EXPANDED SITE INSPECTION REPORT

Environmental Investigation at the Formerly Used Defense Site (FUDS)
at the Benicia Arsenal, Benicia, California
FUDS Number: J09CA075600

FINAL

Prepared for:

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EXPANDED SITE INSPECTION REPORT

BENICIA ARSENAL, BENICIA, CALIFORNIA

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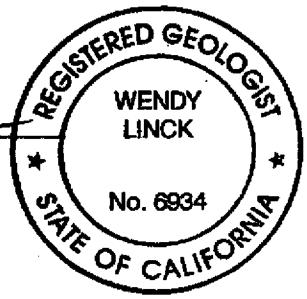

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HITS REPORT

This data has been included on CD in Adobe® Acrobat® PDF format for easier use and to reduce the size of the report. This data is comprised of all analytes detected above method reporting limits for the Expanded SI and all previous investigations at the Arsenal conducted by USACE.

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LIST OF ACRONYMS AND ABBREVIATIONS

AFV	Armored Fighting Vehicle
Arsenal	former Benicia Arsenal
ASTM	American Society for Testing and Materials
ASTs	Above Ground Storage Tanks
bgs	below ground surface
BSL	Benicia Screening Level
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
BIS2EHP	bis (2-ethylhexyl) phthalate
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CHM	Conceptual Hydrogeologic Model
COI	chemicals of interest
CPT	Cone Penetration Testing
CSM	Conceptual Site Model
DCE	dichloroethene
DERP	Defense Environmental Restoration Program
DoD	Department of Defense
DDT	Dichloro Dipheryl Trichloroethene
DWR	Department of Water Resources
EC	electrical conductivity
EPA	Environmental Protection Agency
ESLs	Environmental Screening Levels
Expanded SI	Expanded Site Investigation
FA/BC	Forsgren Associates/Brown and Caldwell
FAR	Further Action Recommended
FUDS	Formerly Used Defense Sites
FSIP	Field Site Investigation Plan
GSA	General Services Administration
HVOC	Halogenated Volatile Organic Compound
IDW	Investigation Derived Waste
IRR	Imminent Health Risk Requiring an Immediate Response
MCL	maximum contaminant levels
MDL	method detection limit
mg/kg	milligrams per kilograms
mg/L	micrograms per liter
msl	mean sea level
MtBE	Methyl tertiary-Butyl Ether
NDAI	No DoD Action Indicated
NPDES	National Pollutant Discharge Elimination System
Norcal	Norcal Geophysical
ORP	oxidation reduction potential
PA	Preliminary Assessment
PAH	polynuclear aromatic hydrocarbon
ppbv	parts per billion by volume
PPE	personal protective equipment
PRP	potentially responsible party

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

PVC	poly vinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
QC	quality control
QCSR	Quality Control Summary Report
RA	removal action
RCRA	Resource Conservation Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
RWQCB	Regional Water Quality Control Board
SI	Site Inspection
Spieker	Speiker Properties
SVOC	Semi-volatile organic compound
TCE	trichloroethene
TDS	Total Dissolved Solids
TIC	Tentatively identified compound
TPH	Total Petroleum Hydrocarbon
TPHD	Total Petroleum Hydrocarbon as diesel fuel
TPHG	Total Petroleum Hydrocarbon as gasoline
TPHMO	Total Petroleum Hydrocarbon as motor oil
µg/L	microgram per liter
uS/cm	microsiemens per centimeter
USACE	United States Army Corps of Engineers
UST	Underground Storage Tank
VC	vinyl chloride
VOC	Volatile Organic Compound
1,1-DCA	1,1-dichloroethane
1,1,1-TCA	1,1,1-trichloroethane

EXECUTIVE SUMMARY

This Expanded Site Inspection (SI) Report presents data from an environmental investigation conducted at the former Benicia Arsenal (Arsenal), a formerly used defense site (FUDS), located in Benicia, California. This work was performed on behalf of and with oversight by the United States Army Corps of Engineers (USACE), Sacramento District.

The investigation was based on the Preliminary Assessment (PA) prepared to determine if past United States Department of Defense (DoD) activities warrant further environmental investigation (FA/BC, 2004a). The PA addressed DoD uses of this facility prior to its closure and decommissioning in 1964. Supplemental research was performed after the final PA for the Fuel Storage Tank Removal Action Plan, that changed the recommendations of three sites from Further Action Recommended (FAR) to No DoD Action Indicated (NDAI). As a result, of the 389 sites evaluated in the PA, 327 are considered NDAI and 62 are categorized as FAR. This report covers 53 of the 62 FAR sites. Of the remaining 9 FAR sites, the available records indicate the possibility of fuel storage tanks or the data recommends a risk evaluation. The fuel storage tank-related sites were not included in the scope of the Field Site Investigation Plan (FSIP) and can be found in the Fuel Storage Tank Removal Action Plan (BC, 2004b).

The Expanded SI focused primarily on groundwater impacts at the former Arsenal. This field work was designed to accomplish as much of the investigative work that could be done in 21 field days. A dynamic sampling strategy was used to meet the goal. Samples were collected and quickly evaluated to guide subsequent sample collection. A decision chart was used to guide collection of the necessary data for the study areas. Contingencies were planned so that field activities could be modified quickly as the investigation proceeded.

A total of 14 soil samples, 16 soil gas samples, 117 Hydropunch® groundwater samples, 15 storm water catch basin samples, and 14 groundwater well samples were collected during this investigation. The samples collected were analyzed for compounds that may have been commonly used and discarded by the DoD and chemicals that demonstrate post army use methyl tertiary-butyl ether (MtBE) at these locations. All laboratory data underwent data verification and data validation. In general, the data collected in support of this investigation are considered usable for the purpose of engineering decision making with the exception of a low bias in the mobile lab diesel fuel data due to questionable extraction efficiency of their modified procedures for this method. This resulted in all diesel fuel results reported by the mobile laboratory to be considered as screening level data.

Volatile samples were analyzed by a mobile laboratory for rapid turn-around. The results were evaluated to determine the presence or absence of key contamination indicators (cis-1,2-dichloroethene, trichloroethene, vinyl chloride, benzene, gasoline and diesel fuel). If these key indicators were present above the laboratory method detection limits, additional borings were advanced to vertically and laterally delineate the contamination.

The following are conclusions for each study area:

- All metal results in soil at Spur E, and the Firing Range are lower than the Benicia Screening Levels indicating no significant DoD impact at these locations.

- Another contractor identified trichloroethene, diesel fuel, motor oil, and pesticides in soil and groundwater at the Post Dumpsite. The presence of these contaminants may indicate possible discharge of DoD waste to the area. Further investigation is warranted.

- Diesel fuel and motor oil was found in deep groundwater, approximately 300 feet downgradient of the armored fighting vehicle (AFV). Therefore, there is insufficient evidence to eliminate the possibility of a release at the AFV but the Post Dumpsite, adjacent the AFV, maybe the source area.

- No significant DoD impact was reported at the Salvage Yard, Fillsite 3, the former vehicle maintenance buildings at T222, T221, 171, 172 and TO 73, the former heavy equipment yard (Buildings 50 and 111), and the former battery charge building (Building 101).

- MtBE was detected in the Open Ditch and industrial area indicating post-Army use. MtBE is a fuel additive that was used after the Arsenal was decommissioned in 1964.

- Diesel fuel is also present in the Open Ditch and Valero Well #117. The trend of diesel fuel concentrations in Valero Well #117 have been steadily increasing within the last 10 years. This trend indicates a recent release and the diesel fuel found in this well is not associated with former DoD activities.

- At the Eastern Waste Area, south of the former Nike Missile Assembly Facility (CL1), trichlorothene (TCE) was detected in an upgradient boring suggesting there may be another source of contamination. There is a current Regional Water Quality Control Board San Francisco Region (RWQCB) site nearby, upgradient to the Eastern Waste Area and CL1, 4186 Park Road. This site is currently under review with the RWQCB.

- In the industrial area,
  - There is no additional investigation warranted for the following:
    - The former sandblast building/paint spray shop at Building 4
    - The former store house/engine rebuild at Building 31
    - The garage/repair shop at Building 42
    - The former heavy equipment yard at Building 50 and 111
    - The former battery charge building (Building 101)
    - The locomotive house at Building 156
    - the former storehouse/shop at Building TO-131
    - The former steam cleaning building (Building 165A)

- The former paint shop at Building 166
- The bamstock/storage/vehicle shops at Building 167
- Fillsite 1
- Former maintenance building, body and radiator shop (Building Y199)

o There appears to be separate releases of TCE that have co-mingled into one plume in the industrial area. The primary source areas appear to be from Building 165, the 50 Series Complex, and Building 120. Solvents from degreasing tanks located in Building 165 and the 50 Series Complex may have been discharged into the storm/sewer system. Other sources may be attributed to post Army releases, including the possible discharge of solvent wastes into the Building 57A vat from a former transmission shop and from cleaners used in a former wheel manufacturing business at Building 165. The sources of the solvents found at Building 120 may be attributed to the discharge of process water into an underground neutralizer tank on the north side of the building.

o Releases from the former underground storage tanks (USTs) at Buildings 31, 53, 103, and 154 appear to have impacted shallow groundwater and soil within close proximity of the former USTs with fuels. The lateral and vertical extent of fuels has been defined.

- Gasoline was not detected in any soil samples above RWQCB Environmental Screening Levels (ESLs) of 400 milligrams per kilograms (mg/kg).
- The highest gasoline concentrations in groundwater were reported near the former USTs at Building 53 and 154.
- Diesel fuel soil concentrations that exceed the ESL of 500 mg/kg are at four locations: beneath the 50 Series Complex, in surface soils at the suspected drum storage area at Building 51, west of Building 161, and in the area of a buried asphalt layer at Fillsite 1.
- Diesel fuel is found in shallow groundwater in the area of the former USTs at Buildings 31, 53, and 154, north and south of Building 120, along Tyler Street at FS001HP012 and during a previous investigation at the former Building 118A aboveground storage tanks (ASTs). The source of diesel fuel in the area of Building 120 and at FS001H0012 is not known. A small isolated area of diesel fuel and motor oil reported during a previous investigation in B118ATR005 may be attributed to a small release from the former Building 118A ASTs.
- Motor oil in soil is found exceeding the ESL of 1,000 mg/kg beneath the 50 Series Complex, near former USTs at Building 53 and 154, in the area of a buried asphalt layer at Fillsite 1 and at the former Building 31 UST.
- Motor oil was detected in shallow groundwater exceeding the ESL of 640 μg/L in samples collected near Building 59, at the former Building 118 ASTs and near Building 59, and north of Building 120. All of these areas are isolated and have been delineated.

