small numbers of rejections for TEPH are not expected to significantly affect the project objectives.

Results for the PCBs were rejected in one soil sample due to exceedance of extraction holding time criteria. PCBs are extremely stable and are not likely to dissipate due to storage prior to extraction, so the non-detected results may be considered to indicate that PCBs are not present in any of the qualified samples, and resampling is not considered necessary. The holding time qualifications do not significantly affect the project objectives.

Results for benzidine were rejected in seven soil samples for high relative standard deviations (%RSDs) and for response factors (RFs) less than 0.05 in the continuing calibrations, and the result for benzoic acid in one soil sample was rejected ("R") due to MS/MSD recoveries less than 10 percent. Rejection of benzidine and benzoic acid results is not unusual for this method, benzidine is not a COI for this project, and the project objectives are not affected.

The non-detected results for 2-amDNT and 4-amDNT in one soil sample were rejected for low MS/MSD recoveries. The sample has TNT detected at a concentration of 17 mg/kg, and resampling is not considered necessary. The small number of qualifications are not expected to significantly affect the project objectives

All of the rejected data were either for samples (blanks) or analytes not critical to project objectives, or were for small proportions of data such that resampling is not considered necessary. The rejections are not considered to significantly affect project objectives.

Of the estimated data, in general, data qualifications were not severe, and the resultant data are usable for decision making purposes. The data are considered to meet project objectives.

5.1.2.4 Data Validation Results and QA/QC Review Summary for the Removal Action Investigation.

For the removal action investigation, approximately two percent of the definitive-level data were qualified as rejected and 13.1 percent of the definitive-level data were qualified as estimated for exceeding data quality criteria. The remaining definitive-level data met the data quality criteria. A summary of all rejected data for this sampling event is presented in Table 5-28. For complete explanation of all data qualifications, refer to the QCSR in Volume IV of this document.

Of the rejected data, approximately 85 percent were for temperature problems in several field blanks for various methods. The small number of rejections in field blanks are not expected to significantly affect the project objectives

Two results for nitrite-N were rejected ("R") in soil samples due to holding time exceedance.

Non-detected results for antimony by EPA Method SW6010B in 21 soil samples were rejected for low MS/MSD recoveries. Antimony is subject to matrix interference in soils by this method.

With the exception of antimony in 21 samples, all of the rejected data were either for samples (field blanks) not critical to project objectives, or were for small proportions of data (two results for nitrite-N) and, therefore, not considered to affect project objectives.

Of the estimated data, almost one-half of the qualifications were for marginal holding time exceedances, holding time exceedance for extremely stable compounds (i.e., PCBs), or for field blank samples. In general, data qualifications were not severe, and the resultant data are usable for decision-making purposes. The data are considered to meet project objectives.

5.1.2.5 Data Validation Results and QA/QC Review Summary for the Data Gaps 3 Investigation.

For the data gaps 3 investigation (i.e., data collected in August 2000), approximately 9.9 percent of the definitive-level data were qualified as estimated and no definitive-level data were qualified as rejected for exceeding data quality criteria. The remaining definitive-level data met the data quality criteria. For a complete explanation of all data qualifications, refer to the QCSR in Volume IV of this document.

Of the estimated data, data qualifications were not severe, and the resultant data are usable for decision making purposes. The small number of qualifications are not expected to significantly affect the project objectives. The data are considered to meet project objectives.

5.1.3 Interpretation of Results and Chromatograms for TEPH

TEPH analyses are performed by gas chromatography (GC). Peaks for different compounds elute sequentially creating chromatographic patterns of peaks with each peak representing different concentrations of each compound. Petroleum hydrocarbon fuels are composed of series of alkanes which elute at regular intervals with characteristic patterns for each fuel (e.g., diesel, motor oil, kerosene) (see Attachment I-2 of Appendix I).

When chromatographic patterns for samples appeared consistent with the patterns for a specific fuel, as documented by known standards, the results were reported as the specified fuel. TEPH results that did not adequately match the fuel patterns of the standards were reported as "unknown hydrocarbons," eluting in either the diesel, motor oil, or kerosene range. These results do not represent kerosene, diesel, motor oil or other petroleum fuels as the chromatographic patterns indicate individual peaks or series of peaks not indicative of fuels.

The interpretation of TEPH chromatograms becomes subjective as the patterns become more complex due to organic components in the matrix. For many of the samples for this project, TEPH chromatograms had varying degrees of pattern matches, including partial matches, or complex patterns that may include possible diesel or motor oil components mixed with other compounds, such as TNT and TNT breakdown products. In addition to the review at the laboratory, TEPH chromatograms were reviewed for every environmental sample by the LDC validators and by Earth Tech chemists in San Jose, and a summary table of the interpretation of the chromatographic patterns is presented in each QCSR (see Volume IV of this document).

All results reported as detections for specific TEPH fuels match the specified chromatographic fuel patterns, at least to the degree the reviewers considered the fuel components to be contributing significantly to the integrated sum of the peaks in the range of the specified fuel. In some cases, results reported as unknown hydrocarbons may be considered to potentially represent weathered fuels when portions of the chromatographic pattern for a fuel can be discerned within the overall chromatographic pattern. However, in most cases, it is not possible to distinguish such weathered patterns, and results reported as unknown hydrocarbons should be considered not to contain concentrations of specific fuels at or above the PQL.

5.1.4 Interpretation of 2-Butanone Results

Results for 2-butanone (methyl ethyl ketone [2-butanone]), generally considered to be a common laboratory contaminant according to EPA Region IX data validation guidelines, have not been blank-qualified for common laboratory contamination by the validators for this project. 2-butanone was reported in one method blank during the analysis of data gaps investigation samples, and results for 2-butanone were blank-qualified ("UJ") in the associated samples. Although not qualified for

common laboratory contamination, the remaining trace and low-level results for 2-butanone in samples situated throughout the North Valley should be considered as potential laboratory artifacts. Quanterra has determined that the glue used to bind the septum to the Teflon™ caps of the Encore™ soils preservation vials may produce low levels of 2-butanone upon heating during sample purge. This type of Encore™ preservation vial cap was used for some of the samples during the non-OE RI.

ONSITE did not utilize the special Encore™ soils preservation vials because the mobile laboratory met the 48-hour holding time for all soil samples, thus avoiding the necessity to utilize the special preservation requirements of EPA Method SW5035 for preparation of soil samples for analysis by EPA Method SW8260B. There was only one detected result for 2-butanone by ONSITE in borehole HF-4 at 0.5 foot bgs (see Section 5.3.1).

Comparison of the 2-butanone results reported by Quanterra to other samples collected in close proximity for which VOC analyses were performed by ONSITE show no confirmation of 2-butanone. For example, intermittent trace detected results for 2-butanone in soil samples from boreholes AR-5, -6, -7, -9, -10, and -12 analyzed by Quanterra are not apparent in the soil samples from boreholes AR-1, -2, -3, and -4, and HF-1, -2, -3, and TW-1 analyzed by ONSITE or boreholes AR-11 and MW-1 analyzed by Quanterra. These non-detected locations are nearby, surround, or are in the middle of the areas with detected results for 2-butanone. These data indicate that the apparent trend for intermittent detections for 2-butanone correlates more closely with the preservation method used than with spatial considerations.

Furthermore, given the volatility of 2-butanone, it is unlikely that this compound would be present in the soil (especially near-surface soil) approximately 45 years after DOD activities ceased at the Project Site. Where 2-butanone was detected throughout the soil column, there is no evidence of attenuation (i.e., the concentrations "detected" are all approximately the same order of magnitude). Such results are not consistent with the fundamental fate of transport of organic contaminants in the soil environment. Therefore, not only do the patterns of detections of trace and low-level results for 2-butanone by Quanterra not fit logical fate and transport models, there are significant reasons to consider the trace and low-level detected results for 2-butanone to be due to the potential for laboratory contamination from the Encore™ soils preservation vial cap.

During the data gaps 3 investigation, 2-butanone was reported in one equipment blank, and 2-butanone was reported in water samples MW-4A and -4A/A at concentrations less than 10 times the concentration in the equipment blank. However, the results were not blank-qualified as the equipment blank was from the preceding date, and was not technically associated with the specified field samples. Although not qualified for common laboratory contamination, the low concentration results for 2-butanone in samples MW-4A and -4A/A should be considered as potential laboratory artifacts. Note that 2-butanone was also

qualified for possible high bias due to high MS/MSD recoveries in QC sample MW-4.

5.2 TNT STRIPS RESULTS

The TNT Strips are situated on the south-facing slope of the North Valley. During the interim investigation, soil samples were collected from each of the five TNT Strips, primarily along the axis of the strip where there is no vegetation. Soil samples were collected to a maximum depth of 4 feet bgs (see Table 4-4). Based on the results of the interim investigation, three of the TNT Strips (#1, #4, and #5) were selected for additional investigation to further assess the vertical and lateral extent of the TNT affected soil (see Table 4-5). During the RI, soil samples were primarily collected in sections crossing the strips, in a step-out type program (upslope and downslope) (see Figures 5-1, 5-1A, 5-1B, 5-2, and 5-3). Maximum depths for boreholes included in the step-out program varied depending upon sample collection methods (i.e., direct push or hand auger) and on the depth to bedrock (refusal). All soil samples from the TNT Strips were analyzed for explosives; some of the explosives analyzed included nitroglycerin and PETN, and two samples were analyzed for dioxins/furans. During the data gaps investigation, three additional boreholes were advanced along the axis of the TNT Strip #1 and TNT Strip #2 in order to define the vertical extent of explosives impact beneath the TNT Strips (see Table 4-6). Soil samples were analyzed for explosives and TEPHs. Selected samples were also analyzed for dioxins/furans and one sample was analyzed for PCBs.

Additional surface samples were collected north and northeast of TNT Strip #1, along the ridgeline and throughout the TNT Strips Area. Near-surface samples were also collected from nine off-site locations to the north and east of the Project Site boundary. Five additional boreholes were also advanced along the south-facing slope of the North Valley, downgradient of the TNT Strips. These samples were analyzed for explosives.

Explosives + Nitroglycerin/PETN. Analytical results for soil samples from the TNT Strips are presented in Tables 5-1 through 5-5 and on the schematic cross sections (see Figures 5-1, 5-2, and 5-3). For the purposes of data evaluation, the individual concentrations of TNT, in mg/kg, are shown on the schematic cross sections. All other explosives identified by EPA Method SW8330 were typically reported at several orders of magnitude lower concentrations than TNT. Other types of explosives detected are predominantly the TNT breakdown products: TNB, 2amDNT and 4amDNT (sometimes reported as a summed concentration [amDNTs]), and 2,4-DNT. Individual concentrations of these breakdown products are also shown on the schematic cross sections. All other remaining explosive compounds have been presented as a summed concentration. On the schematic cross sections, HMX and RDX may be included in the "other" compounds. If detected, these compounds are discussed in the text because they exhibit properties different from TNT, and, most importantly, lower solubilities, which has shown them to be resistant to certain biological treatments. When results are

available for nitroglycerin and PETN, they have been included in the schematic cross sections. These compounds are also specifically discussed in the text if detected.

A complete list of EPA Method SW8330 explosives identified at the TNT Strips is presented in Tables 5-1 through 5-5.

TNT Strip #1. Soil samples were collected from seven borehole locations (TNT 1A, -1B, -1C, -1C2, -1F, -1P, and -1Q) along the axis of TNT Strip #1. The explosives data along the axis of the strip are presented in Table 5-1 and on Figure 5-2, Cross Section A. Soil samples were also collected from eight additional locations along the possible extension of TNT Strip #1 toward the southeast (TNT 1D, -1G, -1H, -1E, -1J, -1K, -1L, and -R12). This area is seen as four smaller strips (i.e., areas lacking vegetation) to the southeast of TNT Strip #1. The additional seven borehole locations were between the areas lacking vegetation.

Three additional boreholes were also advanced in close proximity to TNT-1C on the axis of the strip. TNT-1C2A was advanced in order to collect split samples for Quanterra. TNT-1C2Y and -1C2AY were advanced by hand auger and the samples collected from the cuttings; these samples were also submitted to ONSITE and Quanterra, respectively. The additional explosives data on the axis of the strip around TNT-1C2 are presented on Figure 5-2, Cross Section B.

Soil samples were also collected from two sets of step-outs, centered on TNT-1C2 and -1F, respectively. The explosives data along the TNT-1C and -1F step-outs are presented on Figures 5-3, Cross Sections A and B, respectively.

Data collected within the surface expression along the axis of the main portion of TNT Strip #1 indicated total explosive concentrations up to 44,000 mg/kg within the upper 2 feet bgs (see Figure 5-2, Cross Section A). This was exceeded at only one location (TNT-1C), where maximum total explosives concentrations of 380,042 mg/kg (38 percent) and 110,260 mg/kg (11 percent) were detected at 1 foot and 2 feet bgs, respectively. Samples collected from immediately adjacent boreholes (TNT-1C2, -1C2A, -1C2Y, and -1C2AY) at the same depths detected total explosives concentrations ranging from 155 mg/kg to 26,143 mg/kg at 1 foot bgs and 108 mg/kg to 9,237 mg/kg at 2 feet bgs (see Figure 5-2, Cross Section B). This variation is attributed to the very heterogeneous spatial distribution of TNT within the soil and potentially the lack of sample homogenization prior to analysis. Where boreholes extended beyond 2 feet bgs, explosive concentrations were consistently observed to decrease significantly with depth. At the two locations (TNT-1P and -1Q) where samples were collected up to 10 feet bgs, the same pattern was observed. At TNT-1P, total explosives were detected at a concentration of 17.2 mg/kg at 10 feet bgs. At TNT-1Q, total explosives were detected at a concentration of 1.2 mg/kg at 10 feet bgs; however, explosives were not detected in the two shallower samples at the same location collected at 6 feet and 8 feet bgs, respectively.

TNT Strip #1 was further characterized vertically and laterally via the step-out program (see Figure 5-3, Cross Section A). The TNT-1C series step-out boreholes (TNT-1C2 through -1C10) were oriented across TNT Strip #1, upslope and downslope, in a north-south direction, respectively. The depth to weathered bedrock varies from 5.5 feet bgs at the north end of the step-out to 7 feet bgs at the south end of the step-out. Explosive concentrations decrease both vertically and laterally away from the center axis of the strip. At both of the 5-foot step-outs, the concentrations of total explosives are significantly lower (typically less than 500 mg/kg), with one exception; 1,057 mg/kg was detected at the surface at the downslope 5-foot step-out (TNT-1C3). Overall, slightly higher concentrations were detected on the downslope step-out. Concentrations at both of the 5-foot step-outs decreased significantly below the upper 1 foot bgs. At the 10-foot step-out on the north side of the center axis, TNT was detected only at the surface; however, other explosives up to 2.8 mg/kg were detected at 1 foot bgs, but no deeper. No explosives were detected at the 20-foot northern step-out. To the south, TNT and other explosives were found at both the 10-foot and 20-foot step-outs, but only at depths of 1 foot bgs or less. Samples from both the 30-foot and 40-foot southern step-out contain low concentrations of TNT. At the 30-foot step-out, TNT was detected at the surface (0.6 mg/kg) to a depth of 3 feet bgs (0.9 mg/kg). At the 40-foot step-out, TNT was detected only at the surface at 1 mg/kg.