  - Lead-contaminated soil exists south of the 50 Series Complex at B058ASB001. The lateral extent is bounded to the north, west and east but not to the south. Further delineation is necessary.

- Results from sampling and investigation of shallow storm water catch basins in the industrial area indicate that the storm water drain system intercepts shallow groundwater.

SECTION 1
INTRODUCTION AND BACKGROUND

The Expanded Site Inspection (SI) was conducted at the former Benicia Arsenal (Arsenal) under General Services Administration (GSA) Contract No. GS-23F-0067M, Task Order 9T3N176PG and GSA Contract No. GS-10F-0101L, Veterans Administration Purchase Order 674-V40113 to comply with requirements of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the Resource Conservation Recovery Act (RCRA), as appropriate. This investigation was conducted in accordance with the Expanded SI Field Site Investigation Plan (FSIP) (BC, 2004a) and the Quality Assurance Project Plan (QAPP) (Forsgren Associates/Brown and Caldwell [FA/BC], 2001). This section of the document describes the relationship between the Expanded SI and the Formerly Used Defense Sites (FUDS) program, the methodology of choosing these sites, how this report is organized, a description of the problem and scope, the location, and lastly, the historical and subsequent post-Army use of the Arsenal.

In accordance with FUDS program goals and U.S. Army Corps of Engineers (USACE) guidance documents, this Expanded SI was conducted to determine the presence or absence of chemicals that may have impacted the environment from past Department of Defense (DoD) activities at the former Arsenal. FUDS program funding can only be used to assess and remediate DoD liability at eligible property, which is defined as real property formerly owned by, leased by, possessed by, or otherwise under the jurisdiction of the Secretary of Defense or elements of the U.S. military. Under the FUDS program, land that was previously utilized by DoD and that has no "beneficial use" history will be characterized and, if necessary, remediated to an appropriate standard.

Under the FUDS program, one of the parameters to be considered during the initiation of a project is whether the property (or specific item/site) has been beneficially used by any owner, operator, or other party that may be considered a potentially responsible party (PRP). If USACE determines the contamination was caused solely by DoD, it will be mitigated by USACE through the FUDS program. If an investigation is initiated (by any party) and DoD is determined to be only partially responsible, USACE will investigate to the extent necessary to determine DoD liability.

Consideration must also be given to the ability to identify DoD generated contaminants from contaminants introduced by other PRPs, on or off the FUDS property. If identification of separate contaminant streams cannot be achieved, or if separate remediation of DoD generated contaminants cannot be realized, the project may be ineligible for remediation under the FUDS program. If commingled contamination exists, a PRP project must be initiated and the Department of Justice will negotiate a contribution settlement with the current landowner/responsible party based on a liability analysis.

Further, the Defense Environmental Restoration Program – Formerly Used Defense Sites (DERP-FUDS) policy does not allow the USACE to provide cost recovery to property owners nor does it allow USACE to recover costs from property owners for remedial work. However, the property owner may initiate an investigation and/or clean-up action and subsequently seek cost reimbursement from the Department of Justice by filing a tort claim.

As part of the FUDS process at the former Arsenal, a Preliminary Assessment (PA) was prepared to determine if past DoD activities warrant further environmental investigation (FA/BC, 2004a). The

PA addressed DoD uses of this facility prior to its closure and decommissioning in 1964. The specific goal of the PA was to develop sufficient information to categorize each site within the former Arsenal property as one of the following:

- No DoD action indicated (NDAI);
- Further Action Recommended (FAR); or
- Imminent health risk requiring an immediate response (IRR).

Among the 389 sites evaluated in the PA, 324 were considered NDAI and 65 were categorized as FAR (FA/BC, 2004a). No IRR sites were identified. Since the submittal of the final version of the PA, more research was conducted as part of the Fuel Storage Tank Removal Action Plan (BC, 2004b) where the recommendation of three sites changed from FAR to NDAI. Therefore, there are 327 NDAI sites and 62 FAR sites at the former Arsenal. The Expanded SI investigates 53 of the 62 FAR sites. The remaining 9 FAR sites indicate the possibility of fuel storage tanks and were investigated separately.

The fuel storage tank-related sites were described and field activities were performed as part of the Fuel Storage Tank Removal Action Plan (BC, 2004b). However, the results from Fuel Storage Tank Removal Action are included in this SI Report, where appropriate. More detailed information about the investigation of these fuel storage tanks will be documented in a future report.

Among the 53 FAR sites included in the Expanded SI, five sites (Building 26, Building 28, Building 53, Building 103 and Building 154) underwent UST removal actions in 2002 (Geofon, 2003). Soil and groundwater samples were collected when the USTs were removed. Additional investigation was requested by the lead regulatory agency for further delineation of petroleum impacts at three sites (Buildings 53, 103 and 154) and was performed during the Expanded SI.

This Expanded SI report is organized into eight sections. Section 1.0 presents background information, including the historical uses and a summary of previous investigations. Section 2.0 describes the investigative approach. Section 3.0 presents a summary of field methods and sampling rationale. It also summarizes disposal of Investigation Derived Waste (IDW). Section 4.0 describes the regional, localized, and site-specific geology and hydrogeology. Section 5.0 describes the quality and usability of the data collected during this site inspection. A summary and analysis of results are presented in Section 6.0. Section 7.0 presents the conclusions and recommendations and references are included as Section 8.0.

This Expanded SI report contains seven appendices. Each appendix is described briefly below.

- **Appendix A – Delineation Limits for the Expanded SI Field Investigation**. This appendix includes tables by analytical method of analytes with their respective delineation limits used in the field investigation. These are the same tables included in Section 5 of the Expanded SI FSIP (BC, 2004a).

- **Appendix B – Background Details of the Expanded SI Sites**. This appendix includes PA summary forms for each Expanded SI site. These forms have been updated with information gathered from the Expanded SI and other relevant investigations since the PA.

- **Appendix C – IDW Manifests**. Transportation and disposal manifests for soil generated during the Expanded SI.

- **Appendix D –Cone Penetration Testing and Soil Boring Logs.**

- **Appendix E - Storm Drain Investigation Letter Memorandum**. A letter memorandum sent to USACE that documents the location and analytical sample results of piezometer and storm water drain catch basin samples collected in the industrial area of the Arsenal.

- **Appendix F – Water Quality Measurements**. Data is included in this appendix include water depth to water, groundwater elevations, pH, temperature, electrical conductivity (EC), oxidation reduction potential (ORP), and total dissolved solids. All data gathered for the Arsenal for the Expanded SI and previous investigations is included in this appendix.

- **Appendix F – Legend for Analytical Results**. Definitions of data acronyms, quality control flags, and reason codes.

- **Appendix G – Analytical Results for Soil**. The analytical results for soil are in Adobe Acrobat® PDF format on the included compact disc (CD). The PDF file is bookmarked by analyte.

- **Appendix H– Analytical Results for Soil Gas**. The analytical results for soil gas are in Adobe Acrobat® PDF format on the included compact disc (CD). The PDF file is bookmarked by analyte.

- **Appendix I - Analytical Results for Groundwater**. The analytical results for groundwater are in Adobe Acrobat® PDF format on the included compact disc (CD). The PDF file is bookmarked by analyte.

- **Appendix J - URS 2004 Pipeline Soil and Groundwater Investigation**. Complete set of tables for soil and groundwater samples collected in the area of the Post Dumpsite and the former Nike Missile Assembly Facility.

- **Appendix K - Armored Fighting Vehicle Groundwater Investigation Letter Report**. A letter report sent to USACE that documents the location and analytical sample results of groundwater samples collected downgradient of the buried armored fighting vehicle (AFV). The AFV is also known as the popping pot in this Expanded SI.

1.1 Problem Definition and Scope

Among the 53 FAR sites included in the Expanded SI, no previous investigation had been performed at most of them. An initial evaluation had already been performed at the 50 Series Complex, the surrounding UST sites (Building 31, 47, 53, 103 and 154) and a nearby fillsite (Fillsite 1). An impact to the environment was found but additional investigation was necessary to delineate the impact to the environment. The goal for the Expanded SI was to determine the extent of any impact found at the 53 FAR sites.

The Expanded SI focused primarily on potential groundwater impacts at the former Arsenal. This strategy was based on the assumption that any significant subsurface releases related to DoD activity would have impacted groundwater by this time, since groundwater is shallow (usually less than 8 feet below ground surface [bgs]) in the flatland areas adjacent to Suisun Bay and it has been at least 40 years since DoD activity ceased at the former Arsenal.

Six Most Frequently Detected Groundwater Contaminants at Benicia Arsenal	
Analyte Name	Analytical Method
Cis-1,2-dichloroethylene	SW8260B
Trichloroethylene	SW8260B
Diesel-range organics	SW8015B
Trans-1,2-dichloroethene	SW8260B
Gasoline-range organics	SW8015B
Vinyl chloride	SW8260B

Delineation limits of six key indicators were used to characterize the lateral and vertical extent of contamination. The six key indicators were selected from the most frequently detected groundwater contaminants found at the Arsenal and the mobile laboratory's capabilities. Each key indicator had a delineation limit that was used. For water, all of the delineation limits were based on the mobile laboratory's abilities. The delineation limits were at least as stringent as the maximum contaminant levels (MCLs) established by Environmental Protection Agency (EPA) and the State of California for drinking water. For those analytes where a MCL was not established (i.e., fuels), the Environmental Screening Levels (ESLs) established by the California Regional Water Quality Control Board San Francisco Region (RWQCB) is used (RWQCB, 2005). In soil, delineation limits for metals were based on the Benicia Screening Levels (BSLs)[1], which are described in the Final Soil Assessment Criteria for the Former Benicia Arsenal, Benicia, California (FA/BC, 2002b). The BSLs include ambient metals concentrations. Appendix A includes tables listing the delineation limits used in this investigation by analytical method.

Key Groundwater Indicators for Expanded SI	
Analyte Name	Analytical Method
Cis-1,2-dichloroethylene	SW8260B
Trichloroethylene	SW8260B
Diesel-range organics	SW8015B
Benzene	SW8260B
Gasoline-range organics	SW8260B
Vinyl chloride	SW8260B

All investigative work in the study area was designed to be conducted in a single field mobilization and for no longer than 21 field days. The number of field days was an estimate determined during the planning stages of the project. Funding for the project was based on this estimate. A dynamic sampling strategy was used to meet this goal. The strategy involved collecting samples and quickly evaluating the resulting data to guide subsequent sample collection. A decision diagram (Diagram 1-1) was developed and used to help the project team acquire the necessary data for each study area. The diagram was used to determine if additional step-out/step-in borings were needed at each Expanded SI Site.