TNT-1F step-out series boreholes (TNT-1F through -1F9) were oriented across TNT Strip #1, in an east-west direction, in an area where the shallow soil within the strip has been disturbed by annual discing along a historical firebreak (see Figure 5-3, Cross Section B). The boreholes encountered weathered bedrock between 3 feet and 6 feet bgs. To the east of the strip, the concentration of explosives decreases rapidly by the 5-foot step-out. At the 10-foot step-out, TNT was detected at 3.3 mg/kg "J+" (2 feet bgs), and no TNT or other explosives were detected at the 20-foot step-out. At the 5-foot step-out to the west of the strip, up to 290,080 mg/kg (29 percent) of total explosives were detected at 2 feet bgs; the concentrations decrease significantly (to 8.2 mg/kg) by 4 feet bgs. High concentrations (33,027 mg/kg) of total explosives were detected at the surface at the 10-foot step-out, and again the concentrations decrease significantly within the upper 2 feet bgs to 0.5 mg/kg. At the 20-foot step-out, total explosive concentrations are higher at 1 foot bgs (724 mg/kg) than at the surface (5.8 mg/kg). No explosives were detected at 4 feet bgs. No explosives were detected in either the 30-foot or 40-foot step-outs. The levels of explosives detected at the 5-foot and 10-foot western step-outs are likely a result of the surface soil being disturbed in the area by discing.

TNT was detected in one of the surface samples (TNT-R12) collected during the data gaps investigation 60 feet beyond the surface expression of TNT Strip #1 to the southeast. Both a homogenized and unhomogenized sample were collected at this location (see Figure 5-1). TNT and 2amDNT were detected in the unhomogenized surface sample at 36 mg/kg and 0.6 mg/kg, respectively, and TNT was detected at 900 mg/kg in the homogenized surface sample.

No explosives were detected in any of the soil samples collected from the boreholes between areas lacking vegetation along the potential extension of TNT Strip #1 beyond TNT-R12 (see Figure 5-1).

HMX was detected in two samples, collected at TNT-1F2 (0.66 mg/kg) at 1 foot bgs and TNT-1Q (0.24 mg/kg "J") at 2 feet bgs. RDX was detected in 14 samples collected from TNT Strip #1 as follows:

- TNT-1F2 at 7.6 mg/kg and 5.3 mg/kg at 1 foot and 2 feet bgs, respectively
- TNT-1F3 at 9.8 mg/kg at the surface
- TNT-1C2Y at 0.93 mg/kg, 0.72 mg/kg and 5.7 mg/kg at the surface, 0.5 foot, and 1 foot bgs, respectively
- TNT-1C2 at 2.1 mg/kg, 1.9 mg/kg, 0.8 mg/kg, 0.88 mg/kg, and 2.1 mg/kg at 1 foot, 2 feet, 2.5 feet, 3 feet, and 3.5 feet bgs respectively.
- TNT-1P at 0.87 mg/kg, 1.6 mg/kg, and 0.25 mg/kg "J" at surface, 0.5 foot, and 2 feet bgs.

RDX concentrations are all less than 10 mg/kg and are predominantly within the upper 2 feet bgs.

Twenty-one of the samples collected at TNT Strip #1 were analyzed for nitroglycerin and PETN. Nitroglycerin was detected in only one of the samples analyzed for this compound at an estimated concentration of 0.36 mg/kg "J-" in the near-surface sample collected at TNT-1A. PETN was not detected in any of the soil samples analyzed for this compound.

TNT Strip #2. Soil samples were collected from four locations (TNT-2A, -2B, -2C, and -2F) along the axis of TNT Strip #2. One additional surface sample (SS-1) was collected along the axis of TNT Strip #2 during a previous investigation conducted by SECOR. Soil samples were also collected from two step-out locations (TNT-2D and -2E) immediately adjacent to TNT Strip #2. The explosives data along the axis of the strip and step-out are presented in Table 5-2 and on Figure 5-2, Cross Section C.

Data collected along the center axis of the strip indicated total explosive concentrations of up to 92,204 mg/kg within the upper 2 feet bgs. At the two borehole locations on TNT Strip #2, which extended beyond 2 feet bgs (TNT-2B and -2F), total explosive concentrations were observed to decrease significantly with depth. At the one location (TNT-2F) where samples were collected up to 10 feet bgs, the same pattern was observed. At TNT-2F, explosives were detected at a total concentration of 0.9 mg/kg at 10 feet bgs.

Explosives concentrations within the upper 2 feet bgs were also observed to decrease in the two step-out boreholes (TNT-2D and -2E) advanced at approximately 2 feet from the strip.

HMX and RDX were detected in the soil samples collected from TNT-2F at 1.3 mg/kg and 6.0 mg/kg, and 1.1 mg/kg "J-" and 18 mg/kg "J-" at the surface and 1 foot bgs, respectively. Of the 10 samples analyzed for nitroglycerin and PETN, nitroglycerin was detected in the near-surface sample and the 3.5-foot sample collected from TNT-2B at 0.48 mg/kg "J" and 0.33 mg/kg "J-", respectively. Nitroglycerin was also detected at TNT-2D and -2E at 1.5 feet bgs at 0.39 mg/kg "J-" and 0.24 mg/kg "J-", respectively. PETN was not detected in any of the samples analyzed for this compound.

TNT Strip #3. Soil samples were collected from three locations (TNT-3A, -3B, and -3C) along the axis of TNT Strip #3. The explosives data along the axis of the strip and step-out are presented in Table 5-3 and on Figure 5-2, Cross Section D.

Data collected along the center axis of the strip indicated total explosive concentrations of up to 51,096 mg/kg within the upper 1 to 2 feet bgs. At the one borehole location on TNT Strip #3, which extended beyond 2 feet bgs (TNT-3B), explosive concentrations were observed to decrease significantly with depth to a concentration of 160 mg/kg at 4 feet bgs.

Neither HMX nor RDX were detected in any of the soil samples collected from TNT Strip #3. Seven of the soil samples were analyzed for nitroglycerin and PETN. Nitroglycerin was detected at TNT-3B at 0.38 mg/kg "J-" and 0.24 mg/kg "J-" at 0.5 foot and 3.5 feet bgs, respectively. PETN was not detected in any of the samples analyzed for this compound.

TNT Strip #4. Soil samples were collected from five locations (TNT-4A, -4B, and -4C, and SS-2 and -3) along the axis of TNT Strip #4. The explosives data along the axis of the strip are presented in Table 5-4 and on Figure 5-2, Cross Section E.

Soil samples were also collected from two sets of step-outs, centered on TNT-4C. One step-out series continues off the end of TNT Strip #4, while the other lies in a northeast-to-southwest direction perpendicular to the strip. The explosives data for these two step-outs are presented on Figure 5-3, Cross Sections C and D, respectively.

Data collected within the surface expression along the axis of the main portion of TNT Strip #4 indicated total explosive concentrations up to 12,200 mg/kg within the upper 2 feet bgs. This was exceeded at only one location (TNT-4C), which detected a maximum concentration of 20,068 mg/kg at 1 foot bgs. At the one borehole location on TNT Strip #4, which extended beyond 2 feet bgs (TNT-4B), total explosive concentrations were observed to decrease significantly with depth to a concentration of 260 mg/kg at 4 feet bgs.

TNT Strip #4 was further characterized vertically and laterally via the step-out program. The TNT-4C series axial step-out boreholes (TNT-4C, -4C7 through -4C9, -4C13, and -4C14) were oriented in a northwest-to-southeast direction extending beyond the end of the strip. Weathered bedrock was encountered in most boreholes at a depth of 4 feet to 5 feet bgs. Explosive concentrations decrease immediately and significantly from the end of the strip (TNT-4C) to the 5-foot step-out (TNT-4C7). The maximum concentration of explosives found at TNT-4C is 20,068 mg/kg at 1 foot bgs compared with the maximum concentration found at TNT-4C7 of 4.4 mg/kg at 1 foot bgs. Low explosive concentrations can be found as far away as the 40-foot step-out (TNT-4C14) and down to depths of 5 feet bgs (6.2 mg/kg). The explosives detected in the 20-foot, 30-foot, and 40-foot step-outs typically show TNT breakdown products at higher concentrations than the TNT concentrations.

The TNT-4C perpendicular step-out series boreholes (TNT-4C through -4C6, -4C11, and -4C12) were oriented across TNT Strip #4 in a northeast-to-southwest direction. The depth to weathered bedrock along this series of step-outs varies from 1.5 feet bgs (TNT-4C12), to 6 feet bgs (TNT-4C3). The highest concentration of total explosives, 20,068 mg/kg, was found on the axis of the strip (TNT-4C) at a depth of 1 foot bgs. Explosive concentrations decrease vertically and laterally away from the surface center of the strip. At both 5-foot step-outs, the concentrations of total explosives are significantly less than over the strip with a maximum concentration of 35.9 mg/kg. Explosives were found down to bedrock at 3 feet bgs. At the 10-foot (TNT-4C5) and 20-foot (TNT-4C6) northeast (upslope) step-outs, no explosives were detected. At the 10-foot, 20-foot, and 30-foot step-outs downslope from TNT Strip #4, explosives were found at depths up to 2 feet bgs at concentrations less than 5 mg/kg. No explosives were found at the 40-foot step-out (TNT-4C12).

HMX and RDX were not detected in any of the soil samples collected from TNT Strip #4. Six of the soil samples from TNT Strip #4 were analyzed for nitroglycerin and PETN; neither of these compounds were detected.

TNT Strip #5. Soil samples were collected from five locations (TNT-5A, -5A10; SS-4; and -5B and -5C) along the axis of TNT Strip #5. The explosives data along the axis of the strip are presented in Table 5-5 and on Figure 5-2, Section F. Soil samples were also collected from six additional locations (SS-5; and TNT-5D, -5E, -5G, -5H, and -5I) along the westernmost south projection from TNT Strip #5 (see Figure 5-3, Cross Section F). Three other sampling locations (TNT-5F, -5J, and -5L) were used to characterize the eastern portion of the south projection of TNT Strip #5. Soil samples were also collected from one set of step-outs, centered on TNT-5A10. The explosives data along the TNT-5A step-out are presented on Figure 5-3, Cross Section E.

Data collected within the surface expression along the axis of the main portion of TNT Strip #5 indicated total explosive concentrations up to 49,000 mg/kg within the upper 2 feet bgs. At the one borehole location on TNT Strip #5, which

extended beyond 2.5 feet bgs (TNT-5A10), total explosive concentrations were observed to decrease with depth to a concentration of 151 mg/kg at 7.75 feet bgs.

TNT Strip #5 was further characterized vertically and laterally via the step-out program (see Figure 5-3, Cross Section E). The TNT-5A series step-out boreholes (TNT-5A through -5A10) were oriented across TNT Strip #5, upslope and downslope, in a north-south direction. Weathered bedrock was encountered at most boreholes between 5.5 feet and 8.5 feet bgs. Total explosives were detected at a maximum concentration of 25,083 mg/kg at the surface at TNT-5A10, on the strip at the center of the step-out series, and were detected at all sampling depths down to bedrock (7.75 feet bgs), although the concentrations decreased significantly below the upper 1 foot bgs. Explosive concentrations decrease both vertically and laterally away from the center axis of the strip. At both of the 5-foot step-outs, the concentration of total explosives is significantly lower (3,500 mg/kg) than over the strip and decrease rapidly with depth. To the north of the strip, at the 5-foot step-out (TNT-5A4), total explosives were detected at a concentration of 3,500 mg/kg at the surface, decreasing to 2.7 mg/kg at a depth of 5.5 feet bgs. At the 10-foot step-out (TNT-5A5), explosives were detected at low concentrations at the surface (0.9 mg/kg) and not at all with depth. At the 20-foot step-out, no explosives were detected. To the south of the strip, total explosives were detected at the surface and at depth at low concentrations (less than 9.9 mg/kg) at the 10-foot, 20-foot, 30-foot, and 40-foot step outs.

For sampling locations TNT-5D, -5E; and SS-5, which are on the westernmost south projection of TNT Strip #5 (see Figure 5-3, Cross Section F), explosives were found at the surface and at depth generally at levels below 10 mg/kg, and down to 2 feet bgs, which was the extent of sampling. Explosives were detected in a surface sample (SS-5) at 738 mg/kg (screening-level result). One sample collected from TNT-5D at 2 feet bgs detected total explosive concentrations of 760 mg/kg. At location TNT-5G, beyond the end of the western south projection, total explosives were detected to a maximum concentration of 379 mg/kg within the upper 1 foot bgs, decreasing rapidly to non-detect at 2 feet bgs. At two additional sampling locations further downslope (TNT-5H and -5I), low concentrations of explosives (up to 4.1 mg/kg) were detected within the upper 2 feet bgs (see Figure 5-1).

For TNT-5F, -5J, and -5L, which extend beyond the end of the easterly southern projection of TNT Strip #5, total explosives were found at depths of up to 2 feet bgs at concentrations up to 25 mg/kg (see Figure 5-1).

HMX was detected in two samples collected from TNT-5A10 on TNT Strip #5 at the surface and 2 feet bgs at a maximum concentration of 3.6 mg/kg. RDX was detected in five samples collected from TNT-5A10. The five samples range in depth from the surface to 7.5 feet bgs with a maximum concentration of 13 mg/kg. Eleven samples from TNT Strip #5 were analyzed for nitroglycerin and PETN. Nitroglycerin was detected in five of the samples analyzed for this compound. Two of the samples detecting nitroglycerin were collected from TNT-5C at depths of

0.5 foot and 1.5 feet bgs, both having an estimated concentration of 0.6 mg/kg "J-". The other three samples were collected from TNT-5A at the surface, 0.5 foot, and 1.5 feet bgs and detected at estimated concentrations of 0.35 mg/kg "J-", 0.18 mg/kg "J-", and 0.3 mg/kg "J-", respectively. PETN was not detected in any of the soil samples analyzed.