Soil samples were focused in areas of suspected surface releases or in areas that needed delineation of existing soil contamination. An additional consideration was added to the sites with suspected surface release. Where asphalt was present, soil samples were planned at 2 and 5 feet below any subgrade materials to minimize the possible impact from leaching of the asphalt into the underlying soil. Where asphalt was not present, soil samples were planned at 0.5 and 5 feet below subgrade

[1] BSLs are intended to identify concentrations of chemicals in soil that are protective given the exposure scenarios assumed. These values will be used by the FUDS program to evaluate chemicals in soil at the former Arsenal.

materials. These depths were developed with the regulators in order to comply with any risk modeling that may be conducted in the future.

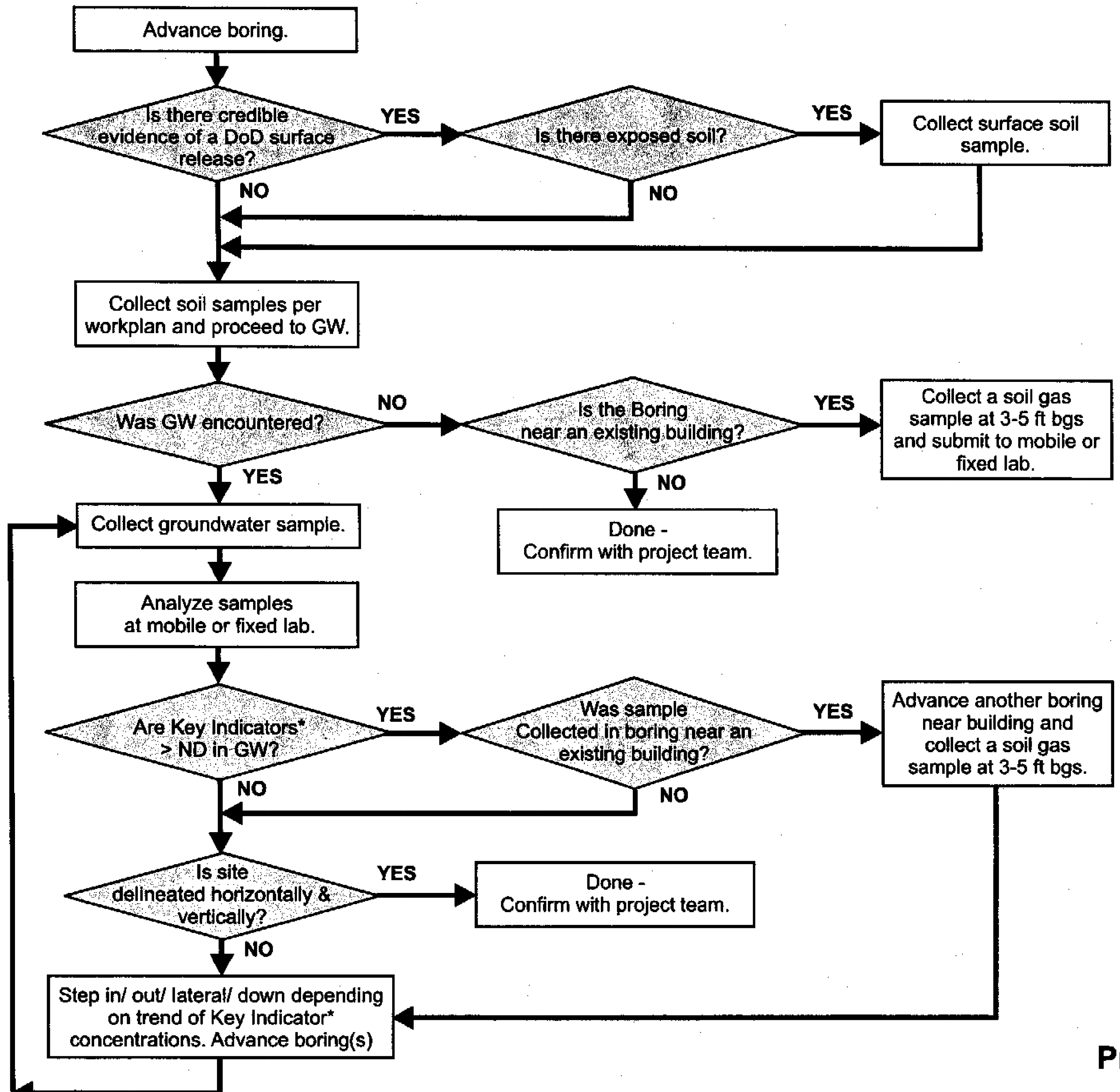
After the primary effort was conducted for the Expanded SI in April and May 2004, chemical results from the groundwater samples collected in the industrial area indicated a distinct trend in lateral extent that coincided with the location of the storm water drain system. Additional investigative work was performed to locate and sample storm drain catch basins upstream, within and downstream of the industrial area.

New terminology of "delineation limits" was introduced in the Expanded SI FSIP and definitions are listed below to aid the reader in understanding the terminology and approach used in this report (BC, 2004a).

- The word "delineation" in terms of contamination means to non-detect in the vertical and horizontal direction.

- Comparisons of groundwater results to MCLs were used as a criterion for possible drinking water sources at sites located in the highlands since groundwater quality meets the total dissolved solids (TDS) (less than 3,000 mg/L)or 200 gallon per day criteria (State Board Resolution No. 889-63, Regional Board Resolution No. 89-39 , and the Basin Plan). If MCLs were not established for a particular analyte, then the representative RWQCB ESL was used. However, MCLs are not appropriate in the lowland areas, where TDS is high (>3,000 mg/L). In the lowland areas, comparison criteria of RWQCB ESLs (RWQCB, 2005) were used for groundwater categorized as not a source of drinking water. Some sites are complicated by the fact that a portion of the site is within the lowlands and the highlands (e.g. the former NIKE missile repair facility). Therefore, tables included with these sites include comparison criteria for MCLs or ESLs. In order to minimize the confusion, a summary of the location of the lowlands and highlands is provided in Section 4 and repeated in Section 6 with more detail by each site.

- Comparisons to soil results were made to RWQCB ESLs and BSLs. For metals in soil, ambient concentrations were also considered. These values were established for the program and can be used as limits to guide any further investigation (FA/BC, 2003a). As a result, figures and text include these references.



*** Key Indicators**
Cis-1,2-dichloroethene
Trichloroethene
Vinyl Chloride
Benzene
Gasoline
Diesel Fuel

Sites will be delineated in the following order based on highest risk to human health and the environment:
1. Sites with possible exposure by direct contact (e.g. exposed soil)
2. Sites with impacted subsurface soil with no cap
3. Sites with impacted groundwater by VOCs
4. Sites with impacted groundwater with TPH
5. Sites with impacted subsurface soil with a cap

"Near" defined as any boring placed for investigating a building suspected to have a DoD related source.

Diagram 1-1
Process Flow and Decision Diagram
Expanded Site Inspection Report
Former Benicia Arsenal

Additionally, per regulatory guidance and to determine the possible impact on groundwater from polyaromatic hydrocarbons (PAHs), the highest diesel fuel or motor oil range hydrocarbon concentrations detected above the delineation limit were also analyzed for PAHs.

1.2 Project Objectives

The overall objectives of this investigation are to ascertain whether soil gas, soil or groundwater contamination resulted from past DoD use at the locations identified in Table 1-1 and determine if some contamination is the result of post-DoD use. The project objectives (FA/BC, 2004a) were to:

- identify DoD-related contamination based on the highest risks to human health and/or the environment;
- determine if additional data is necessary to characterize potential impacts; and,
- delineate the extent of contamination (if additional data is necessary).

Chemicals associated with post-Army activities are not listed in Table 1-1. However, chemical indicators of releases resulting from post-Army use will be reported and discussed in this report (i.e. sampling for fuel oxygenates such as methyl tertiary-butyl ether [MtBE]. MtBE, a fuel oxygenate was added to gasoline in the 1970s after Arsenal closure).

Table 1-1. Inspection Sites

Inspection Site	DoD Use	DoD Activity	Suspected Contaminants
4	Sandblast Building/Paint Spray	Cleaning, painting	VOCs, metals
26	Lieutenant's quarters	UST (removed)	Fuels, metals, oils
28	Quarter's Commanding Officer	UST (removed)	Fuels, metals, oils
31	Store House/Engine Rebuild	Degreasing, UST* (removed)	Fuels, metals, oils, solvents
42	Garage/Repair Shop	Solvent washer, maintenance, possible UST*	Fuels, oils, solvents
50	Heavy Equipment Yard	Maintenance, ASTs* (removed)	Fuels, oils, lead
51	Stable/ Maintenance	Maintenance	Fuels, oils, metals
53	Dynamometer Shop (motors)/Engine Testing/Fuel Storage	UST (removed)	Fuels, lead
55	Blacksmith Shop/Machine/Welding Shops	Repair/ Maintenance	Fuels, oils
56	Leather & Canvas Shop/Welding Shop	Dip tanks	Oils
56A	Small Arms Shop/Leather Canvas Shop	Degreaser	Solvents
57	Small Arms Shop, Firing Range	Firing ranges, degreaser	Metals (firing range only)**, solvents
58(A)	Small Arms Repair and Retinning/ Boiler Room	Repair, former boiler UST?	Fuels, lead
59	Tool House/ Degreaser Pit	Cleaning, degreaser	Fuels, oils, solvents, lead
59(A)	Tool House	Storage	Fuels, oils, lead
65(A)	Boiler House	Former UST/AST?	Fuels, lead
90	Locomotive Building	Repair/ Maintenance	Fuels, oils, solvents
91	Machine Shop/Combat Vehicle and Artillery Repair	Cleaning, Degreasing	Fuels, oils, solvents, metals
91A	Temporary Machine Shop/Engine Rebuild	Cleaning, Degreasing	Fuels, oils, solvents, metals
93	Truck Storage Building/MMW Repair, Motor	Maintenance, grease	Fuels, oils, solvents

Table 1-1. Inspection Sites

Proposed Inspection Site	DoD Use	DoD Activity	Suspected contaminant(s)
	Vehicle Maintenance Building	tanks	
101	Battery Charge Building	Steam cleaning battery cases	Metals, fuels
103	Service Station/Office Building	UST (removed)	Fuels, lead
111	Heavy Equipment Shop	Storage	Fuels, oils, solvents
118(A)	Diesel Fuel Tank, Fuel Oil Tank, Oil Storage Tank	Former ASTs	Fuels, oils
120	Quartermaster Storage/Shop/Electroplating	Dip tanks, degreaser	Solvents, metals
154	Motor Test Shed/Paint Spray/ Fuel storage	USTs (removed)	Fuels, oils, lead
156	Locomotive House	Maintenance	Fuels, oils, solvents, metals
161	Motor Cleaning Building/Steam Cleaning/Paint Spray/Fuel Storage	Maintenance Storage, UST*	Fuels, oils, solvents, metals
165	Reclamation Building/Transport Vehicle Shop	Degreaser	Solvents, oils, metals
165A	Steam Cleaning Building	Cleaning	Fuels, oils, solvents
166	Paint Shop	Grease rack	Oils
167	Bar Stock Building/Storage/Vehicle Shop for Motor Pool	Maintenance	Fuels, oils, solvents
168	Bar Stock Building/Storage/Vehicle Shop for Motor Pool	Maintenance	Fuels, oils, solvents
171	Vehicle Shop	Maintenance	Fuels, oils, solvents
172	Vehicle Repair and Maintenance Shop	Maintenance	Fuels, oils, solvents
194	Former Septic Tank for CL1	Sewer	Solvents, metals
CL1	Clip-Link and Belt Plant (1942-1944); Guided Missile Shop/Nike Missile Assembly	Assembly area	Solvents, metals
CL2	Boiler House	Boiler house (former UST and AST)	Fuel, oils, metals
Fillsite 1 (formerly Landfill 1)	Dump	Disposal	Fuels, oils, solvents
Fillsite 3 (formerly the Dumpsite)	Dump	Disposal	Fuels, oils, solvents
Firing range	Test Firing of .45 and .50 Caliber Weapons	Firing Range	Metals
Popping pot (formerly the Incinerator and also known as the Armored Fighting Vehicle)	Incineration	Disposal	Metals, explosives, fuels, oils
Post Dumpsite (formerly Landfill 3)	Dump	Disposal	Metals
Salvage yard	Salvage Yard	Disposal	Fuels, oils
Spur A^	Revetment and Burn Cage Area/Hydrazine Burn Area (1958/59)	Burn cage	Fuels, metals, explosives
Spur E	Revetment and Burn Cage Area	Burn cage	Fuels, metals, explosives
Spur G^	Revetment and Burn Cage Area	Burn cage	Fuels, metals, explosives
T199	Maintenance Building, Body and Radiator Shop	Maintenance	Fuels, solvents
T221	Vehicle Maintenance	Maintenance	Fuels, oils, solvents
T222	Steam Cleaning	Cleaning	Solvents
TO73	Recreation and Storage Building/Photo Lab/Depot Facilities Shop	Cleaning	Solvents
TO131	Storehouse/Shop	Degreasing	Solvents
Waste Areas/Open Ditch	Waste Areas/Open Ditch for CL1	Disposal	Solvents
53 total sites			

*UST investigated in a separate field event (Fuel Storage Tank Removal Action Plan, BC, 2004b).
^ Investigation at Spurs A and G were dependent on the results from Spur E.

1.3 Site Location and Historical and Chemical Use

This section of the report will summarize the physical setting, historical and chemical use at the Arsenal. The former Arsenal is located about 25 miles northeast of San Francisco in Benicia, California, on the north side of the Carquinez Strait (Figure 1-1). During its active life from 1849 to 1964, this facility served the U.S. Army as a principal depot for ordnance and ordnance stores, as well as the issuance, manufacture and testing of small arms. The former Arsenal eventually grew by land acquisition to a total of 2,728 acres, of which 190 acres were located with the Carquinez Strait to the south and Suisun Bay to the northeast (Jacobs, 1999).

1.3.1 Physical Setting

The Benicia area is located along the eastern margin of the Coast Range Geomorphic Province of California, in an area of low hills along the northern shore of the Carquinez Strait. North-northwest trending hills and valleys are almost parallel to the San Andreas Fault system. The local topography controls the flow pattern of surface water, and to a large degree, the flow direction of groundwater. The east-west trending Carquinez Strait is a notable exception to the northwest trending valleys. The Carquinez Strait was created by erosion from the Sacramento River and San Joaquin River during Pleistocene periods of relatively low sea levels (Norris and Webb, 1990).

The southernmost portion of the former Arsenal (Industrial/Manufacturing Area) rises from sea level at the Carquinez Strait to an elevation of approximately 160 feet above mean sea level (msl) in the low-lying foothills near the former location of Pine Lake (Figure 1-2). The foothills rise to an elevation of over 400 feet in the western part of the former Arsenal. The foothills are cut by natural and man-made drainages that flow into the tidal flats and marshlands of the Carquinez Strait and Suisun Bay. The surface drainage in the northwestern part of the Arsenal area is toward the east into the Sulphur Springs Creek drainage channel. The northeastern corner of the former Arsenal is comprised of low-lying hills up to 250 feet in elevation, with surface drainage generally toward the west into the Sulphur Springs Creek drainage (Figure 1-2).

1.3.2 Arsenal History

The Benicia Arsenal was created in 1849 from the founders of the City of Benicia to the U.S. government (Jacobs, 1999). Originally referred to as "the Post at Point near Benicia, California," the installation was later designated Benicia Barracks (Jacobs, 1999). In 1862, President Lincoln ordered that a plot of land at Benicia be segregated from the public lands for the purpose of a military reservation. Between 1849 and 1958, the United States acquired 1,790.48 fee acres, 351.12 public domain acres, 6.40 license acres, and 580.04 easement acres, for a total of 2,728.04 acres (Jacobs, 1999).

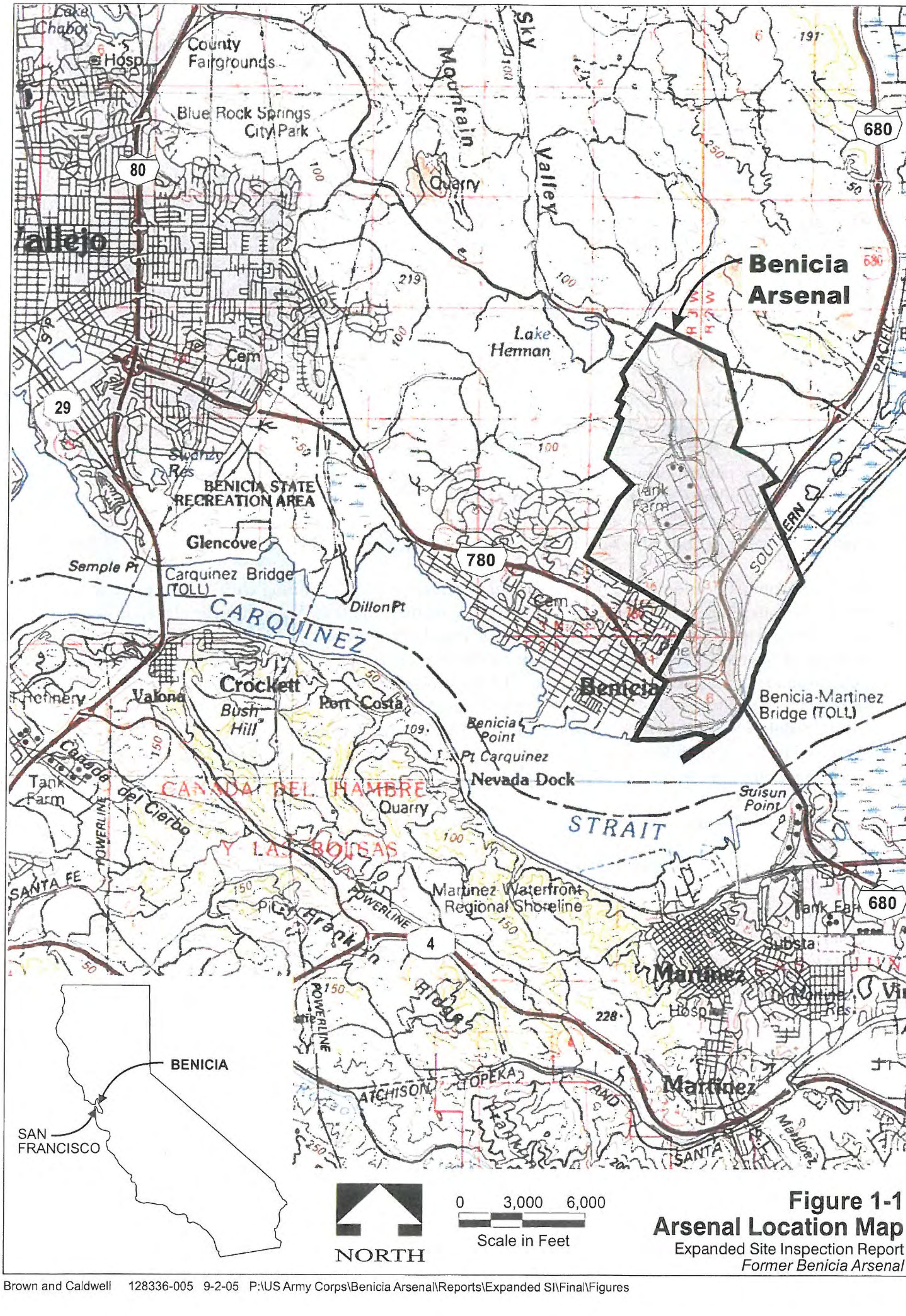
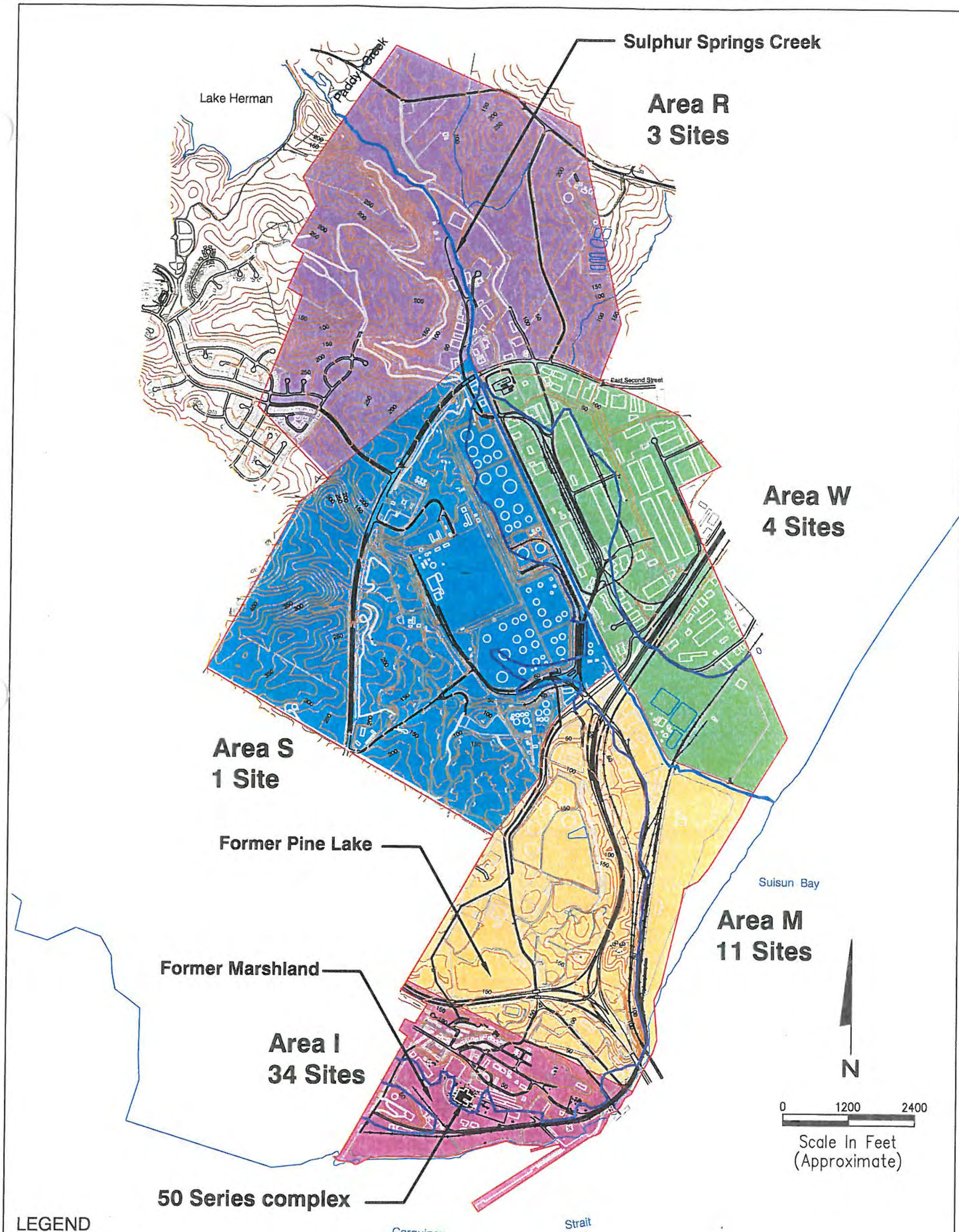