Miscellaneous Samples Within TNT Strips Area. Surface soil samples were collected from twelve locations (TNT-1I, -1M, -1N; TNT-R1 through -R6; TNT-R11, -R-13, and -R15) along the ridgeline above the TNT Strips area. Surface soil samples were also collected from six additional locations (TNT-R7, -R8, -R9, -R10, -R12, and -R14) throughout the TNT Strips area. Five additional boreholes (TNT-R16 through -R20) were advanced along the south-facing slope between the TNT Strips and the North Valley floor. The explosives data for these samples are presented in Table 5-6 and on Figure 5-1. A low concentration (0.6 mg/kg) of TNT was detected in the surface sample at TNT1I, over the ridge from TNT Strip #1; therefore, soil samples were collected from two step-out locations (TNT-1M and -1N). No explosives were detected in the soil samples collected from 1 foot bgs at TNT 1I or from either of the step-out locations. TNT was detected in the surface samples TNT-R1 through -R5, along the ridgeline, at estimated concentrations ranging from 1.9 mg/kg "J+" to 71 mg/kg "J+". Of the remaining samples collected throughout the TNT Strips area, explosives were detected at TNT-R12, situated 60 feet beyond the surface expression of TNT Strip #1 (see TNT Strip #1 data). TNT was not detected in any of the other ridgeline samples or any of the other samples collected from the boreholes situated on the south-facing slope, downgradient of the TNT Strips area.

Off-Site Samples. Near-surface soil samples (surface and 1 foot bgs) were collected from nine locations (TNT-R21 through -R29), north and east of the TNT Strips area and the Project Site boundary. The explosives data for these samples are presented in Table 5-6A and on Figure 5-1. No explosive compounds were detected in any of the off-site samples.

PAHs

Soil samples collected from the TNT Strips during the interim investigation were analyzed for PAHs. Selected soil samples collected from the TNT-1C step-out series were also analyzed for PAHs during the RI. Concentrations of PAHs detected at the TNT Strips are presented in Tables 5-1 through 5-5 and on Figure 5-1.

- **TNT Strip #1** - Low concentrations of three PAHs (fluoranthene [0.049 mg/kg], phenanthrene [0.061 mg/kg], and pyrene [0.049 mg/kg]) were detected at TNT-1B at 0.5 foot bgs. Three more PAHs (benzo[a]anthracene [0.0074 mg/kg "J"], chrysene [0.0074 mg/kg "J"], and naphthalene [0.013 mg/kg "J"]) were also detected in the same sample at estimated concentrations. Two PAHs (fluoranthene and phenanthrene) were also detected at 1 foot (0.01 mg/kg "J" and

0.025 mg/kg "J", respectively) and 2 feet bgs at TNT-1C (0.015 mg/kg "J" and 0.027 mg/kg, respectively).

- **TNT Strip #2** - Estimated concentrations of phenanthrene were detected in the soil samples collected from TNT-2A at 1 foot and 2 feet bgs at 0.0061 mg/kg "J" and 0.011 mg/kg "J", respectively. Fluoranthene and phenanthrene were detected in the soil sample collected from TNT-2C at 1 foot bgs at estimated concentrations of 0.012 mg/kg "J" and 0.018 mg/kg "J", respectively. Phenanthrene was also detected at TNT-2D (0.0082 mg/kg "J"") and TNT-2E (0.0094 mg/kg "J") and 2 feet and 1 foot bgs, respectively.

- **TNT Strip #3** - A low concentration of phenanthrene was detected in the soil sample collected from TNT-3A at 2 feet bgs at 0.025 mg/kg. Fluoranthene was detected at an estimated concentration (0.012 mg/kg "J") in the same sample.

- **TNT Strip #4** - Estimated concentrations of phenanthrene were detected in the soil sample collected from TNT-4B at 0.5 foot bgs (0.01 mg/kg "J") and TNT-4C at 1 foot bgs (0.019 mg/kg "J").

- **TNT Strip #5** - An estimated concentration of phenanthrene was detected in the surface sample collected at TNT-5A at 0.0072 mg/kg "J".

Selected soil samples were also analyzed for PAHs from the TNT-1C series step-outs during the RI. No PAHs were detected in any of the samples analyzed for these compounds.

TEPHs

None of the samples collected from the TNT Strips resembled either the diesel, motor oil, or kerosene standard. Severe interference was encountered due to the concentration of explosives within the samples. Estimated concentrations of unknown hydrocarbons (with minor components potentially resembling weathered fuel in the motor oil range) were detected at two of the three locations sampled for TEPHs. The unknown hydrocarbons are interpreted to represent possible TNT breakdown products. Copies of the chromatograms for the TEPH analyses from the TNT Strips are included in Attachment I-1 of Appendix I. Copies of the TEPH standard chromatograms for diesel, motor oil, and kerosene are included in Attachment I-2, for comparison. The maximum concentration detected was 180 mg/kg "J" at TNT Strip #2 at 1 foot bgs. Hydrocarbons were not detected in deeper samples (i.e., the 2-foot sample at TNT-1Q or the 4-foot sample at TNT-2F).

Metals. Metals data are presented in Tables 5-1 through 5-5 and are shown on Figures 5-1A and 5-1B. A total of 68 samples were collected from the TNT Strips and analyzed for metals (26 samples from TNT Strip #1, 13 samples from TNT Strip #2, 9 samples from TNT Strip #3, 8 samples from TNT Strip #4, and

12 samples from TNT Strip #5). In addition, 18 samples from TNT Strip #1 were analyzed for phosphorous. Table 5-1B summarizes the maximum and minimum values for each metal at the site.

PCBs

The analytical results for the one sample collected from the TNT Strips were rejected during verification/validation.

PCBs were added to the data gaps investigation due to their possible association with fuel hydrocarbons. PCBs were analyzed throughout the North Valley at locations where fuel hydrocarbons were detected. One PCB was detected at a low estimated concentration (0.38 mg/kg "J") in a near-surface sample collected at the Ammunition Renovation/Primer Destruction Site (see Section 5.5). As previously stated, the unknown hydrocarbons detected at the TNT Strips are believed to be associated with TNT breakdown products, rather than fuel hydrocarbons, therefore, the lack of additional PCB data at the TNT Strips was not considered to be a data gap.

Dioxins/Furans. Five samples from the TNT Strips were analyzed for dioxin/furans. Two samples were collected from TNT Strip #2, and one sample was collected from TNT Strip #5 at 1 foot bgs, respectively. Two samples were also collected from TNT Strip #1 at 4 feet and 4.5 feet (duplicate) bgs. The following dioxin/furan compounds were detected at TNT Strip #2: total tetrachlorinated dibenzo-p-dioxins (total TCDD) (0.97 pg/g). The following dioxin/furan compounds were detected at TNT Strip #5: total pentachlorinated dibenzofurans (PeCDF) (4.3 pg/g), and total TCDD (0.94 pg/g). Dioxins/furans were not detected in any of the deeper samples collected at 4 feet and 4.5 feet bgs.

5.3 HOWITZER TEST FACILITY AND STOCKPILE #3 RESULTS

5.3.1 Howitzer Test Facility

Four boreholes (HF-1 through HF-4) were advanced within and adjacent to the Howitzer Test Facility during the RI. Five additional boreholes (HF-5 through -9) were advanced in the general vicinity of Building 540 during the data gaps investigation. Another borehole (HF-3R) was advanced during the data gaps investigation between borehole HF-2 and -3.

Three additional boreholes (TW-4, -5, and -6) were also advanced in this area during the RI, which were to be converted into temporary groundwater monitoring wells if shallow groundwater was encountered. No shallow groundwater was encountered at boreholes TW-5 or -6, prior to refusal at 24 feet and 10 feet bgs, respectively. Shallow groundwater was encountered at borehole TW-4 at 22 feet bgs. This borehole, which is immediately downgradient of the Howitzer Test Facility, was converted into a monitoring well. Two additional groundwater monitoring wells (MW-5 and -6) were installed during the data gaps investigation.

Soil samples collected from the Howitzer Test Facility during the RI were analyzed for explosives including nitroglycerin and PETN, PAHs, TEPHs, VOCs, metals, and nitrate/nitrite. Selected soil samples collected during the data gaps investigation from boreholes (HF-5 through -9) were analyzed for explosives and VOCs. Soil samples collected from borehole HF-8 were also analyzed for organochlorine pesticides and chloropicrin. Additional surface samples were collected immediately adjacent to existing boreholes during the data gaps investigation and analyzed for both TEPHs and PCBs. Soil samples collected from borehole MW-6 were analyzed for explosives, metals, and nitrate/nitrite.

Two soil samples collected from borehole TW-5 at 5.5 feet and 10.5 feet bgs were analyzed for dioxin/furans during the RI. One additional sample was collected from an adjacent borehole (MW-5) at 10.5 feet and 11 feet (duplicate) bgs during the data gaps investigation.

Soil analytical results for the Howitzer Test Facility are presented in Tables 5-7 and 5-12A and on Figure 5-4.

Explosives + Nitroglycerin/PETN. A low concentration of TNT (1.7 mg/kg) was detected in the soil sample collected from borehole HF-4 at a depth of 10 feet bgs during the RI. No explosives were detected in other soil samples collected from the "HF", "TW" and "MW" boreholes at the Howitzer Test Facility. No explosives were detected in any of the soil samples collected from adjacent boreholes during the data gaps investigation, including borehole HF-5 which was advanced immediately adjacent to borehole HF-4. One sample (HF-1 at 1 foot bgs) could not be analyzed for nitroglycerin and PETN due to insufficient sample quantity.

PAHs. No PAHs were detected in any of the soil samples collected from the Howitzer Test Facility.

TEPHs. Estimated concentrations of petroleum hydrocarbons in the motor oil range (4.7 mg/kg "J", 11 mg/kg "J", and 58 mg/kg "J-") were detected in the surface soil samples collected from boreholes HF-3R, -2 and -3, respectively. Estimated concentrations of petroleum hydrocarbons in the motor oil range were also detected in the soil samples collected from borehole TW-5 at 5 feet (5.9 mg/kg "J") and 10 feet (6.9 mg/kg "J") bgs, respectively. Low concentrations of petroleum hydrocarbons in the motor oil range were detected in the soil samples from borehole TW-4 at 4.5 feet (16 mg/kg) and 20 feet (18 mg/kg); an estimated concentration (12 mg/kg "J") was also detected in the same borehole at 15 feet bgs. No petroleum hydrocarbons in the kerosene range were detected at the Howitzer Test Facility.

Estimated concentrations of unknown hydrocarbons in the motor oil range were also detected in the surface sample collected from boreholes HF-2R and HF-3R1 at 97 mg/kg "J" and 15 mg/kg "J-", respectively.

VOCs. Isolated low concentrations of VOCs commonly associated with petroleum hydrocarbons were detected at the Howitzer Test Facility. Estimated concentrations of benzene (0.0035 mg/kg "J"), toluene (0.0055 mg/kg "J"), and xylenes (0.0022 mg/kg "J") were detected at borehole HF-7 at 10 feet bgs. An estimated trace concentration of benzene (0.0018 mg/kg "J") was also detected at borehole HF-9 at 20 feet bgs. Estimated concentrations of 1,2,3-trichlorobenzene (0.0016 mg/kg "J") and 1,2,4-trichlorobenzene (0.0012 mg/kg "J ") were detected at the surface at borehole HF-8. 1,2,3-trichlorobenzene and 1,2,4-trichlorobenzene are similar to PCBs in that they were used as insulator fluids for transformers and are also used in hydraulic oils.

The only other VOC detected at the Howitzer Test Facility was MEK. This compound is considered a laboratory contaminant as discussed in Section 5.1.

SVOCs (Chloropicrin). Chloropicrin was not detected in any of the soil samples collected from borehole HF-8.

Metals. Metals data are presented in Tables 5-7 and 5-12A and are plotted on Figure 5-4A. A total of 18 soil samples were analyzed for metals. Table 5-1B summarizes the maximum and minimum values for each metal at the site.

Dioxins/Furans. Two samples collected from borehole TW-5 at 5.5 feet and 10.5 feet bgs during the RI were analyzed for dioxins/furans. One furan (2,3,7,8-tetrachlorodibenzofuran [2,3,7,8-TCDF]) was detected at 10.5 feet bgs at an estimated concentration of 0.78 pg/g "J". No dioxins/furans were detected in a sample collected at the same depth from an adjacent borehole (MW-5) or in the duplicate sample during the data gaps investigation.

Organochlorine Pesticides. No organochlorine pesticides were detected in any of the soil samples collected from borehole HF-8.

PCBs. No PCBs were detected in any of the soil samples analyzed for PCBs at the Howitzer Test Facility.

Nitrate/Nitrite. Nitrate was detected in all samples analyzed at predominantly estimated concentrations ranging from 0.18 mg/kg "J" (MW-6 at 10 feet bgs) to 2.3 mg/kg "J" (MW-6 at 4 feet bgs). Nitrite was detected in two of the soil samples analyzed at a concentration of 0.54 mg/kg (TW-4 at 5 feet bgs) and an estimated concentration of 0.12 mg/kg "J" (TW-5 at 5.5 feet bgs).

5.3.2 Stockpile #3 Results

Discrete soil samples were collected at four locations (SP3-1, SP3-2, SP3-3, and SP3-4) during the interim investigation from Stockpile #3 situated adjacent to the east boundary of the Howitzer Test Facility. These samples were collected approximately 2 feet below the stockpile surface. The stockpile samples were analyzed for explosives, PAHs, and SVOCs. No additional stockpile samples were collected during the RI.

Stockpile #3 was resampled during the data gaps investigation, since most of the SVOC and all the PAH data from the interim investigation were rejected during data verification/validation. The stockpile was divided into quarters. Four stockpile samples were collected approximately 2 feet below the stockpile surface from each quarter (SP3-R1[A,B,C,D], -R2[A,B,C,D], -R3[A,B,C,D], and -R4[A,B,C,D]). Each set of four samples was composited into a single sample for analysis. The samples were analyzed for PAHs by EPA Method SW8270C (SVOCs) and TEPHs.

Soil analytical results for Stockpile #3 are presented in Table 5-8 and on Figures 5-4 and 5-5A.

Explosives. No explosives were detected in any of the soils samples collected from Stockpile #3.

PAHs. All the PAH data were rejected for the stockpile samples analyzed by EPA Method SW8310; however, several PAHs were detected via EPA Method SW8270C, as described below.