Figure 1-1
Arsenal Location Map
Expanded Site Inspection Report
Former Benicia Arsenal



LEGEND

Topographic Contour, 25 Foot Interval

Former Arsenal Boundary

Source of Thickness of Bay Mud in Lowlands is Edward Schwafel Engineers, 1969

Figure 1-2
Areas of Arsenal
Expanded Site Inspection Report
Former Benicia Arsenal

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The former Arsenal served as a principal depot for ordnance and ordnance stores, issuance of supplies, ammunition, small arms parts and accessories, the testing of small arms, mobile and seacoast artillery targets, and vehicle maintenance for the Division of the Pacific. A massive expansion of the former Arsenal took place during World War II. Physical expansion included the addition of 1,847 acres and over 200 structures. Another full-scale expansion took place just prior to and following the Korean Conflict (1950s), with the addition of approximately 40 to 50 structures. Many of these additions were warehouses for inert materials and transitory shelters. Throughout the former Arsenal's history, the functions of many buildings and operation areas changed, in response to changing government needs.

The former Arsenal was continuously occupied by the military from its establishment in 1849 to its closure in 1964. Benicia Arsenal was declared excess by the DoD and was reported to the GSA on January 11, 1963. Deactivation and closure of the former Arsenal was completed on 31 March 1964 (Jacobs, 1999).

Drilling efforts were undertaken in the late 1800s to increase water supply. However, the effort to find potable groundwater was unsuccessful. To counter the problem, cisterns were installed to store stormwater, and reservoirs were built to capture and store surface water.

The former Arsenal can be divided into five areas according to the primary DoD land uses shown on Figure 1-2. These areas are listed below:

- Area W Warehouse Area
- Area I Industrial/Manufacturing Area
- Area R Revetment/Explosives Holding Area
- Area M Motor Pool and Historical Ordnance Storage Area
- Area S Magazine Storage Expansion Area

Area W (Figure 1-2) is occupied by structures that were erected during World War II and the early 1950s. Most of the construction in Area W was completed by 1942. Improvements in this area include a clip-link and belt plant (later converted to a Nike missile reconditioning shop), transitory shelters, materiel warehouses, open storage areas, storage igloos, small arms storage magazines, a rail yard, sewer and storm drainage systems, and a firehouse with accompanying support structures. This area was used mainly to receive and store small arms, ammunition, and related supplies throughout World War II. Area W includes four sites to be investigated during the Expanded SI.

Area I (Figure 1-2) served as the main industrial and manufacturing area throughout the 115-year history of the facility and was the center of activity at the former Arsenal. Several machine shops, manufacturing shops, and cleaning and painting shops were housed here, along with a blacksmith shop, a welding shop, numerous vehicle and artillery repair shops, and a small arms shop. The industrial area also housed the former Arsenal's administrative offices, most of the permanent housing facilities, photographic laboratories, a firehouse, and a hospital. Fuel storage and dispensing facilities, a locomotive house, boiler houses, storehouse and warehouse facilities, open storage facilities, fillsites, and quarries were also located within this area. Approximately 64 percent (34 sites) of the 53 proposed inspection sites are located in Area I.

Area R (Figure 1-2) became part of the former Arsenal in 1944 to meet the need for a staging area for ammunition shipments during World War II. Land use in this area was mainly for temporary storage of explosives on flatbed railroad cars, artillery testing, demilitarization, and demolition of damaged and obsolete ammunition (FA/BC, 2004a). The Army built very few permanent structures in this area between 1944 and the closure of the former Arsenal in 1964. Buildings in Area R were mainly used for demolition and demilitarization of damaged and obsolete ammunition and for weapons testing. Between the end of World War II and 1950, the former Arsenal received thousands of tons of ammunition from American military bases across the Pacific. The returned ammunition was inspected for obsolescence or damage, with the bulk of it taken to the northern portion of the former Arsenal and destroyed (FA/BC, 2004a). Three proposed inspection sites in Area R are associated with demilitarization of damaged and obsolete ammunition.

Several original structures (built between 1852 and 1857) are located north of the industrial area in Area M (Figure 1-2) on the low-lying hills. Area M was the location of the original Benicia Barracks, established in 1849 by two companies of the 2nd Infantry. This area housed officers and enlisted men, a hospital, the Adjutant's office, a storehouse, a carpenter shop, a blacksmith shop, and several buildings to house livestock (FA/BC, 2004a). The buildings were supplied with water from a series of six cisterns, two holding tanks, and four non-potable water wells. The cisterns had a total capacity of 212,000 gallons and were located near the hospital, the Commanding Officer's Quarters, the "north and south block" officers' quarters, the Adjutant's office, and the "band quarters." The two holding tanks had a total capacity of 24,500 gallons (Jacobs, 1999). For nearly 100 years, this area was primarily used to store ammunition, gunpowder, and ordnance. There are eleven sites in Area M to be investigated as part of the Expanded SI. They are mostly related to former DoD vehicle maintenance activities.

The Army acquired Area S (Figure 1-2) in 1941 during the 1,800-acre expansion program (FA/BC, 2004a). The structures within this area include a network of ammunition storage igloos built in 1942-1943. During the 1940s, these igloos were used largely to store artillery projectiles and aerial bombs (FA/BC, 2004a). The mission of the Arsenal changed in the late 1940s and the igloos in this area were then used for general storage. There is one site in Area S to be investigated during the Expanded SI.

1.3.3 Historical Chemical Use

The Army operated industrial and manufacturing shops, maintenance facilities, and fuel and waste storage areas at the former Arsenal. Potential sources of chemical releases from these activities include USTs, vapor degreasers, grease maintenance pits, degreasing tanks and waste disposal areas. Fuel-related petroleum hydrocarbons are expected at the former Arsenal due to known releases from former USTs and possibly from remaining USTs. The contents of these USTs included fuel oil, diesel fuel and gasoline. These petroleum products were used in boilers, vehicles, machinery and other equipment. In addition to fuel-related petroleum hydrocarbons, various chemicals were used in manufacturing processes that included coloring, cleaning, degreasing, and preserving.

The process of cleaning, coloring, and preserving metal parts was conducted primarily at the 50 Series Complex and surrounding buildings. These operations evolved from the Browning process of the early 1900s to the Parkerizing process that started in the 1940s. Building 31, Building 91 and Building 91A near the 50 Series Complex also performed some of these manufacturing operations.

The overall approach to these processes included the removal of oil and grease from metal using boiling water, caustics or phosphoric acid. Some vapor degreasing was also performed. A vapor degreasing unit was added in the 1950s in Building 56A and Building 57 (part of the 50 Series Complex). Records research indicates that trichloroethene (TCE) use at the 50 Series Complex was limited. The location and use of Stoddard solvent is not well understood, but this material was prescribed as a cleaner in the 1940s. Acid and caustic dip tanks were located in many buildings (Building 56, Building 56A, Building 57, Building 91, Building 91A, and Building 31) for degreasing small arms or vehicle parts. Preservation (primarily with light oil/wax oil) and coloring was performed in Building 56 and Building 57.

During the World War II era, the west wing of Building 56 (commonly referred to as Building 57A) was built and named the "Parkerizing Room." Parkerizing (or Phosphating) is a metal finishing technique that gained in popularity during World War II, when the Army sought to replace the typical blued finish on most small arms with a rust resistant and anti-reflective coating that would be both durable and abrasion resistant and would also hold up in extreme climates. The Parkerizing technique is a phosphate etching process that produces a hard matte or dull finish. There are no solvents associated with Parkerizing, and therefore solvents are not associated with Building 57A.