SVOCs. Two PAHs (chrysene and pyrene) were detected in one of the discrete soil samples (SP3-1), collected from Stockpile #3 during the interim investigation, at estimated concentrations of 0.077 mg/kg "J-" and 0.033 mg/kg "J-", respectively. Three additional PAHs (benzo[g,h,i,]perylene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene) were detected in one of the composite samples (SP3-R1) collected from Stockpile #3 during the data gaps investigation, at estimated concentrations of 0.11 mg/kg "J", 0.11 mg/kg "J", and 0.10 mg/kg "J", respectively.

TEPHs. None of the samples collected from Stockpile #3 resembled either the diesel, motor oil, or kerosene standard. Unknown hydrocarbons in the motor oil range were detected in each of the composite samples at estimated concentrations ranging from 79 mg/kg "J" to 200 mg/kg "J-".

Metals. Metals data are presented in Table 5-8 and are plotted on Figure 5-4A. A total of five samples were analyzed for metals from Stockpile #3. Table 5-1B summarizes the maximum and minimum values for each metal at the site.

5.4 NORTH VALLEY MILITARY LANDFILL RESULTS

Thirty test pits (LFP-1 through -30) were excavated within the North Valley Military Landfill during the removal action investigation. Soil samples were collected from fifteen of the test pits, while four additional samples (LFM-1 through -4) were collected from soil excavated from the test pits and placed in stockpiles situated adjacent to them. Two grab groundwater samples were collected from two of the test pits (LFP-9 and -24) where shallow groundwater was encountered. Soil and grab groundwater samples were analyzed for explosives, including nitroglycerin and PETN, PAHs, TEPHs, VOCs, SVOCs (chloropicrin and pentachlorophenol),

metals, dioxins/furans, organochlorine pesticides, PCBs, nitrate/nitrite, and perchlorate.

Soil analytical results for the North Valley Military Landfill test pits and stockpiles are presented in Tables 5-9A and 5-9B, respectively. Grab groundwater analytical results for the North Valley Military Landfill are presented in Table 5-9C. The North Valley Military Landfill analytical results are also presented on Figures 5-5 and 5-5A.

Explosives + Nitroglycerin/PETN. No explosives were detected in any of the soil samples collected from the North Valley Military Landfill. Estimated concentrations of HMX (0.26 µg/L "J") and 2,4-DNT (0.66 µg/L "J") were detected in the grab groundwater sample collected from test pit LFP-24.

PAHs. No PAHs were detected in any of the soil samples or the grab groundwater samples collected from the North Valley Military Landfill.

TEPHs. Unknown hydrocarbons were detected in the central portion of the North Valley Military Landfill. Unknown hydrocarbons in the diesel and motor oil range were detected in three of the test pits sampled; LFP-10 (6.5 feet bgs), -12 (6 feet bgs), and -27 (1 foot bgs) at concentrations ranging from 1.5 mg/kg to 9.6 mg/kg "J-". Unknown hydrocarbons in the entire hydrocarbon range were detected in stockpile soil samples LFM-1 and -2 at concentrations of 15 mg/kg and 10 mg/kg "J", respectively. Unknown hydrocarbons in the diesel and motor oil range were detected in stockpile soil samples LFM-3 and -4 at concentrations of 61 mg/kg and 52 mg/kg "J", respectively.

Estimated concentrations of unknown hydrocarbons in the diesel and motor oil range were also detected in the grab groundwater samples collected from test pits LFP-9 (81 µg/L "J-") and -24 (200 µg/L "J-").

VOCs. MEK was detected throughout the North Valley Military Landfill. This compound is considered a laboratory contaminant, as discussed in Section 5.1.4. The only other VOCs that were detected in the soil at the North Valley Military Landfill were estimated concentrations of 1,4-dichlorobenzene (0.0014 mg/kg "J") and naphthalene (0.0013 mg/kg "J") at 8 feet bgs in pit test LFP-24. Naphthalene is commonly associated with petroleum hydrocarbons detections. An estimated concentration of 2-hexanone was detected in stockpile soil sample LFM-4 at 0.018 mg/kg "J". Two VOCs, p-cymene (p-isopropyltoluene) and acetone, were also detected in the grab groundwater sample collected from test pit LFP-24 at estimated concentrations of 0.67 µg/L "J" and 0.16 µg/L "J", respectively. No VOCs were detected in the grab water sample from test pit LFP-9.

SVOCs (chloropicrin and pentachlorophenol). No SVOCs, including chloropicrin and pentachlorophenol, were detected in the soil and grab groundwater samples collected from the North Valley Military Landfill.

Metals. Metals data are presented in Table 5-9 and are plotted on Figure 5-5A. A total of 34 samples were analyzed for metals and phosphorous. Table 5-1B summarizes the maximum and minimum values for each metal at the site.

Dioxins/Furans. Two dioxins (1,2,3,4,6,7,8-HpCDD [89 pg/g] and OCDD [1,200 pg/g]) and two furans (1,2,3,4,6,7,8-HpCDF [110 pg/g] and OCDF [89 pg/g "J+"] were detected at 8 feet bgs in test pit LFP-24. OCDD was detected in the grab groundwater sample collected from the same test pit at a concentration of 260 pg/L. OCDD (17 pg/g) was also detected in the sample collected from 6.5 feet bgs in test pit LFP-1. Dioxans/furans were detected in three of the four samples collected from the stockpile soil (LFM-2, -3, and -4). Estimated concentrations of 1,2,3,4,6,7,8-HpCDD (3.2 pg/g "J") and 1,2,3,4,6,7,8-HpCDF (3.8 pg/g "J") were detected in stockpile sample LFM-2. 1,2,3,4,6,7,8-HpCDD, 1,2,3,4,6,7,8-HpCDF, OCDD, and OCDF were detected in LFM-3 at concentrations of 5.4 pg/g, 9.4 pg/g, 57 pg/g, and 6.8pg/g "J", respectively. 1,2,3,4,6,7,8-HpCDD, 2,3,7,8-TCDF, OCDD, and OCDF were detected in LFM-4 at 5.1 pg/g "J", 1.5 pg/g, 54 pg/g, and 5.4 pg/g "J", respectively.

Organochlorine Pesticides. An estimated concentration (0.007 mg/kg ("J") of beta-BHC was detected at 3 feet bgs in test pit LFP-27. No organochlorine pesticides were detected in any other soil samples or the grab groundwater samples collected from the North Valley Military Landfill.

PCBs. No PCBs were detected in any of the soil or grab groundwater samples collected from the North Valley Military Landfill.

Nitrate/Nitrite. Nitrate was detected in most of the soil samples analyzed at estimated concentrations ranging from 0.28 mg/kg "J" (LFP-20 at 4 feet bgs and LFP-27 at 1 foot bgs) to 2.6 mg/kg "J-" in stockpile soil sample LFM-3. Nitrate was also detected in the grab groundwater sample from test pit LFP-9 at an estimated concentration of 0.084 mg/L "J". Nitrite was detected in only one sample (LFM-3) at an estimated concentration of 0.17 mg/kg "J". Neither nitrate nor nitrite were detected in the grab groundwater sample from test pit LFP-24.

Perchlorate. No perchlorate was detected in any of the soil or grab groundwater samples analyzed for perchlorate at the North Valley Military Landfill.

5.5 AMMUNITION RENOVATION/PRIMER DESTRUCTION SITE AND STOCKPILES #1 AND #2 RESULTS

5.5.1 Ammunition Renovation/Primer Destruction Site

Four boreholes were advanced within the Ammunition Renovation/Primer Destruction Site (AR-1 through -4) during the RI. Eight additional boreholes (AR-5 through -12) were advanced during the data gaps investigation in the vicinity of the highest petroleum hydrocarbon concentrations identified during the RI.

Two additional boreholes (TW-1 and -7) were advanced within and adjacent to this site. No shallow groundwater was encountered in boreholes TW-1 and -7. Two additional groundwater monitoring wells (MW-1 and -7) were installed during the data gaps investigation.

"AR" and "MW" boreholes within the Ammunition Renovation/Primer Destruction Site were advanced to a maximum depth of 44 feet bgs. Soil samples collected from the Ammunition Renovation/Primer Destruction Site during the RI were analyzed for explosives including nitroglycerin and PETN, PAHs, TEPHs, VOCs, metals, and nitrate/nitrite. Two bulk samples from borehole TW-1 were also analyzed for total organic carbon. Soil samples collected during the data gaps investigation were analyzed for TEPHs and VOCs. Additional surface samples were collected immediately adjacent to existing boreholes during the data gaps investigation and analyzed for both TEPHs and PCBs. Soil samples collected from MW-1 at 17.5 feet and 21 feet bgs during the data gaps investigation were also analyzed for dioxins/furans.

Soil analytical results for the Ammunition Renovation/Primer Destruction Site are presented in Table 5-10 and on Figure 5-6.

Explosives + Nitroglycerin/PETN. No explosives were detected in any of the soil samples collected from the Ammunition Renovation/Primer Destruction Site.

PAHs. A low concentration of naphthalene (0.46 mg/kg) was detected in the sample collected from borehole AR-1 at 8 feet bgs. Naphthalene was also detected by VOC analysis as indicated below. No PAHs were detected in any of the other soil samples collected from the Ammunition Renovation/Primer Destruction Site.

TEPHs. Low concentrations, including estimated concentrations ("J" qualified), of petroleum hydrocarbons in the diesel and motor oil range were detected throughout the Ammunition Renovation/Primer Destruction Site. Toward the northwest portion of the site, petroleum hydrocarbons in the diesel and motor oil range were detected throughout the soil column to the maximum depth investigated. Diesel concentrations ranged from 0.96 mg/kg "J" at 10 feet bgs at borehole AR-2 to 4.5 mg/kg in the surface sample collected at TW-7. Motor oil ranged from 7.4 mg/kg "J" at 7 feet bgs at borehole TW-7 to 67 mg/kg at 0.5 foot bgs at borehole AR-1. Estimated concentrations of unknown hydrocarbons in the motor oil range were also detected in the surface samples collected in close proximity to AR-1 and -2; 7.3 mg/kg "J" (AR-2R) and 75 mg/kg "J-" (AR-1R). A similar pattern is also observed toward the east portion of the site where petroleum hydrocarbons in the diesel and motor oil range were detected throughout the soil column at borehole AR-4 at concentrations of up to 13 mg/kg (30 feet bgs) for diesel and at concentrations up to 82 mg/kg (10 feet bgs) for motor oil. Toward the southeast corner of the site, petroleum hydrocarbons in the diesel range were detected. Unknown hydrocarbons in the motor oil range were also detected in the surface samples in this portion of the site at concentrations ranging from 15 mg/kg

(AR-11) to 310 mg/kg "J" (AR-7R). Petroleum hydrocarbons were also detected at depth ranging from 630 mg/kg at 17.5 feet bgs at borehole AR-3 to 220 mg/kg at 22 feet bgs at borehole TW-1.

VOCs. A low concentration of sec-butylbenzene (0.014 mg/kg) and an estimated concentration of naphthalene (0.006 mg/kg "J") were detected at the same location and depth as the highest petroleum hydrocarbon concentration, i.e., borehole AR-3 at 17.5 feet bgs. Naphthalene (0.46 mg/kg) was also detected at borehole AR-1 at 8 feet bgs. Both compounds are commonly associated with petroleum hydrocarbons detections. A low concentration of ethylbenzene (0.0016 mg/kg), another VOC commonly associated with petroleum hydrocarbons, was also detected at nearby borehole AR-7 at 10 feet bgs. Other isolated detections of VOCs include an estimated concentration (0.0012 mg/kg "J") of 1,2,3-trichlorobenzene (a compound similar to PCBs in that it was used as an insulator fluid for transformers and in hydraulic oils) detected at borehole AR-11 at 17 feet bgs and an estimated concentration (0.0037 mg/kg "J") of p-cymene (p-isopropyltoluene) detected at AR-8 at 4 feet bgs.

The only other VOC detected at the Ammunition Renovation/Primer Destruction Site was MEK. This compound is considered a laboratory contaminant, as discussed in Section 5.1.4.

Metals. Metals data are presented in Table 5-10 and are plotted on Figure 5-6A. A total of 19 samples were analyzed for metals and phosphorous. Table 5-1B summarizes the maximum and minimum values for each metal at the site.

PCBs. An estimated concentration (0.038 mg/kg "J") of Arochlor 1254 was detected in the surface soil sample collected from borehole MW-7. No PCBs were detected in any of the other soil samples analyzed for PCBs at the Ammunition Renovation/Primer Destruction Site.

Dioxins/Furans. No dioxins/furans were detected in the soil samples collected from borehole MW-1 at 17.5 feet and 21 feet bgs.

Nitrate/Nitrite. Nitrate was detected in most of the samples analyzed at concentrations ranging from 0.20 mg/kg "J" (AR-4 at 30.5 feet bgs) to 10.1 mg/kg (AR-2 at 0.5 foot bgs). Nitrite was detected only in the surface (0.16 mg/kg "J") and 1-foot (0.26 mg/kg "J") samples collected from borehole AR-1, in the surface (0.14 mg/kg "J"), and 5.5-foot (0.27 mg/kg "J") samples collected from borehole AR-2, and in the 4.5-foot (0.68 mg/kg) sample collected from borehole TW-7.

Total Organic Carbon. Total organic carbon concentrations ranged from 2,470 mg/kg "J-" to 16,600 mg/kg "J-" in the bulk samples collected from borehole TW-1.

5.5.2 Stockpile #1 Results

Soil samples were collected from two discrete locations (SP1-A and SP1-B) at approximately 2 feet below the surface of Stockpile # 1 during the interim investigation and analyzed for explosives, PAHs, and metals. One of the samples (SP1-B) was also analyzed for SVOCs. Soil samples were collected from one additional location (SP1-C) at approximately 2 feet below the surface of Stockpile #1 during the RI and analyzed for explosives including nitroglycerin and PETN, PAHs, TEPHs, metals, and nitrate/nitrite. Stockpile #1 was resampled during the data gaps investigation, since some SVOC data and all of the PAH data from the interim investigation were rejected during data verification/validation. The stockpile was divided into halves. Four stockpile samples were collected approximately 2 feet below the stockpile surface from each half (SP1-R1[A,B,C,D] and -R2[A,B,C,D]). Each set of four samples was composited into a single sample for analysis. The samples were analyzed for PAHs by EPA Method SW8270C (SVOCs) and TEPHs.

Soil analytical results for Stockpile #1 are presented in Table 5-11 and on Figures 5-6 and 5-6A.

Explosives + Nitroglycerin/PETN. A low concentration of TNT (0.67 mg/kg) was detected in sample SP1-A1. No other explosives, including nitroglycerin and PETN, were detected in any of the soil samples collected from Stockpile #1.

PAHs. Some of the PAH data were rejected for the soil stockpile samples analyzed by EPA Method SW8310; however, two PAHs were detected by EPA Method SW8270C, as described below.

SVOCs. Two PAHs (benzo[g,h,i,]perylene and indeno[1,2,3-c,d]pyrene) were detected in one of the composite samples (SP1-R1), collected from Stockpile #1 during the data gaps investigation, at estimated concentrations of 0.71 mg/kg "J" and 0.050 mg/kg "J", respectively.

TEPHs. Petroleum hydrocarbons in the motor oil range were detected in one sample (SP1-C), collected during the RI, at an estimated concentration of 6.7 mg/kg "J. Unknown hydrocarbons in the diesel and motor oil range were detected in both the composite samples (SP1-R1 and -R2), collected during the data gaps investigation, at estimated concentrations ranging from 9.2 mg/kg "J" to 1,400 mg/kg "J-". No petroleum hydrocarbons in the kerosene range were detected in the stockpile samples.

Metals. Metals data are presented in Table 5-11 and are plotted on Figure 5-6A. A total of three samples were analyzed for metals. One sample was analyzed for phosphorous. Table 5-1B summarizes the maximum and minimum values for each metal at the site.

Nitrate/Nitrite. Nitrate (1.7 mg/kg) was detected in the one sample (SP1-C) analyzed for these compounds. Nitrite was not detected in the same sample.

5.5.3 Stockpile #2 Results

Soil samples were collected from two discrete locations (SP2-A and-B) at approximately 2 feet below the surface of Stockpile #2 during the interim investigation and analyzed for explosives, PAHs, and metals. One of the samples (SP2-B) was also analyzed for SVOCs. Soil samples were collected from one additional location (SP2-C) at approximately 2 feet below the surface of Stockpile #2 during the RI and analyzed for explosives including nitroglycerin and PETN, PAHs, TEPHs, metals, and nitrate/nitrite. Stockpile #2 was resampled during the data gaps investigation, since some SVOC data and all of the PAH data from the interim investigation were rejected during data verification/validation. The stockpile was divided into halves. Four stockpile samples were collected approximately 2 feet below the stockpile surface from each half (SP2-R1[A,B,C,D] and -R2[A,B,C,D]). Each set of four samples was composited into a single sample for analysis. The two composited samples were analyzed for PAHs by EPA Method SW8270C (SVOCs) and TEPHs.

Soil analytical results for Stockpile #2 are presented in Table 5-11 and on Figures 5-6 and 5-6A.

Explosives + Nitroglycerin/PETN. No explosives, including nitroglycerin and PETN were detected in any of the soils samples collected from Stockpile #2.

PAHs. Some of the PAH data were rejected for the stockpile samples analyzed by EPA Method SW8310; however, nine PAHs were detected by EPA Method SW8270C, as described below.

SVOCs. Nine PAHs (benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, fluoranthene, indeno[1,2,3-c,d], and pyrene) were detected at estimated concentrations ranging from 0.044 mg/kg "J-" to 0.11 mg/kg "J-" were detected in one of the soil samples (SP2-B1) collected from Stockpile #2 during the interim investigation. Indeno[1,2,3-c,d]pyrene was also detected in two of the composite samples (SP2-R1 and -R2) collected during the data gaps investigation at estimated concentrations of 0.033 mg/kg "J" and 0.054 mg/kg "J", respectively.

TEPHs. Petroleum hydrocarbons in the motor oil range were detected in one sample (SP2-C), collected during the RI, at a concentration of 160 mg/kg. Unknown hydrocarbons in the motor oil range were detected in both the composite samples (SP2-R1 and -R2), collected during the data gaps investigation, at estimated concentrations ranging from 65 mg/kg "J-" to 150 mg/kg "J-". No petroleum hydrocarbons in the kerosene range were detected in the stockpile samples.

Metals. Metals data are presented in Table 5-11 and are plotted on Figure 5-6A. A total of three samples were analyzed for metals, and one sample was analyzed

for phosphorous. Table 5-1B summarizes the maximum and minimum values for each metal at the site.

Nitrate/Nitrite. Nitrate (2.5 mg/kg) was detected in the one sample (SP2-C) analyzed for these compounds. Nitrite was not detected in the same sample.

5.6 NORTH VALLEY SOIL, GROUNDWATER, AND SEEPS

Nine boreholes (TW-1 through TW-9) were advanced in the North Valley during the RI. Groundwater was encountered in only two of the boreholes (TW-3 and -4) at 25 feet and 22 feet bgs, respectively. Groundwater monitoring wells were constructed at these two locations. Thirteen additional groundwater monitoring wells (MW-1, -2, -3A, -3B, -4A, -5, -6, -7, -8, -9, -13, -14, and -15) were installed during the data gaps investigation.

No seeps were observed in the North Valley at the time of the RI activities; however, three seeps (NV-S1, -S2, and -S3) were present during the data gaps investigation.

5.6.1 Soil

Six of the boreholes (TW-4, MW-4A, TW-5, MW-5, TW-6, and MW-6) advanced in the North Valley were situated in and immediately adjacent to the Howitzer Test Facility, and four of the boreholes (TW-1, MW-1, TW-7, and MW-7) were situated within and adjacent to the Ammunition Renovation/Primer Destruction Site. Analytical results for soil samples collected from these boreholes have been discussed in Sections 5.3.1 and 5.5.1, respectively.

Soil samples were collected from boreholes TW-8 and -9, situated in a small valley that slopes to the northwest beyond the North Valley groundwater divide, during the RI. One soil sample was collected from each of these boreholes at 15.5 feet and 11 feet bgs, respectively, and analyzed for explosives including nitroglycerin and PETN, PAHs, TEPHs, and VOCs. The soil sample from borehole TW-8 was also analyzed for metals, sulfate, chloride, and nitrate/nitrite. A bulk sample was collected from borehole TW-8 and analyzed for total organic carbon. The soil sample from borehole TW-9 was analyzed for perchlorate. During installation of groundwater monitoring wells (MW-8 and -9) as part of the data gaps investigation, additional soil samples were collected and analyzed for explosives, TEPHs, and VOCs.

A bulk sample was collected from borehole TW-2 and analyzed for total organic carbon. No soil samples were collected from borehole TW-3. During installation of groundwater monitoring wells (MW-2, -3A, -13, -14, and -15) as part of the data gaps investigation, additional soil samples were collected and analyzed for explosives, TEPHs, and VOCs. Soil samples collected at 0.5 foot and 1 foot bgs from boreholes MW-14 and -15 were also analyzed for PCBs.

Soil analytical results for TW-2, MW-2, MW-3A, TW-8, MW-8, TW-9, MW-9, MW-13, MW-14, and MW-15 are presented in Table 5-12A and on Figures 5-4, 5-4A, 5-6, and 5-6A.

Explosives + Nitroglycerin/PETN. Low concentrations of explosives were detected in most of the soil samples collected from boreholes MW-3A, MW-13, MW-14, and MW-15, and in one sample collected from borehole MW-2 at 4 feet bgs. Many of these detections are at estimated concentrations. These boreholes are situated along the toe of the south-facing slope of the North Valley downgradient of the TNT Strips and along the valley floor southeast of the Howitzer Test Facility toward the eastern Project Site boundary. TNT is the most commonly detected explosive compound, ranging in concentrations from 0.15 mg/kg "J" at borehole MW-3A (20 feet bgs) to 17 mg/kg "J+" at borehole MW-13 (4 feet bgs). TNB was also detected as follows: 0.83 mg/kg at borehole MW-14 (4 feet bgs); and 0.17 mg/kg "J" and 0.62 mg/kg at borehole MW-15 (0.5 foot and 20 feet bgs, respectively). An estimated concentration of HMX (0.14 mg/kg "J") was also detected at borehole MW-2 at 4 feet bgs.

No explosives were detected in any of the soil samples collected from boreholes TW-8, MW-8, TW-9, and MW-9, situated northwest of the Ammunition Renovation/Primer Destruction Site.

PAHs. No PAHs were detected in any of the soil samples collected from boreholes TW-8 and TW-9.

TEPHs. No TEPHs were detected in any of the soil samples collected from boreholes TW-8, MW-8, TW-9, and MW-9, situated northwest of the Ammunition Renovation/Primer Destruction Site. Low concentrations of unknown hydrocarbons in the motor oil range were detected in the near-surface samples (0.5 foot bgs) collected from boreholes MW-14 and MW-15 at 92 mg/kg and 61 mg/kg, respectively. An estimated concentration of petroleum hydrocarbons in the motor oil range (21 mg/kg "J-") was detected in the near-surface sample (0.5 foot bgs) collected from borehole MW-13. No petroleum hydrocarbons were detected in any of the samples collected from boreholes MW-2 and -3A. No petroleum hydrocarbons in the kerosene range were detected in any of the soils samples collected from the North Valley.

VOCs. An estimated concentration of 1,2,4-trichlorobenzene (0.00093 mg/kg "J") was also detected in the soil sample collected from borehole MW-3A, situated southeast of the Howitzer Test Facility, at 15 feet bgs.

The only other VOC detected in the North Valley soil was MEK. This compound is considered a laboratory contaminant, as discussed in Section 5.1.4.

Metals. Metals data are presented in Table 5-12A and are plotted on Figures 5-4A and 5-6A. A total of 29 miscellaneous samples from boreholes scattered throughout the North Valley were analyzed for metals and phosphorous. Table

5-1B summarizes the maximum and minimum values for each metal from these miscellaneous North Valley samples.

Perchlorate. No perchlorate was detected in the soil sample collected from borehole TW-9.

Nitrate/Nitrite + Chloride + Sulfate. Nitrate was detected in the soil sample collected from TW-8 (15.5 feet bgs) at 0.28 mg/kg "J". Nitrite was not detected in the same sample. Chloride and sulfate were detected in the same soil sample at 16.6 mg/kg and 14.9 mg/kg, respectively.

Total Organic Carbon. Total organic carbon concentrations ranged from 1,770 mg/kg "J" to 2,490 mg/kg "J-" in the bulk samples collected from borehole TW-2 and was 4,660 mg/kg "J-" in the bulk sample collected from TW-8.

5.6.2 Groundwater and Seeps Results

Of the nine boreholes advanced in the North Valley during the interim investigation, groundwater was encountered at only two locations (TW-3 and -4). Temporary groundwater monitoring wells were constructed at these two locations. The temporary monitoring wells had a filter pack and bentonite seal, to allow for a better quality grab groundwater sample, but did not have a sanitary seal (i.e., cement grout) nor were they developed (sediment removed from the casing or filter pack) due to their anticipated temporary nature for use in a one-time groundwater monitoring event. The temporary wells were purged of three bore volumes, and grab groundwater samples collected. Grab groundwater samples from the temporary wells were analyzed for explosives, including nitroglycerin and PETN, PAHs, TEPHs, VOCs, dissolved metals, perchlorate, and general water chemistry. No seeps were present for sample collection during the RI.

During the data gaps investigation, temporary wells TW-3 and -4 were converted into permanent wells by the addition of a sanitary seal and renamed MW-3(TW-3) and MW-4(TW-4), and 13 additional permanent groundwater monitoring wells (MW-1, -2, -3A, -3B, -4A, -5, -6, -7, -8, -9, -13, -14, and -15) were installed. All the wells in the North Valley, except MW-3A (see Section C.8.2) were thoroughly developed during the data gaps investigation to allow the collection of "representative" groundwater samples. Groundwater samples from developed permanent wells provide a better quality sample than grab groundwater samples collected from either open boreholes or underdeveloped wells. Developed wells allow collection of groundwater samples that better represent natural conditions because well development removes potential impurities and suspended solids and allows free flow of groundwater through the well filter pack. Grab samples from either open boreholes or underdeveloped wells may contain impurities and suspended solids from the drilling and well installation activities or represent stagnant water. Groundwater samples collected from the permanent wells MW-3 (TW-3) and MW-4 (TW-4) were analyzed for explosives, including nitroglycerin and PETN and TEPHs (to confirm previous results from the RI), as well as pesticides,

hydrazine, chloropicrin, and general water chemistry. PAHs, VOCs, dissolved metals, and perchlorate were subsequently added to the groundwater analytical suite for these wells. Groundwater samples from all remaining wells were analyzed for explosives, including nitroglycerin and PETN, PAHs, TEPHs, dissolved metals, pesticides, hydrazine, perchlorate, and general water chemistry. Due to insufficient water and slow recharge, well MW-5 was not analyzed for dissolved metals, pesticides, perchlorate and hydrazine. Groundwater samples from wells MW-3(TW-3) and MW-4(TW-4) and MW-7 were also analyzed for PCBs.

Groundwater monitoring wells with sufficient water for sample collection were resampled in August 2000 for all COIs previously detected at the Project Site. The metal strontium was added to the list of metals analyzed. No groundwater samples could be collected from wells MW-5, -7, -13, and -15 because they were dry.

Three seeps were sampled in the North Valley during the data gaps investigation. Grab seep samples were analyzed for explosives, including nitroglycerin and PETN, PAHs, TEPHs, dissolved metals, pesticides, hydrazine, perchlorate, and general water chemistry. These seeps were all dry during the August 2000 monitoring event.

Analytical results for the North Valley groundwater are presented in Tables 5-12B, 5-12C, and 5-12D and on Figures 5-7 and 5-7A.

Explosives + Nitroglycerin/PETN. Estimated concentrations of two explosives were detected in the grab groundwater sample collected from temporary well TW-4 during the RI. TNT and amDNTs (total) were detected at 0.9 µg/L "J" and 4.9 µg/L "J", respectively. No explosives, including TNT and amDNTs, were detected in any of the groundwater samples collected from the permanent wells during the April 2000 and August 2000 monitoring events conducted as part of the data gaps investigation.

Estimated concentrations of TNT (0.17 µg/L "J") and amDNTs (0.38 µg/L "J") were detected in the grab seep sample NV-S3, situated west of the Howitzer Test Facility.

PAHs. An estimated concentration of acenaphthylene, a compound often associated with petroleum hydrocarbons, was detected in the groundwater water sample collected from well MW-13 (0.38 µg/L "J") during the April 2000 monitoring event conducted as part of the data gaps investigation. This compound was not detected during the August 2000 monitoring event. Low estimated concentrations of two other PAHs, anthracene (0.011 µg/L "J") and fluoranthene (0.11 µg/L "J"), were detected in the groundwater samples collected from wells MW-3B and MW-4(TW-4) during the August 2000 monitoring event.

Acenaphthylene was also detected in two of the seep samples (NV-S2 and -S3) collected during the data gaps investigation at a concentration of 5.8 µg/L and an estimated concentration of 0.84 µg/L "J", respectively.