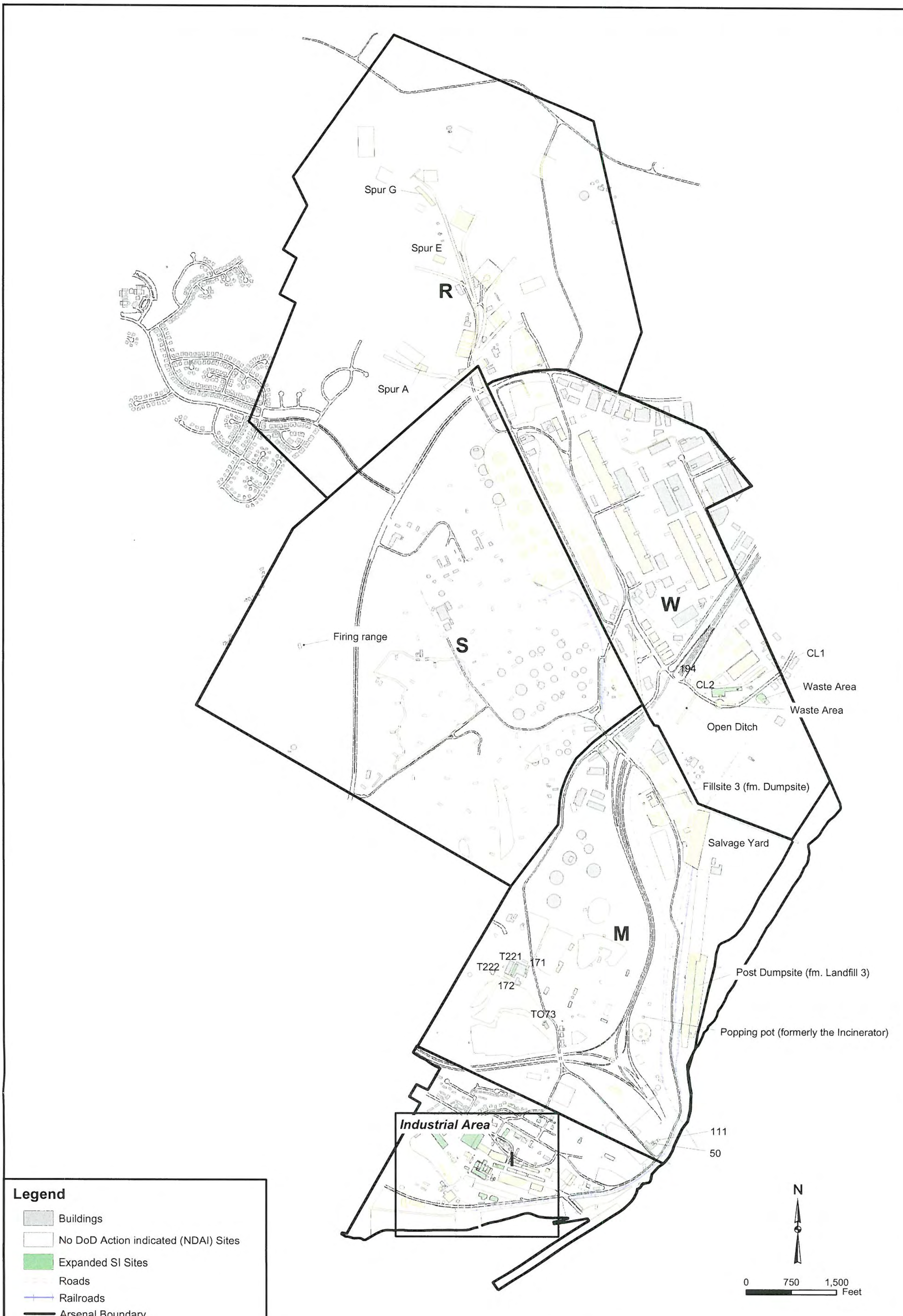
Used materials may have been dumped or drained into the former marshland area (Figure 1-2) prior to placement of artificial fill in the late 1920s (FA/BC, 2004a). Based on the processes occurring in the industrial area prior to World War II, it appears that any used material dumped into the former marshland would have been acids and possibly light oils.

It is not clear where the contents of the solvent-based materials in the vapor degreasers or degreaser tanks or other used materials were disposed. Storm drains and the sanitary sewer system were the most likely locations (Jacobs, 1999).

The above descriptions of manufacturing activities do not account for post-Army use. After closure of the Arsenal, several subsurface structures remained (e.g. the Parkerizing vat in Building 57A, the caustic tank in Building 56 and the storm drain/sewer system). Tenants and landowners used these structures for a variety of manufacturing, maintenance and repair activities. Prior to the 1970s, it was customary to discharge untreated waste into the sewer and/or storm drain system. Regulations were later enacted and enforced to prohibit these activities. The discharge of untreated wastes into the sewer system continued for five years after the Army left in 1964, when an upgrade to the sewer system was completed and untreated wastes were diverted from the Carquinez Strait into the City of Benicia Wastewater Treatment Plant.

1.4 Expanded SI Sites Location and Suspected Contaminants

Each inspection site is listed in Table 1-1, with the DoD use, features and contaminants that are suspected based on its former DoD use. Further details and background information are provided in Appendix B. The locations of the inspection sites are indicated on Figure 1-3 and subsequent figures in this report.



BROWN AND CALDWELL

PROJECT: 24785-007
DATE: 4/8/2005

TITLE: **Expanded SI Sample Locations and Figure Reference Map**
SITE: **Benicia Arsenal, Benicia, California**

Figure 1-3

Table 1-1 shows fuel-related contaminants such as diesel fuel, gasoline and motor oil that have been associated with maintenance activities, USTs and above ground storage tanks (ASTs). Volatile organic compounds (VOCs) and other solvents have been associated with cleaning, degreasing and maintenance activities. Oils were primarily used in preserving small arms were also commonly associated with the same sites where fuels were used. Metals and explosives are related to incineration, small arms disposal, and firing ranges. Lead has also been associated with USTs due to the use of leaded gasoline. By 1923, tetraethyl lead was added to gasoline at refineries to prevent engine knocking. Tetraethyl lead and tetramethyl lead were added to gasoline up until the late 1970s (U.S. Department of Labor, 2003). The uses of lead additives in gasoline were largely banned in the U.S. under the Clean Air Act of 1970.

1.5 Previous Investigations

The results of selected previous investigations at the former Arsenal are summarized below. Only those investigations that are relevant to this Expanded SI are discussed below. The relevant investigations include the following:

- The 50 Series Complex;
- Area I Fuel Facilities;
- Fillsite 1, and
- 4186 Park Road.

1.5.1 50 Series Complex

The 50 Series Complex is a collection of buildings within the central portion of Area I (Figure 1-2). The complex was originally constructed as three separate workshop buildings (Building 55, Building 56, and Building 57) between 1876 and 1884 (Photo B55-56-57). The remodeling of the original buildings occurred over many phases and included the addition of eight buildings and the removal and relocation of three buildings. Important features within the 50 Series Complex included a former smokestack/incinerator, degreasers, dip tanks, forges, firing ranges and USTs. Low-lying marshland areas to the south, east and west of the complex were filled in during site development in the late 1920s.

Mr. Gordon Potter, the present owner of the complex, conducted an investigation in 1994 within Building 57A that was required for a bank loan. As part of this investigation, soil samples were collected from various depths and locations near a U-shaped gravel-filled vat for analysis. Test results from the field investigation indicated that TCE, trans-1,2-dichloroethene (trans-1,2-DCE), and methylene chloride were present in the soil beneath Building 57A (Meredith/Boli and Associates, 1994).

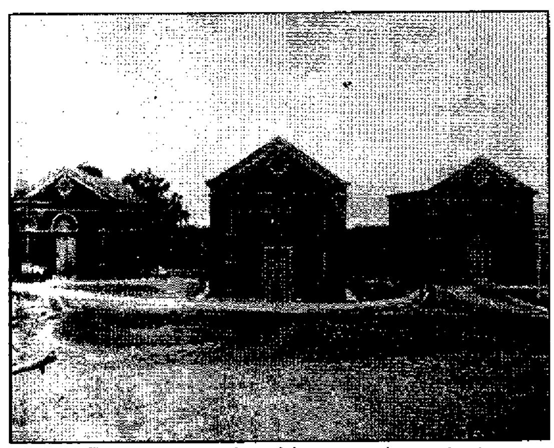


Photo B55-56-57. Looking southwest at Buildings 55, 56, and 57, from left to right. (Circa Early 1900s)

Mr. Potter's investigation at Building 57A generated only limited environmental data for metals and solvents in soil. These data may not indicate the maximum concentrations or extent of solvent or metals contamination at the 50 Series Complex.

A site investigation was performed at the 50 Series Complex between 7 September 1999 and 28 September 1999 (FA/BC, 2004b). Chemicals of Interest (COIs) were identified to historical DoD use at the complex. However, post-Arsenal use has also occurred in these buildings and evidence exists that some original structures (Parkerizing vat in Building 57A) had post-Army beneficial uses.

In general, solvents and fuel-related hydrocarbons were identified in several of the areas investigated at the 50 Series Complex. Detections of metals are expected in soil because these constituents generally occur naturally, but there were areas that indicated concentrations of various metals above typical ambient values. The predominant COIs in soil, soil gas and groundwater were chlorinated solvents. Fuel-related compounds and metals were also found in soil and groundwater. Some of the COIs detected were widespread and from multiple sources, while others may have been the result of an isolated source. The Expanded SI focused on further delineation of solvents and fuels in groundwater in the area of the 50 Series Complex.

MtBE, a fuel oxygenate used since the early 1970s (i.e., after Arsenal closure), was detected in three groundwater samples at concentrations of 0.59 micrograms per liter (μg/L), 0.52 μg/L, and 17 μg/L during the 1999 investigation. These detections of MtBE indicate a post-Army gasoline release. MtBE was found in groundwater at Building 57A and southeast of Building 56A.

1.5.2 Area I Fuel Facilities

FA/BC conducted site investigations for the Fuel Only Facilities in June 1999 and June 2000 (FA/BC, 2000 and 2002b). Area I fuel facilities included Building 15, Building 25, Building 26, Building 27, Building 28, Building 45, Building 46(B), Building 53, Building 54, Building 73, Building 103, Building 118(A), Building 152, Building 154, and Building 178. Due to budget constraints, only the mostly likely sites with fuel storage tanks were investigated in 2000. Up to 20 fuel storage tanks were suspected at these locations. The FA/BC investigation focused on confirming the existence of the tanks and associated piping, and verifying whether past DoD activities caused environmental impacts to soil or groundwater by petroleum hydrocarbons and/or lead. Both surface geophysical methods and test pits were used to identify the location of suspected USTs and associated piping.

Six of the 20 suspected fuel storage tanks were located during this investigation (one 1,000-gallon UST at Building 53, one 15,000-gallon UST at Building 103, one 7,000-gallon and 10,000-gallon UST at Building 154, one 250-gallon UST at Building 26 and one 250-gallon UST at Building 28). In March 2002, the six confirmed USTs were removed (Geofon, 2003). Two fuel storage tanks at Building 27 and Building 45 could not be confirmed due to lack of access by landowner. The remaining 12 suspected fuel storage tanks were never installed or had been removed.

Building 53, Building 103, Building 154, and Building 118(A) had reported total petroleum hydrocarbon (TPH), PAHs, and/or lead levels above soil or groundwater ESLs (RWQCB, 2005). These findings are discussed below in further detail by building. Information on the remaining fuel facility buildings at the former Arsenal can be found in more detail in the following reports:

- *Technical Memorandum for Area I Fuel Facilities* (FA/BC, 2000);
- *Technical Memorandum for Area I – Fuel Storage Facilities at Buildings 15, 25, 26, 27, 28, 45, 46(B), 54, 118(A), 152 and 178 for the Benicia Arsenal* (FA/BC, 2002b); and
- *Revised Final Underground Storage Tank Removal Report* (Geofon, 2003).

Graphical results from these investigations can be found in their respective reports; a brief summary is included below. These results are also combined with results from the Expanded SI on figures included in Section 6 by group of compounds (i.e. fuels, solvents) with a comprehensive discussion in order to give a complete picture of the impacts to the environment.

Building 53. In 2002 during the Geofon investigation, two soil samples were collected from the northern and southern sidewalls (at the soil/water interface) of the UST excavation at Building 53. The northern soil sample reported diesel fuel range organics, gasoline range organics, toluene, ethylbenzene, xylenes and lead above ESLs. The southern sample reported diesel fuel and motor oil range organics and lead above ESLs at 5 feet bgs.

The UST at Building 53 was located within a hollowed-out sandstone cavity and groundwater at this location is shallow (approximately 4 to 5 feet bgs). The vertical extent of impacted soil could not be delineated because of the presence of shallow groundwater.

Dichloroethene (DCE) isomers were detected in groundwater samples collected at this location. The presence of DCE is likely due to degradation of TCE that had been released in the past.

Geofon recommended further investigation at Building 53 based on the detection of hydrocarbons and lead above ESLs in groundwater and/or soil samples. Investigation of shallow surface soils was also recommended to determine the vertical and lateral extent of impacted soil (Geofon, 2003).

Building 103. Diesel fuel and motor oil range organics were detected above ESLs in a soil sample collected along the southern sidewall of the UST excavation near the soil/water interface (10 feet bgs). Fuels and lead in three other samples collected from the northern and eastern excavation sidewalls were less than ESLs. A groundwater sample collected from the excavation also reported gasoline range organics, toluene and xylenes above ESLs. Diesel fuel range organics were not evaluated in the water sample.

Geofon recommended further investigation at Building 103 based on the detection of hydrocarbons and lead above ESLs in groundwater and/or soil samples. Investigation of shallow surface soils was also recommended to determine the vertical and lateral extent of impacted soil (Geofon, 2003).

Building 154. Fuels and lead were not identified above ESLs in soil samples collected from the UST excavation at Building 154. However, groundwater was impacted with gasoline range organics and lead above the ESLs. Isomers of DCE were detected in groundwater samples, likely the result TCE degradation.

Geofon recommended further investigation at Building 154 based on the detection of hydrocarbons and lead above ESLs detected in groundwater (Geofon, 2003).

Building 118(A). The FA/BC investigation included a geophysical survey and the excavation of five test pits. Soil and groundwater samples were collected from the test pits. Gasoline and motor oil range organics did not exceed the ESLs for soil. However diesel fuel organics exceeded ESLs for soil and groundwater and motor oil range organics in groundwater. Recommendations were made to collect additional samples in the area of trench (test pit) TR005 at former Building 118(A) to determine the extent of petroleum hydrocarbons and VOCs in soil and groundwater (FA/BC, 2002b).

1.5.3 Fillsite 1

FA/BC conducted an environmental site inspection at Fillsite 1, Fillsite 2, Quarry 1 and Quarry 3 between November 2000 and October 2002 (FA/BC, 2004c). These suspected fillsites and quarries were identified from historical information as possible repositories for industrial wastes from the shop area and other facilities at the former Arsenal. Among the two fillsites and two quarries investigated, only Fillsite 1 is located in an area covered by the Expanded SI. Therefore, only the results from the previous investigation at Fillsite 1 are summarized below.

Fillsite 1 is noted on the 1918 map included in "Benicia, Portrait of an Early California Town," (Jacobs, 1999). Identified on the 1918 map is a "dump" located slightly southeast of the former industrial shop buildings, at what appears to be the beginning of a swale leading northwest from the swamp area to Area I. The marsh area below the swale has since been filled. Building 71 was constructed over the filled marsh in 1920 and overlies the "dump". Compressible clays caused this building and others built on the former marsh to settle unevenly. The Army made several attempts to enhance the structural foundation of this building, including replacing wooden piling supports with concrete piling supports and buttresses. Building 71 was demolished in the 1980s by the current landowner. The site is now paved and used for temporary storage of new vehicles.

The types of materials managed at Fillsite 1 are unknown. At the time of the "dump", prior to 1920, this area used a variety of fuels, acids, and oils when the former Arsenal was operational. Thus, Fillsite 1 may have been a location for dumping of these wastes. It should be noted that such unregulated dumping of waste materials was a common practice prior to the 1970s.

FA/BC conducted a geophysical evaluation of the Fillsite 1 area and then collected soil and groundwater samples. These samples were analyzed for constituents related to materials that may have been commonly used at the 50 Series Complex and discarded at this location.

Geophysical techniques identified metallic and non-metallic anomalies at Fillsite 1, in locations where debris within the artificial fill was found by trenching. The stratigraphy of Fillsite 1 was found to consist of artificial fill up to 8 feet thick with underlying Bay Mud. Fill material included unconsolidated sandy silt with gravel and occasional wood, brick, and a discontinuous buried asphalt layer beneath the western third of the site.

No refuse was encountered in any trenches at Fillsite 1, although motor oil, diesel fuel and lead were detected in soil samples. All of these contaminants decreased in concentration with depth. Groundwater at Fillsite 1 was found to contain degraded solvents, diesel fuel and motor oil.

The source of the solvents in Fillsite 1 groundwater is not clearly understood, but is likely associated with a nearby source area (i.e., the 50 Series Complex or another unknown upgradient area). Widespread use of solvents in manufacturing began during World War II after the area was filled in and Building 71 was placed on top of the suspected "dump."

Fuels were used throughout the former Arsenal and could have been discarded at Fillsite 1. However, it is more likely that the hydrocarbons reported in soil and groundwater at this location result from decomposition of the buried asphalt layer. Additionally, low levels of MtBE were detected in groundwater samples from Fillsite 1. The discovery of MtBE in groundwater at this location demonstrates that fuels were released after the Arsenal closed.

Based on the findings of FA/BC (2004c), soil and/or groundwater at Fillsite 1 appear to have been impacted to some extent by DoD activities. FA/BC recommended additional groundwater testing to assess the vertical and lateral extent of the solvents detected in groundwater at the Fillsite 1 area and identify the source area for these constituents.

1.5.4 4186 Park Road

Warehouse W12, located at 4186 Park Road, was built and used by the Army from 1952 through Arsenal closure in 1964. The warehouse covers 241,900 square feet and was used by the Army for storage. There are no records indicating any potential environmental concerns related to DoD activities at this site.

In September and November 2000, a subsurface investigation was conducted for RREEF America, LLC. (RREEF) to identify environmental concerns at the site prior to the property sale to RREEF from Spieker Properties (Spieker). TCE was detected at a concentration of 12,000 μg/L in a groundwater sample (Kleinfelder, 2001a).

In June 2001, Spieker conducted a subsurface investigation to assess potential source areas for TCE and halogenated volatile organic compound (HVOCs) and to assess the horizontal extent of the chemicals outside the building. Soil samples were analyzed for VOCs and gasoline and diesel fuel range organics. All three types of chemicals were detected in at least one of the samples. No MtBE was reported in any of the samples (Kleinfelder, 2001b). Groundwater impacted by TCE and its breakdown products exists at the site and appears to be migrating to the south from the site (Kleinfelder, 2001b). Groundwater impacted by 1,1-dichlroethane (1,1-DCA) appears to be limited to the area beneath the 4186 Park Road facility. Groundwater impacted by gasoline and diesel fuel organics exists at the site, generally where TCE is found (Kleinfelder, 2001b). Evidence exists that natural attenuation of TCE is occurring at the site. The source(s) of the groundwater contamination appeared to be associated with the 4186 Park Road facility or the adjacent bay (656 Stone Road) (Kleinfelder, 2001b). Later reports narrow down the source area as 4186 Park Road (bay 6).

The RWQCB requested additional information from existing and prior tenants of W12 about past or current operations, time period of operation, list of chemicals stored, estimates of amounts, location of chemical, locations of past spills, etc. Sonoco Products reported to RWQCB in November 2001 that as a producer of composite cans for food and drinks, it did not have any USTs. All chemicals were stored in 55-gallon or 300 to 500-gallon totes. Chemicals used included water-based adhesives, solvent- and water-based sealants, and lubricants. When US Can occupied 4186 Park Road and 635 Indiana Street between 1989 and 1996, it assembled one-gallon cans using pre-coated tinplate sheets. Chemicals used/stored included solvents and oils. In 1974, E-T Industries (E-T), manufacturers of Aluminum wheels who occupied by W11 and W12, was suspected of violating a sewer ordinance by dumping oil, grease, and chrome sludge deposits. Also, a degreaser was in use by E-T in W12 as of June 1979. A review of public records and regulatory documents revealed that E-T occupied W11 and W12 between 1970/71 and 1983 and operated a TCE (and later, 1,1,1 trichloroethane [1,1,1-TCA] degreaser, a sump, and a TCE filtering and recycling system. Interviews with several former E-T employees confirmed the historical use and location of an approximate 300-gallon conveyorized TCE degreaser. One interviewee reported a substantial TCE spill of up to 300 gallons, and several other interviewees reported numerous and long-term poor historical waste management practices. An Order was issued by the RWQCB for the environmental clean-up at 4186 Park Road. (FA/BC, 2004a)

In 2001, five monitoring wells were installed and currently the RWQCB is reviewing an Additional Investigation and Remediation Report performed during 2003 and 2004. The goals of this investigation were to:

1) Evaluate a groundwater mound in the vicinity of MW-1 (north of I-680 inside the warehouse at 4186 Park Road);
2) Complete a passive soil gas survey within the Benicia Industrial Park south of I-680;
3) Complete the vertical and lateral delineation of VOCs in groundwater in the unconsolidated sediments and weathered bedrock;
4) Conduct a remediation pilot study to evaluate potential remedial alternatives for the site and begin removing VOC mass from soil and groundwater; and
5) Evaluate shallow soil gas conditions to characterize potential long-term risks to site workers associated with VOCs in groundwater.

The passive soil gas survey was conducted in the area of the Benicia Industrial Park, south of I-680. The passive soil gas sorbers were placed approximately three feet bgs, in the clay/silty clay. TCE was detected in only one sample collected at a concentration of 0.06 μg (Kleinfelder 2004). Benzene, toluene, ethelbenzene, and xylene (BTEX) compounds were detected in the majority of the samples collected and was attributed to activities within the Benicia Industrial Park.

Included in this investigation was upgradient and cross gradient well installation and borings. The borings/well south of I-680 did not delineate the TCE impacts and an additional investigation was recommended to characterize the VOC plume in this direction. A total of 13 groundwater monitoring wells are associated with this site.

This site is approximately 1,800 feet north-northwest and upgradient of the Expanded SI site CL1. CL1 is part of the Benicia Industrial Park.