No other PAHs were detected in the groundwater samples collected from the North Valley.

TEPHs. Petroleum hydrocarbons in the kerosene range were detected in the groundwater sample collected from well MW-4A during the April 2000 monitoring event conducted as part of the data gaps investigation at an estimated concentration (34 µg/L "J"). This compound was also detected in both the primary and duplicate sample collected from this well during the August 2000 monitoring event at a concentration of 210 µg/L "J" and 160 µg/L "J", respectively. Petroleum hydrocarbons in the diesel range were detected in both grab groundwater samples collected during the RI from temporary shallow wells TW-3 and-4 at estimated concentrations of 170 µg/L "J-" and 79 µg/L "J-, respectively. Petroleum hydrocarbons in the motor oil range were also detected in the grab groundwater sample collected from temporary well TW-4 at a concentration of 860 µg/L. No petroleum hydrocarbons in either the diesel or motor oil range were detected in these same wells during the April 2000 monitoring event of the data gaps investigation. Unknown hydrocarbons were detected in the groundwater sample collected from MW-4(TW-4) at an estimated concentration of 350 µg/L "J" during the August 2000 monitoring event.

VOCs. No VOCs were detected in the grab groundwater samples collected from temporary wells TW-3 and -4 during the RI. Several VOCs were detected in the groundwater sample collected from well MW-4A during the April 2000 monitoring event conducted as part of the data gaps investigation as follows: MEK (6.8 µg/L "J"), bromodichloromethane (0.15 µg/L "J"), carbon disulfide (3.7 µg/L), and chloroform (2.9 µg/L). MEK was detected in the primary and duplicate groundwater sample collected from well MW-4A at a concentration of 14 µg/L and 17 µg/L, respectively. Acetone was also detected in the same well at an estimated concentration of 1.9 µg/L "J". It is anticipated that this result will be rejected during data verification/validation since acetone was also detected in the associated equipment blank.

The following VOC was also detected in the grab groundwater sample collected from seep NV-S2 during the data gaps investigation: p-cymene (p-isopropyltoluene) at 0.61 µg/L "J".

SVOCs (Chloropicrin). Chloropicrin was not detected in the samples collected during the data gaps investigation from wells MW-3(TW-3) and MW-4(TW-4).

Metals. Concentrations of dissolved metals detected in the grab and groundwater/seep samples collected from the North Valley are presented in Tables 5-12B, 5-12C, and 5-12D. Concentrations of total metals detected in the groundwater samples during the August 2000 monitoring event are also presented

in Table 5-12D. Metals data are plotted on Figures 5-7A and 5-7B. Grab groundwater samples from temporary wells and seeps are also shown on Figure 5-7A. Metals data from groundwater samples collected from permanently installed monitoring wells in April and August 2000 are also shown on Figure 5-7B.

Organochlorine Pesticides. No pesticides were detected in any of the groundwater samples collected from the monitoring wells during the data gaps investigation. One pesticide, p'p'-DDD, was detected in the grab water sample collected from one of the seeps (NV-S2) situated along the west boundary of the Howitzer Test Facility, during the April 2000 monitoring event at an estimated concentration of 0.0077 µg/L "J".

Hydrazine. No hydrazine was detected in the groundwater/seep samples collected from the North Valley.

Perchlorate. No perchlorate was detected in the groundwater/seep samples collected from the North Valley.

PCBs. No PCBs were detected in any of the groundwater samples analyzed for PCBs.

General Water Chemistry. General water chemistry data obtained from the groundwater samples collected from wells in the North Valley during the data gaps investigation (April 2000 monitoring event) are as follows: TSS concentrations ranged from 12 mg/L (MW-2 and -4A) to 5,880 mg/L (MW-6). TDS concentrations ranged from 402 mg/L (MW-4A) to 3,620 mg/L (MW-7). Chloride concentrations ranged from 53.1 mg/L (MW-2) to 1,930 mg/L (MW-7). Sulfate concentrations ranged from 43 mg/L (MW-3B) to 121 mg/L (MW-1). Nitrate concentrations ranged from non-detect (MW-4A) to 6.0 mg/L (MW-1). Nitrite was detected in the groundwater samples collected from the following wells: MW-1, -2, -4(TW-4), MW-8, -9, and -14 at concentrations ranging from 0.16 mg/L to 0.7 mg/L "J-".

Field Parameters. Field parameter data obtained from the representative groundwater samples collected from wells in the North Valley during the data gaps investigation are presented in Table 5-29 and are summarized as follows. During the April 2000 monitoring event, electrical conductivity ranged from 700 micromhos per centimeter (µmhos/cm) (MW-4A) to 5,500 µmhos/cm (MW-7); pH ranged from 7.06 (MW-9) to 8.52 (MW-4A); turbidity ranged from 16.3 nephelometric turbidity units (NTUs) (MW-3B) to 158.6 NTUs (MW-1); and, temperature ranged from 16.9° Celsius (C) (MW-8) to 20.7°C (MW-14).

During the August 2000 monitoring event, electrical conductivity ranged from 815 µmhos/cm (MW-14) to 1,542 µmhos/cm (MW-1); pH ranged from 7.23 (MW-4[TW-4]) to 8.04 (MW-4A); turbidity ranged from 15 NTUs (MW-3B) to 660 NTUs (MW-6); and temperature ranged from 18.0°C (MW-9) to 20.2°C (MW-6).

5.7 DYNAMITE BURN SITE RESULTS

Four discrete bedrock samples (R1-A through R1-D) were collected from the graded surface of the Ridge in the approximate location of the Dynamite Burn Site during the RI. Three additional samples (R1-E, -F, and -G) were subsequently collected based on a reevaluation of the location of the Dynamite Burn Site. When the Dynamite Burn Site was in use, the Ridge was approximately 20 to 40 feet higher than its current elevation of approximately 235 feet above MSL. Material removed from this portion of the Ridge area during grading activities appears to have been used in the construction of the McAllister Drive Land Bridge (see Section 2.3.3). Bedrock samples collected from this area of the Ridge were analyzed for nitroglycerin and PETN and nitrate/nitrite.

Soil analytical results for the Dynamite Burn Site are presented in Table 5-13 and on Figure 5-8.

Nitroglycerin/PETN. No nitroglycerin or PETN were detected in any of the bedrock samples from the Dynamite Burn Site.

Nitrate/Nitrite. Nitrate was detected in all of the bedrock samples from the Dynamite Burn Site except R1-C at concentrations ranging from 0.03 mg/kg to 0.4 mg/kg "J". Nitrite was detected in only one of the samples (R1-A) at 0.28 mg/kg.

5.8 FLARE SITE RESULTS

Soil samples were collected from three boreholes (FA-1 through -3) during the interim investigation and from three boreholes (FA-4 through -6) during the RI. Boreholes were advanced both within and toward the suspected periphery of the Flare Site. No additional boreholes were advanced during the data gaps investigation.

All soil samples collected from the Flare Site were analyzed for metals. All samples collected from boreholes FA-1, -2, and -3 during the interim investigation were analyzed for explosives and PAHs. The 1-foot sample collected from borehole FA-6 during the RI was also analyzed for explosives and PAHs. The samples collected from borehole FA-3 at 0.5 foot bgs and borehole FA-6 at 1 foot bgs, toward the center of the Flare Site, were analyzed for dioxins/furans. The sample collected from borehole FA-6 at 1 foot bgs was also analyzed for nitrate/nitrite.

In addition, one surface soil sample (SS-22) was collected toward the center of the Flare Site during a previous investigation conducted by SECOR (see Table 3-4 and Figure 3-1). The surface soil sample was analyzed for metals, explosives, and nitrate/nitrite.

Soil analytical results for the Flare Site are presented in Table 5-14 and on Figures 5-9 and 5-9A.

Explosives. No explosives were detected in any of the soil samples collected from the Flare Site.

PAHs. No PAHs were detected in any of the soil samples collected from the Flare Site.

Metals. Metals data are presented in Table 5-14 and are plotted on Figure 5-9A. A total of 20 samples were analyzed for metals, and an additional 14 samples were analyzed for phosphorous. Table 5-1B summarizes the maximum and minimum values for each metal at the site.

Dioxins/Furans. Dioxins/furans were detected at various concentrations ranging from estimated concentrations up to a maximum concentration of 490 pg/g (total TCDF) in the surface sample collected from borehole FA-3. One dioxin and one furan were also detected in the 1-foot sample collected from borehole FA-6. 2,3,7,8-TCDF and 1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin (OCDD) were detected at 1.3 pg/g and 10 pg/g "J", respectively.

Nitrate/Nitrite. Nitrate was detected in the 1-foot and 1.5-foot (duplicate) samples from borehole FA-6 at concentrations of 2.7 mg/kg and 0.82 mg/kg, respectively. Nitrite was detected at an estimated concentration of 0.23 mg/kg "J" in the primary sample, but not the duplicate sample. Nitrate and nitrite were also detected in surface sample SS-22 at 3.21 mg/kg and 1.35 mg/kg (both screening-level results), respectively.

5.9 DEMOLITION SITES RESULTS

Initially, three suspected demolition sites (Demolition Sites #1, #2, and #3) were thought to exist in the South Valley. All three suspected demolition sites were investigated during the interim investigation. Since no physical evidence (e.g., live ordnance, magnetic anomalies) or ordnance-related activities were found at Demolition Site #2, the site was eliminated from further investigation; therefore, no additional sampling of Demolition Site #2 was performed during the RI activities. Subsequently, no additional sampling of Demolition Sites #1 and #3 was conducted during the data gaps investigation.

5.9.1 Demolition Site #1

Two shallow boreholes (DA1-1 and -2) were advanced to a maximum depth of 4.5 feet bgs, in what was believed to be the general vicinity of Demolition Site #1, during the interim investigation. Soil samples were analyzed for explosives, PAHs, and metals. Two additional samples were collected from the sidewall of the incised channel in the vicinity of the previous borehole locations during the RI. The sidewall samples were analyzed for explosives including nitroglycerin and PETN, PAHs, metals, and nitrate/nitrite.

One surface soil sample (SS-24) was collected within Demolition Site #1 during a previous investigation conducted by SECOR (see Table 3-5 and Figure 3-1) and analyzed for explosives, metals, and nitrate/nitrite.

Soil analytical results for Demolition Site #1 are presented in Table 5-15 and on Figures 5-9 and 5-9A.

Explosive + Nitroglycerin/PETN. No explosives, including nitroglycerin and PETN, were detected in the soil samples associated with Demolition Site #1.

PAHs. No PAHs were detected in the soil samples associated with Demolition Site #1.

Metals. Metals data are presented in Table 5-15 and are plotted on Figure 5-9A. Nine samples were analyzed for metals, and an additional two samples were analyzed for phosphorous. Table 5-1B summarizes the maximum and minimum values for each metal at the site.

Nitrate/Nitrite. Nitrate was detected in both channel sidewall samples at 1.4 mg/kg (DA1-3W1) and 2.0 mg/kg (DA1-3W2). Nitrite was detected in one of the sidewall samples (DA1-3W2) at an estimated concentration of 0.17 mg/kg "J". Nitrate was detected in surface sample SS-24 at 9.16 mg/kg (screening-level result). Nitrite was not detected in the same sample.

5.9.2 Demolition Site #2

Soil samples were collected from two borehole locations (DA2-1 and -2) during the interim investigation. The boreholes were advanced toward the downslope periphery of Demolition Site #2 to a maximum depth of 4.5 feet bgs. All soil samples were analyzed for explosives, PAHs, and metals.

One surface soil sample (SS-23) was collected at Demolition Site #2 during a previous investigation conducted by SECOR (see Table 3-6 and Figure 3-1) and analyzed for explosives, metals, and nitrate/nitrite.

Soil analytical results for Demolition Site #2 are presented in Table 5-16 and on Figures 5-9 and 5-9A.

Explosives. No explosives were detected in any of the soil samples collected from Demolition Site #2.

PAHs. No PAHs were detected in any of the soil samples collected from Demolition Site #2.

Metals. Metals data are presented in Table 5-16 and are plotted on Figures 5-9A. A total of eight samples were analyzed for metals. Table 5-1B summarizes the maximum and minimum values for each metal at the site.

Nitrate/Nitrite. Nitrate was detected in surface sample SS-23 at 11.6 mg/kg (screening-level result). Nitrite was not detected in the same sample.

5.9.3 Demolition Site #3

Two shallow boreholes (DA3-1 and -2) were advanced to a maximum depth of 4.5 feet bgs toward the upslope periphery of Demolition Site #3 during the interim investigation. Soil samples were analyzed for explosives, PAHs, and metals. Four deep boreholes (DA3-3 through -6) were advanced during the RI to a maximum depth of 17 feet bgs. These boreholes are toward the center and downslope periphery of Demolition Site #3. Soil samples from these boreholes were analyzed for explosives, PAHs, and metals. Two samples collected from central borehole locations DA3-5 and -6 at 8 feet and 10 feet bgs were analyzed for nitroglycerin and PETN. These samples were collected from the bedrock immediately beneath the fill material at Demolition Site #3. One sample collected from DA3-6 at 10.5 feet bgs was also analyzed for nitrate/nitrite.

Three additional surface soil samples (SS-26, -27, and -28) were collected within Demolition Site #3 during a previous investigation conducted by SECOR (see Table 3-7 and Figure 3-1) and analyzed for explosives, metals, and nitrate/nitrite.

Soil analytical results for Demolition Site #3 are presented in Table 5-17 and on Figures 5-9 and 5-9A.

Explosives + Nitroglycerin/PETN. No explosives were detected in any of the soil samples collected from Demolition Site #3. Nitroglycerin and PETN were not detected in the two samples analyzed for these compounds.

PAHs. No PAHs were detected in any of the soil samples collected from Demolition Site #3.

Metals. Metals data are presented in Table 5-17 and are plotted on Figure 5-9A. A total of 16 soil samples were analyzed for metals, and an additional 9 samples were analyzed for phosphorous. Table 5-1B summarizes the maximum and minimum values for each metal at the site.

Nitrate/Nitrite. Nitrate was detected at an estimated concentration of 0.27 mg/kg "J" in the one sample collected from DA3-6 at 10.5 feet bgs. Nitrite was not detected in the same sample. Nitrate was detected in one of the surface samples (SS-27) at 4.13 mg/kg (screening-level result). Nitrite was not detected in the same sample.

5.10 SOUTH VALLEY WETLAND SEDIMENT AND SURFACE WATER RESULTS

5.10.1 Sediment

Sediment samples were collected from one location (WET -1B) in the South Valley wetland area during the interim investigation and were analyzed for explosives,

PAHs, and metals. Sediment samples were collected from two additional locations (WET-1 and -2) during the RI, upgradient and downgradient of the Demolition Sites and the Flare Site, respectively. Sediment samples were analyzed for explosives, including nitroglycerin and PETN, PAHs, metals, and nitrate/nitrite. The sediment sample (WET-2) downgradient of the Flare Site was to have been analyzed for dioxins/furans during the RI. This analysis was inadvertently omitted; therefore, a sediment sample (WET-2R) was collected from the same location during the data gaps investigation and analyzed for dioxins/furans. Sediment samples were also collected from five additional boreholes locations (WET-3 through -7) during the data gaps investigation and analyzed for mercury and methyl mercury.

Analytical results for the South Valley sediment are presented in Tables 5-18A and 5-18B and on Figures 5-10 and 5-10A.

Explosive + Nitroglycerin/PETN. One explosive compound, TNT, was detected at an estimated concentration of 1.5 mg/kg "J-" in the downgradient sediment sample (WET-2). This compound was not detected in the duplicate sample (WET-2A) collected during the same sampling event. No other explosives were detected in the sediment samples collected from the South Valley wetland area.

PAHs. A low concentration of one PAH, benzo(b)fluoranthene, was detected at a concentration of 0.094 mg/kg in the downgradient sediment sample (WET-2). This compound was not detected in the duplicate sample (WET-2A) collected during the same sampling event. No other PAHs were detected in the sediment samples collected from the South Valley wetland area.

Metals/Methyl Mercury. Metals data are presented in Table 5-18A and are discussed in Chapter 6.0. Methyl mercury data are presented in Table 5-18B and are discussed in Chapter 7.0.

Dioxins/Furans. No dioxins/furans were detected in the sediment sample collected downgradient of the Flare Site.

Nitrate/Nitrite. Nitrate was detected in both sediment samples analyzed at concentrations ranging from 0.58 mg/kg "J" (WET-1) to 0.69 mg/kg (WET-2). Nitrite was not detected in the same samples.

5.10.2 Surface Water

Grab surface water samples were collected from two locations (SW-1 and SW-2) in the South Valley wetland area, upgradient and downgradient of the Demolition Sites and the Flare Site, respectively, during the RI. Grab surface water samples were analyzed for explosives, including nitroglycerin and PETN, PAHs, total and dissolved metals, and general water chemistry. The surface water was resampled during the data gaps investigation and analyzed for explosives, including nitroglycerin and PETN, based on preliminary data quality review of the RI data.

Two surface water samples (WS-1 and -2) were also collected from upgradient and downgradient locations within the South Valley wetland area by SECOR during a previous investigation (see Table 3-9 and Figure 3-1) and were analyzed for explosives, metals, and nitrite/nitrate.

Analytical results for the South Valley surface water are presented in Table 5-19 and on Figures 5-10 and 5-10A.

Explosive + Nitroglycerin/PETN. An estimated concentration of TNT (2.2 µg/L "J") was detected in the downgradient surface water sample (SW-2) collected during the RI. No explosive compounds were detected in either the upgradient or downgradient surface water samples collected during the data gaps investigation.

PAHs. No PAHs were detected in the South Valley surface water samples.

Total and Dissolved Metals. Concentrations of total and dissolved metals detected in the surface water samples are presented in Table 5-19.

General Water Chemistry. General water chemistry data obtained from the grab surface water samples collected from the South Valley wetland are as follows. TSS concentrations ranged from 192 mg/L (SW-2) to 461 mg/L (SW-1). TDS concentrations ranged from 704 mg/L (SW-1) to 719 mg/L (SW-2). Chloride concentrations ranged from 66.8 mg/L (SW-1) to 67.9 mg/L (SW-2). Sulfate concentrations ranged from 127 mg/L (SW-2) to 131 mg/L (SW-1). Nitrate concentrations from the previous SECOR data ranged from non-detect (WS-1) to 338 mg/L (WS-2) (screening-level results). Nitrite was not detected in the same samples.

5.11 SOUTH VALLEY GROUNDWATER AND SEEPS RESULTS

It was proposed to advance three boreholes (TW-10, -11, and -12) in the South Valley during the RI to evaluate the depth and quality of the shallow groundwater. Only two of the boreholes (TW-11 and -12) were advanced at the time of the RI. TW-11 was advanced in the vicinity of the Flare Site, and TW-12 was advanced immediately downgradient of the McAllister Drive Land Bridge. Groundwater was encountered at only one location (TW-12) at 23 feet bgs. No groundwater was encountered at TW-11, prior to bedrock refusal at 17 feet bgs. Borehole TW-12 was converted into a permanent monitoring well. Two additional groundwater monitoring wells (MW-10 and -11) were installed during the data gaps investigation.

No seeps were observed in the South Valley at the time of the RI activities; however, one seep (SV-S1) was present during the data gaps investigation.

5.11.1 Soil

Soil samples were collected from borehole TW-11 between 15.5 feet and 16.5 feet bgs and analyzed for explosives, including nitroglycerin and PETN, PAHs, TEPHs,

VOCs, and metals, VOCs. No soil samples were collected for analysis from boreholes MW-10 and -11 during the data gaps investigation.

Soil analytical results for borehole TW-11 are presented in Table 5-20A and on Figures 5-9 and 5-9A.

No compounds tested for (except metals) were detected in the samples collected from borehole TW-11.

5.11.2 Groundwater

A permanent groundwater monitoring well (TW-12) was constructed in the South Valley during the RI and a grab groundwater sample collected. At the time of groundwater sample collection, well TW-12 had not undergone a proper development; therefore, the sample collected from the well was considered to be a grab sample. The grab groundwater sample was analyzed for explosives, including nitroglycerin and PETN, dissolved metals, PAHs, VOCs, perchlorate, and general water chemistry (TDS and TSS only). No seeps were present for sample collection during the RI.

During the data gaps investigation existing well TW-12 was renamed MW-12 (TW-12), and two additional permanent groundwater monitoring wells (MW-10 and -11) were installed. All wells in the South Valley were thoroughly developed during the data gaps investigation. Groundwater samples from well MW-12 (TW-12) were analyzed for explosives, including nitroglycerin and PETN, and hydrazine. Groundwater samples from the remaining wells were analyzed for explosives, including nitroglycerin and PETN, PAHs, VOCs, dissolved metals, perchlorate, and hydrazine. All South Valley groundwater monitoring wells were resampled in August 2000 for all COIs previously detected at the Project Site. The metal strontium was added to the list of metals analyzed.

One seep was sampled in the South Valley during the data gaps investigation. The grab seep sample was analyzed for explosives, PAHs, VOCs, dissolved metals, and perchlorate. This seep was dry during the August 2000 monitoring event.

Analytical results for the South Valley groundwater and seeps are presented in Tables 5-20B, 5-20C, and 5-20D, and on Figures 5-7, 5-7A, and 5-7B.

Explosives + Nitroglycerin/PETN. An estimated concentration of one explosive, 3-nitrotoluene (0.59 µg/L "J"), was detected in the groundwater sample collected from permanent well MW-12(TW-12) during the April 2000 monitoring event conducted as part of the data gaps investigation. This compound was not detected during the December 1999 or the August 2000 monitoring events.

No other explosives, including nitroglycerin or PETN, were detected in the groundwater/seep samples collected from the South Valley during the data gaps investigation.

PAHs. An estimated concentration of one PAH, acenaphthylene (1.1 µg/L "J"), was detected in the groundwater sample collected from well MW-10 during the August 2000 monitoring event conducted as part of the data gaps investigation. No other PAHs were detected in the groundwater/seep samples collected from the South Valley.

VOCs. No VOCs were detected in the groundwater/seep samples collected from the South Valley.

Metals. Concentrations of dissolved metals detected in the groundwater samples are presented in Tables 5-20B, 5-20C, and 5-20D. Concentrations of total metals detected in the groundwater samples during the August 2000 monitoring event are also presented in Table 5-20D. Metals data are plotted on Figures 5-7A and 5-7B. Analytical results of the grab samples collected from wells and seeps are shown on Figure 5-7A. Metals data from groundwater samples collected from permanently installed monitoring wells in April and August 2000 are shown on Figure 5-7B.

Perchlorate. No perchlorate was detected in the groundwater/seep samples collected from the South Valley.

Hydrazine. No hydrazine was detected in the groundwater samples collected from the South Valley.

General Water Chemistry. General water chemistry data obtained from the groundwater samples collected from permanent wells in the South Valley during the data gaps investigation are as follows: TSS concentrations ranged from 74 mg/L (MW-10) to 2,240 mg/L (MW-12). TDS concentrations ranged from 653 mg/L (MW-12) to 1,120 mg/L (MW-10). Chloride concentrations ranged from 61.8 mg/L (MW-12) to 235 mg/L (MW-10). Sulfate concentrations ranged from 74.9 mg/L (MW-12) to 307 mg/L (MW-10). Nitrate concentrations ranged from 0.042 mg/L "J" (MW-10) to 0.065 mg/L "J" (MW-11). No nitrite was detected in any of the South Valley groundwater samples.

Field Parameters. Field parameter data obtained from the representative groundwater samples collected from wells in the South Valley during the data gaps investigation are presented in Table 5-29 and are summarized as follows. During the April 2000 monitoring event, electrical conductivity ranged from 925 µmhos/cm (MW-12[TW-12]) to 1,400 µmhos/cm (MW-10); pH ranged from 6.88 (MW-10) to 7.47 (MW-12[TW-12]); turbidity ranged from 15.6 NTUs (MW-10) to 1,090 NTUs (MW-11); and temperature ranged from 15.7°C (MW-11) to 18.9°C (MW-12[TW-12]).

During the August 2000 monitoring event, electrical conductivity ranged from 933 µmhos/cm (MW-12[TW-12]) to 1,585 µmhos/cm (MW-10); pH ranged from 7.34 (MW-10) to 7.7 (MW-12[TW-12]); turbidity ranged from 39 NTUs (MW-10) to

845 NTUs (MW-12[TW-12]); and temperature ranged from 16.9°C (MW-11) to 20.1°C (MW-10).

5.12 RIDGE STOCKPILES #1 through #9 RESULTS

Soil samples were collected from nine stockpiles (RSP-1 through -9) on the Ridge between the North and South Valleys during the RI. Ridge stockpile samples were collected from 2 feet to 2.5 feet below the stockpile surface. Four samples were collected from each Ridge stockpile and composited by the analytical laboratory into a single sample. Ridge stockpile samples were analyzed for explosives, TEPHs, and metals. Ridge stockpile samples were not analyzed for TEPHs in the kerosene range. It should be noted that the analytical laboratory inadvertently analyzed all four discrete samples collected from Ridge Stockpile #3 and #4 for explosives (i.e., the samples were not composited).

Soil analytical results for the Ridge Stockpiles are presented in Table 5-21 and on Figures 5-8 and 5-8A.

Explosives. No explosives were detected in any of the soil samples collected from the Ridge stockpiles.

TEPHs. Petroleum hydrocarbons in the diesel range (7.7 mg/kg "J-") were detected in the soil sample collected from Ridge Stockpile #1. Petroleum hydrocarbons in the motor oil range were detected in the soil samples collected from Ridge Stockpiles #1, #2, #3, #5, #6, #7, and #9 at concentrations ranging from 7.7 mg/kg "J" to 53 mg/kg "J-". Most of the petroleum hydrocarbons were detected at estimated trace concentrations.

Metals. Metals data are presented in Table 5-21 and are plotted on Figure 5-8A. A total of ten composite samples were analyzed for metals, and an additional ten samples were analyzed for phosphorous. Table 5-1B summarizes the maximum and minimum values for each metal in the Ridge Area Stockpiles.

5.13 McALLISTER DRIVE LAND BRIDGE RESULTS

Three boreholes were advanced during the RI at the upgradient toe and at the downgradient toe of the McAllister Drive Land Bridge, respectively, and selected soil samples were analyzed for nitroglycerin and PETN, and nitrate/nitrite. One soil sample was also analyzed for metals.

Soil analytical results are presented in Table 5-22 and on Figure 5-9.

Nitroglycerin/PETN. No nitroglycerin or PETN were detected in any of the soil samples collected from the land bridge.

Metals. Metals data are presented in Table 5-22 and are plotted on Figure 5-9A. One sample was analyzed for metals and phosphorous. Table 5-1B summarizes the metals values detected at the site.

Nitrate/Nitrite. Nitrate was detected in one of the samples collected from the upgradient toe of the land bridge at a concentration of 0.61 mg/kg. Nitrite was not detected in the same sample. Nitrate and nitrite were detected in all samples collected from the downgradient toe of the land bridge at concentrations ranging from 0.44 mg/kg to 1.2mg/kg and from 0.038 mg/kg to 0.042 mg/kg, respectively.

5.14 AMBIENT SAMPLE RESULTS

Twenty surface soil samples (NO-19, -27, -38, -44, -50, -68, -89, -99, -100, -118, -129, -132, -146, -170, -173, -179, and -184) were collected from outside of the areas of interest during the RI. These 20 surficial soil samples, which were used to evaluate "ambient concentrations" (as defined in Chapter 6.0, were collected from outside the areas of interest from randomly selected locations within 3 areas specified by DTSC as being acceptable sample collection locations. The three areas include the areas northwest and southwest of the TNT Strips (Figure 5-11), the west end of the South Valley (Figure 5-12), and the Ridge area northeast of the McAllister Drive Land Bridge (Figure 5-13).

Sample locations within the above three areas were chosen using a random systematic sampling design. The three areas were number gridded, and a random number generator was used to choose 20 of the grids as sample locations, using a 5:1 nodal system, as shown on Figures 5-11, 5-12, and 5-13. The grid sizes were weighted, depending on the size of the area available for ambient sample collection, such that any grid would have an equal chance of being picked by the random number generator. The total number of grids was based on a sampling design allowing the collection of up to 50 background samples. The ambient soil samples were collected from the ground surface to a depth of approximately 6 inches bgs, with the sample identification corresponding to the grid number. All ambient soil sampling locations are shown on Figure 4-3.

The ambient soil samples were analyzed for metals and phosphorous. The results are summarized on Table 5-23.

6.0 NATURE AND EXTENT OF CHEMICALS

This chapter presents a summary of the nature and extent of those chemicals detected in soil, sediment, surface water, or groundwater at the Project Site. For some chemicals (i.e., naturally occurring inorganic compounds), the evaluation of nature and extent is conducted within the context of ambient concentrations. For purposes of this evaluation, "ambient" concentrations are defined as "background" concentrations plus any anthropogenic component unrelated to DOD activities (e.g., contributions from local or regional industrial or agricultural activities). Section 6.1 discusses statistical methods (i.e., 95th percentile and Wilcoxon Rank Sum Test) and other graphical tools used to help identify metals impact within the Project Site. The remaining sections examine the lateral and vertical extent, migration pathways, and transport mechanisms for chemicals in each area of interest at the Project Site (i.e., TNT Strips; Howitzer Test Facility; North Valley Military Landfill; Ammunition Renovation/Primer Destruction Site; North Valley Groundwater; Miscellaneous North Valley Soil; Dynamite Burn Site; Flare Site; Demolition Sites #1, and #3; South Valley Soil, Sediment, Surface Water, and Groundwater; Ridge Stockpiles #1-#9; and McAllister Drive Land Bridge).

The findings and conclusions found in this chapter are based on the data collected during the non-OE RI. The findings and conclusions could change if significantly different conditions are encountered during and/or after remediation. Additionally, regardless of the findings presented in this section, all chemicals detected in site media are further evaluated in Chapter 7.0 of this document to evaluate the potential human health and ecological impacts.

6.1 AMBIENT CONCENTRATIONS FOR NATURALLY OCCURRING METALS

Ambient soil concentrations are calculated using data from the 20-sample ambient soil data set (as described in Section 5.14). Ambient concentrations for inorganic compounds were calculated as the 95th percentile of the ambient soil data. The 95th percentile values, along with other information, are used to assess the nature and extent of inorganic soil impact. Table 6-1 summarizes the 95th percentile-based ambient concentrations for each of the inorganic compounds analyzed in the ambient soil samples (including the four "essential elements" calcium, magnesium, sodium, and potassium). Ambient samples were not analyzed for nitrate or nitrite; therefore, a 95th percentile could not be calculated. The 95th percentile could also not be calculated for silver, thallium, molybdenum, and selenium due to very high rates of non-detected results for the ambient soil data set.

Data on ambient concentrations for naturally occurring chemicals in groundwater are not extensive.

Monitoring well MW-10 is the only well upgradient of all known sites and was sampled one time in April 2000. This well is situated in the South Valley, upslope and upgradient of Demolition Sites #1, #2, and #3 and the Flare Site. During the RI, it was placed upgradient of known sites to provide reference for ambient groundwater conditions at the Project Site. Samples collected in April 2000 were analyzed for metals (filtered) using EPA Method SW6010B, VOCs using EPA Methods SW8260B, PAHs using EPA Method SW8310, explosives using EPA Method using SW8330, hydrazine using EPA Method SW8315, general water chemistry (EPA Methods E160.1, E160.2, and E300 series), and total organic carbon using EPA Method E415.1. All organic compounds were non-detect. Detected inorganic compounds include barium (0.045 mg/L), calcium (155 mg/L), magnesium (92.4 mg/L), manganese (0.2 mg/L), potassium (1.35 mg/L), and sodium (87.1 mg/L). Chloride was reported at 235 mg/L, sulfate at 307 mg/L, and nitrogen (nitrate as N) at 0.042 mg/L "J". TDS was measured at 1120 mg/L and suspended solids were measure of at 74 mg/L.

As noted in Section 5.14, the ambient soil samples were collected at the surface to a depth of approximately 6 inches bgs. These samples are used in comparison to other samples collected from areas of interest from similar depths and soil types, as well as samples from significantly greater depths and different soil/lithology. Questions concerning the comparability of these samples to other in situ samples collected at varying depths and lithologies are addressed in Appendix E, which presents a detailed evaluation of the heterogeneity associated with soil data for selected metals. The evaluation presented in Appendix E indicates that weak, but statistically significant, concentration differences can occur with respect to both sample depth and sample lithology. However, the differences, in general, do not appear to be of sufficient magnitude to preclude the use of surficial-only samples to represent ambient conditions.

It is important to understand that exceedance of the 95th percentile is not necessarily an indication of impact. For example, even if the 20-sample soil data set truly characterized the ambient population without any biases, 5 percent of any group of samples compared to the 95th percentile of the ambient soil data set would, in theory, exceed the 95th percentile based on random chance alone. This is referred to as the statistical false-positive error rate. Since hundreds of soil sample results are available for the site as a whole for comparison to the 95th-percentile-based ambient concentration, it can be expected that all chemicals will exceed their respective ambient concentrations in several soil samples due simply to statistical false-positives. Therefore, it is useful to also compare sets of data from specific areas to the ambient data set using other statistical methods, such as the Wilcoxon Rank Sum Test. The Wilcoxon Rank Sum Test examines systematic differences between data sets. Such a procedure provides a broader view of potential soil impact, but can also be sensitive to relatively slight concentration differences.

Ninety-fifth percentile exceedance rates that are well in excess of 5 percent and Wilcoxon Rank Sum Test results that indicate a statistically significantly higher

concentration in an area of interest relative to ambient concentrations tend to occur together and indicate some type of systematic, rather than random, effect. The systematic effect may not represent a chemical impact; natural chemical variability, analytical bias, and other processes need to be considered. These issues are addressed further in Appendix E.

Table 6-2 summarizes the soil samples from the areas of interest that exceed the 95th percentile of the ambient soil data set. Table 6-3 presents the results of the Wilcoxon Rank Sum Test that compares the areas of interest to the ambient soil data set, by area of interest and by COIs for those specific cases where a 95th percentile was exceeded. These tables, as well as isoconcentration contour maps and concentration versus depth scatter plots (presented in Appendix E), are used in the following descriptions of the nature and extent of impact.

For each COI, isoconcentration contour maps were generated using the highest reported concentration between a depth of 0 feet and 2 feet. In order to differentiate the values presented, color grading was used. The colors were set equal to the 95th percentile, the remediation goal as defined in Chapter 7.0, and the Preliminary Remediation Goal (PRG).

The scatter plots (Appendix E) show the 95th percentile and identifies some or all specific samples that exceed 95th percentile (depending on the number of exceedances). For example, the isoconcentration contour maps in Appendix E were generated using only surficial samples, which best represent worst-case concentrations and allow use of the ambient samples for better areal control of the contours. The scatter plots (Appendix E) present soil samples from all depths but included only in situ soil samples, thereby excluding the relatively few sediment and stockpile samples, none of which provide data on concentration variability as a function of depth. Alternatively, Tables 6-2 and 6-3 account for all soil samples collected, both in situ and stockpiled. Sediment samples were generally excluded from the tables and graphics because they are not directly comparable to soil samples. Sediment samples have been subjected to natural concentrating processes and can generally be expected to exhibit naturally higher concentrations of heavy minerals (which include many of the metals designated as COIs) relative to soil samples.

6.2 NATURE AND EXTENT, NORTH VALLEY AREAS OF INTEREST

6.2.1 TNT Strips

DOD-related activities at the TNT Strips have impacted soil/bedrock toward the upper portion of the south-facing slope of the North Valley. Explosive-impacted soil/bedrock was also identified downgradient of the TNT Strips area in the North Valley floor. Explosives were not detected outside the Project Site boundary to the north and east.

Other chemicals were detected at the TNT Strips as shown on Figures 5-1, 5-1A, and 5-1B. These include unknown hydrocarbons in the motor oil range, PAHs, dioxins/furans (combustion by-products), and inorganics. The unknown hydrocarbons are interpreted to represent possible TNT breakdown products, since the characteristic chromatogram signature of fuel hydrocarbons is minimal (Appendix I). Unknown hydrocarbons were detected at two of the three locations sampled for TEPH along the TNT Strips at concentrations ranging from 3.7 mg/kg to 180 mg/kg. Unknown hydrocarbons were not detected in those samples collected at depths greater than 2 feet bgs.

Inspection of the inorganic data does not appear to indicate impact with respect to metals in the TNT Strip area. For those metals exceeding the 95th percentile (Table 6-2), five (chromium, cobalt, copper, iron, and nickel) exhibited a statistically significant difference between the TNT Strip area concentrations and ambient concentrations, based on the Wilcoxon Rank Sum Test results (Table 6-3). However, further review of the isoconcentration contour maps and the scatter plots (Appendix E) shows no systematic contaminant pattern for these metals in the TNT Strips area.

The lateral and vertical extent of the unknown hydrocarbons, PAHs, and dioxins/furans soil impact has not been fully defined; however, these compounds are typically not mobile in the soil environment and would not be expected to extend great distances from the source (i.e., the strips), except when disturbed by erosive mechanisms. By addressing the TNT issues, these compounds will be addressed as part of the remedial action alternative(s). Therefore, the lateral and vertical extent of the explosive compounds has been used to characterize the extent of soil affected by COIs, (including unknown hydrocarbons, PAHs, and dioxins/furans) at the TNT Strips. Characterization of extent of unknown hydrocarbons, nitrate, PAHs, and dioxin/furans at the TNT Strips will be determined through excavation confirmation sampling (see Table 8-1).

6.2.1.1 Lateral and Vertical Extent of Explosive Compounds.

As shown on Figures 5-1, 5-2, and 5-3, explosive compounds were detected in the immediate vicinity of the TNT Strips. For purposes of the following discussion, the evaluation of lateral and vertical extent of TNT is conducted, in part, within the context of the PRG of TNT of 16 mg/kg. The PRG is further discussed in Section 7.0. The following observations can be made with regard to the nature and extent of explosive compounds along, and in close proximity to, the strips (i.e., areas identified by the lack of vegetation) (see Figure 5-2).

TNT is present at significantly higher concentrations than any other explosive compound. The maximum concentration of TNT detected along the TNT Strips is 380,000 mg/kg (38 percent by weight) at TNT Strip #1 at 1 foot bgs. Two additional samples exceeded 10 percent: One in TNT Strip #1, directly below the 38 percent sample, and the other also in TNT Strip #1, further to the south (29 percent concentration of 2, 4, 6 TNT). Soil impacted with TNT at concentrations

exceeding 100,000 mg/kg (10 percent by weight) is classified as OE and needs to be handled accordingly.

TNT concentrations greater than 100,000 mg/kg were not detected away from the strips or at depths greater than 2 feet bgs. Significant variations in TNT concentrations occur within relatively short distances.

Generally, rapid decreases in TNT concentrations were noted between 2 feet and 4 feet bgs.

TNT breakdown products (TNB, 2,4-DNT, and amDNTs), when present, are detected at significantly lower concentrations than TNT.

TNB is typically present at higher concentrations than either amDNTs or 2,4-DNT, is present predominantly along the strips or is in close proximity to the strips, and is usually detected in association with TNT. The maximum concentration of TNB detected along the strips is 310 mg/kg at TNT Strip #2 at 2 feet bgs.

2,4-DNT is also present at low concentrations and is typically encountered along the TNT Strips or in close proximity to the strips. The maximum concentration of 2,4-DNT detected along the strips is 110 mg/kg at TNT Strip #1 at 2 feet bgs. Low levels of explosive compounds (16 mg/kg or less) have been detected in the bedrock to a depth of 10 feet bgs, directly beneath the axis of the strips in some locations.

Similarly, the following observations can be made with regard to the nature and extent of explosive compounds off the axis of the strips (see Figure 5-3).

Very high (i.e., percent) TNT concentrations were not identified off the axis of the strips. TNT concentrations decrease significantly, approximately 5 feet away from the axis of the strips. One exception was noted in the vicinity of the TNT-1F series step-out situated along a firebreak in an area where the surficial soil has been regularly disturbed via discing.

AmDNTs are typically encountered off the strips, especially in the downslope direction. The maximum concentration of amDNTs detected is 80 mg/kg at TNT Strip #1 at the surface.

In general, low concentrations of explosive compounds (16 mg/kg or less) were observed between 5 and 10 feet in the upslope direction, between 5 and 20 feet in the downslope direction from the axis of the TNT Strips, and predominantly within the upper 2 feet of soil. The greater downslope impact is likely the result of downslope gravity movement of soil and/or surface precipitation runoff.

Data from the TNT-1C, -1F, -4C and -5A series step-outs are shown on Figures 6-1, 6-2, and 6-3 to compare the lateral and vertical extent of total explosive compound concentrations that have impacted the soil/bedrock in the immediate

vicinity of the TNT Strips. Figures 6-1, 6-2, and 6-3 indicate that the lateral and vertical extent of soil impacted with varying concentrations of explosives (in particular percent concentrations of TNT) can be drawn or estimated. Soils impacted with explosive compounds on, and in close proximity to, the strips themselves are estimated to reach to a depth of approximately 10 feet immediately below the axis of each strip, decreasing rapidly away from the strips to depths of 2 feet or less, approximately 40 feet in the downslope direction and less than 20 feet in the upslope direction.

Surface soil samples collected during the data gaps investigation, along the ridgeline (approximately 20 feet to the north, 160 feet to the east, and 420 feet southeast of TNT Strip #1), detected TNT at concentrations ranging from 8.4 mg/kg "J+" (TNT-R4) to 71 mg/kg "J+" (TNT-R2). TNT was also detected approximately 320 feet northwest of TNT Strip #4 at 200 mg/kg (screening-level result) along an old trail. Figure 6-4 shows the estimated lateral extent of soil/bedrock potentially impacted by explosive compounds above the PRG (17 mg/kg or greater).

It should be noted that no explosive compounds were detected in a series of five additional boreholes advanced along the south-facing slope, between the TNT Strips and the boreholes in the valley floor where low concentrations (17 mg/kg or less) of explosive compounds were detected. Similarly, additional surface samples collected on the Ridge, approximately 45 feet northwest of TNT Strip #1 and 275 feet northwest of TNT Strip #4, show no explosives impact in the surficial soils. Six additional locations on the Ridge to the east and southeast of TNT Strip #1 also show no explosives impact in the surficial soils. No explosive compounds were detected outside the Project Site boundary. A portion of TNT Strip #1 and TNT Strip #2 extends onto property owned by the City of Benicia (see Figure 6-4). These locations are situated within the Project Site boundary.

The analytical results indicate that the extent of soil impacted with concentrations of explosive compounds greater than 16 mg/kg encompasses the TNT Strips in the central portion of the north Ridge, (see Figure 6-4) approximately 450 feet downslope of the TNT Strips.

The upper area of soil impacted by explosives represents the TNT Strips area and its immediate vicinity, where explosive compounds originating on the strips themselves have been spread by the transport mechanisms described below. The lower area along Midway Road represents soil impacted by low concentrations of explosives likely from spillage along the roadway and deposited along the surficial drainageway in the bottom of the valley.

Three additional isolated areas are identified along the top of the Ridge, as depicted on Figure 6-4. An elongated area extending a distance of approximately 450 feet in an east-west direction defined along an old trail was identified on aerial photographs. In addition, two areas were identified on the Ridge along the northeastern boundary of the Project Site (TNT-R4 and TNT-R5).