SECTION 2
INVESTIGATIVE APPROACH

Conceptual site models (CSM) are used as a planning tool to design and guide investigations usually incorporating site-specific, geologic, and hydrogeologic information to identify contaminants of interest, sources of pollution, and pathways of migration. A CSM is a representation of an environmental system. It is meant to be dynamic such that new information may change the CSM."

The CSM established for this site evolved from the *Records Research Report* and the *Area I 50 Series Complex Site Investigation Report*, Preliminary *Conceptual Hydrogeologic Model* (PCHM), *Preliminary Assessment*, and the *Area I Fillsite 1, Fillsite 2, Quarry 3 and Area M Quarry 1 Site Inspection Report* (Jacobs 1999, FA/BC 2004b, FA/BC 2003b, FA/BC, 2004a, FA/BC 2004c). The CSM is a critical component in understanding what is occurring in the subsurface and was developed after reviewing the Arsenal's 115-year military history and 35 years of post closure non-military activities. Incorporating the geologic and hydrogeologic findings from past investigations also helped to develop the CSM.

This section of the report will include a general discussion of the regional geology and hydrogeology of the area and the CSM developed for this investigation. Specific site geology and hydrogeology incorporated with the findings from the Expanded SI is discussed in detail in Section 4.0.

2.1 Regional Geology

The former Arsenal is located in the southern part of the Northern Coast Range of California where the geologic history has been complicated by stresses associated with the San Andreas strike-slip fault system. The stratigraphic names used in this report are from the most recent geologic publication for the area (Graymer et. al., 1999) (Figure 2-1).

Throughout the San Francisco Bay Area, the Mesozoic Franciscan Assemblage probably forms the structural basement in the eastern portion of the Coast Range (Bailey et al., 1964). The Franciscan Assemblage is a complex mixture of rock types. The most abundant rock types are sandstone and shale (or mudstone). Overlying the Franciscan Assemblage, is the Cretaceous Great Valley Sequence which consists of steeply dipping siltstone, sandstone, shale, mudstone, and conglomerate. In the industrial area, the Great Valley sequence is unconformably overlain by steeply-dipping siltstones and sandstones of the Paleocene Vine Hill Sandstone (formerly the Martinez Formation in Dibblee, 1980). The Cretaceous Great Valley Sequence and the Paleocene Vine Hill Sandstone are considered to be bedrock for the purposes of this report.

The sediments above the bedrock consist of older alluvium, Holocene Bay Mud, younger alluvium, and artificial fill material. The older Pleistocene alluvial and fluvial deposits are gravelly and clayey sand or clayey gravel that fine upward into sandy or silty clay and cover the Great Valley Sequence in the foothills (Highlands) of the Arsenal. These deposits are denser and less permeable than the more recent Holocene alluvial deposits due to weathering and compaction (Graymer et. al., 1999). In the lower reaches of the Sulphur Springs Creek drainage and the southern edge of the industrial area (Lowlands), the older Pleistocene alluvial deposits are present on the bedrock surface, below the Holocene Bay Mud when it is present. The Holocene alluvial deposits overlie or are interbedded with the Holocene Bay Mud in some areas.

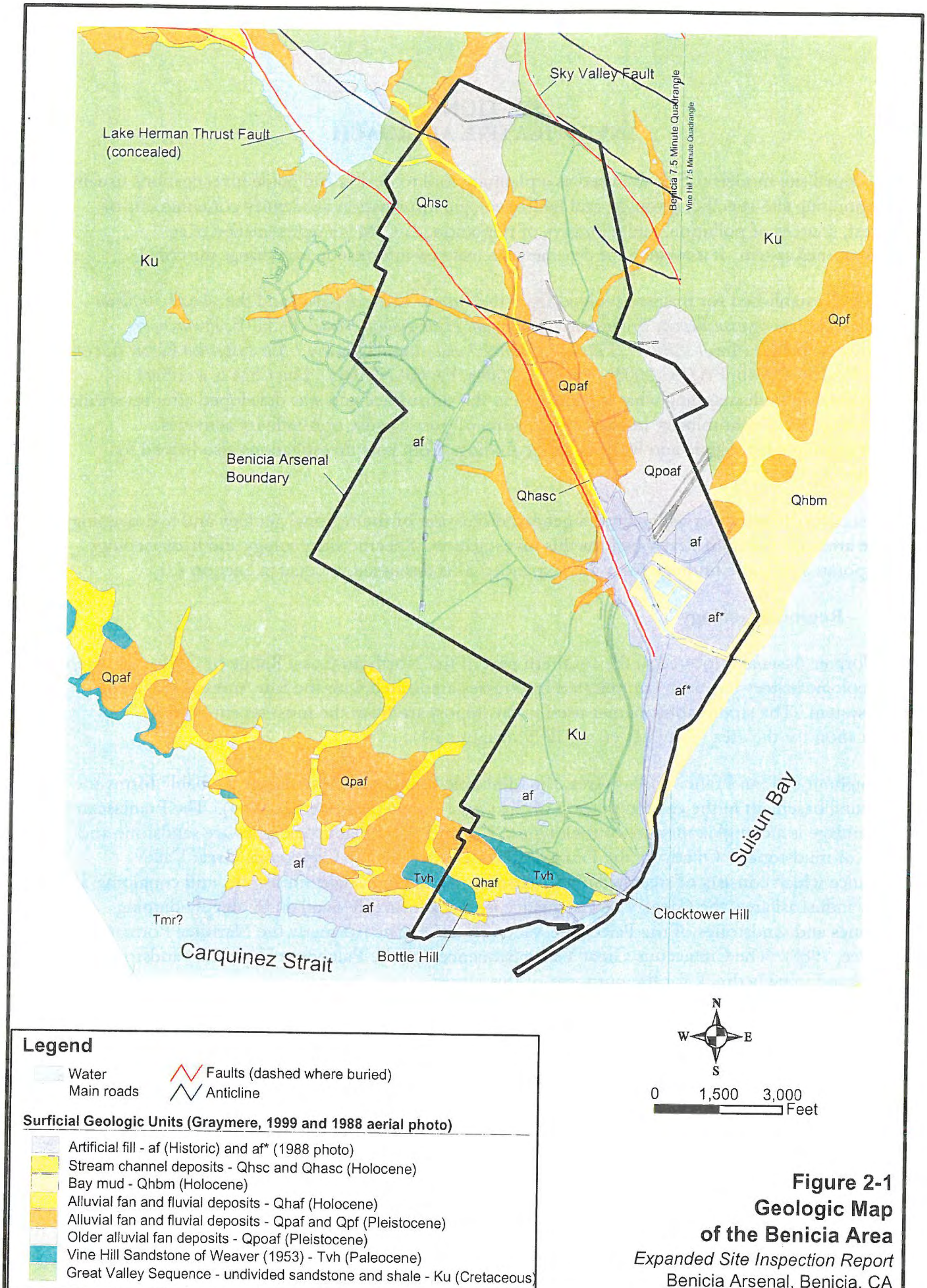


Figure 2-1
Geologic Map
of the Benicia Area

Expanded Site Inspection Report
Benicia Arsenal, Benicia, CA

The Holocene (Recent) Bay Mud, an estuarine deposited mud, is predominantly gray, green, and blue, clay or silty clay that was deposited in the marshlands, tidal mud flats, and the bay itself. The mud contains lenses of well-sorted fine sand and silt, a few shelly layers (oysters) and peat (Graymer et. al., 1999). In contrast, the alluvial clays are lean and usually silty or sandy.

There are two prominent faults in the Benicia area the Sky Valley Fault and the Lake Herman Fault (Graymer et. al., 1999). The Lake Herman Fault is a west-dipping thrust fault that trends north-northwest from the Carquinez Strait up the drainage channel of Sulphur Springs creek and across the foothills to the northwest beneath Lake Herman (Figure 2-1). The Sky Valley fault is an east-dipping oblique reverse fault, it has both vertical and horizontal (strike-slip) offset. A section of this fault cuts across the northeastern corner of the former Arsenal (Figure 2-1). Neither fault cuts Quaternary strata.

2.2 Regional Hydrogeology

The hydrogeology of the former Arsenal is described in detail in the PCHM (FA/BC, 2003b). A brief overview of the hydrogeology is presented here.

California's groundwater basins usually include one or a series of alluvial aquifers (coarse-grained sand and gravel) with intermingled aquitards (fine-grained silt and clay). Bedrock material, such as the Great Valley Sequence in the Benicia area, underlies the alluvial sediments, has relatively low permeability, and forms the boundaries of the groundwater basins (DWR, 2003). The permeability and extent of water-yielding deposits vary considerably within the basins (Planert and Williams, 1995).

In the Highlands, most of the groundwater is found within the overburden and weathered bedrock, which is found in the alluvial valleys. Some water supply wells are drilled into the bedrock and appear to intercept groundwater within fractures. Based on the IT Panoche Facility, located approximately 1 mile northeast of the former Arsenal, saturated thickness of the alluvial sediments is about 60 feet within the center of the valleys and thins at the valley edges (IT Corporation, 2001). The groundwater gradient is generally steeper in the valleys within the Highland area (ranges from 0.045 to 0.0053 feet/feet) than the gradients in the Lowland areas (about 0.0016 feet/feet), which is due to the steeper terrain in the Highlands (FA/BC, 2003b). The hydraulic conductivity of the alluvial material present mainly in the Highlands varies from under 1 to just over 10 feet/day. The hydraulic conductivity of the Bay Mud and clayey fill material in the Lowland area is generally less than 1-foot per day (FA/BC, 2003b). In general, the shallow groundwater in the Lowland areas is brackish to saline (>1,000 mg/L total dissolved solids) and the groundwater in the Highland areas is fresh. The freshwater-saltwater interface along the coast is probably somewhere near the boundary between the Highland area and the Lowland area (FA/BC, 2003b). Groundwater flow on the former Arsenal is generally similar to the surface water flow direction, from high elevations in the topography to low elevations in the topography, or from the Highlands to the Lowlands.

2.3 Conceptual Site Model

The initial CSM was introduced in the 50 Series Complex Investigation Report for the industrial area and can be used as a model for the Arsenal. Any variations to this model are described below. It has since evolved based on subsequent investigations, other pertinent reports, and numerous field surveys and visits.

The industrial area is a network of buildings in close proximity of each other with various types of possible COIs. As a result, it would be expected to have overlapping plumes of contaminates in which there may be a difficulty in discerning each source area because over 40 years has past since any DoD activities were present. Acids have neutralized, contaminates have naturally degraded and vaporized. The focus is to track the degradation products and the non-mobile contaminates, like metals. At a minimum, the extent will be determined but the source area may be more difficult to identify. Figure 2-2 illustrates the updated CSM for the industrial area that was used to guide the Expanded SI.

Outside of the industrial area, possible source areas are more localized and are assumed to be easier to identify.

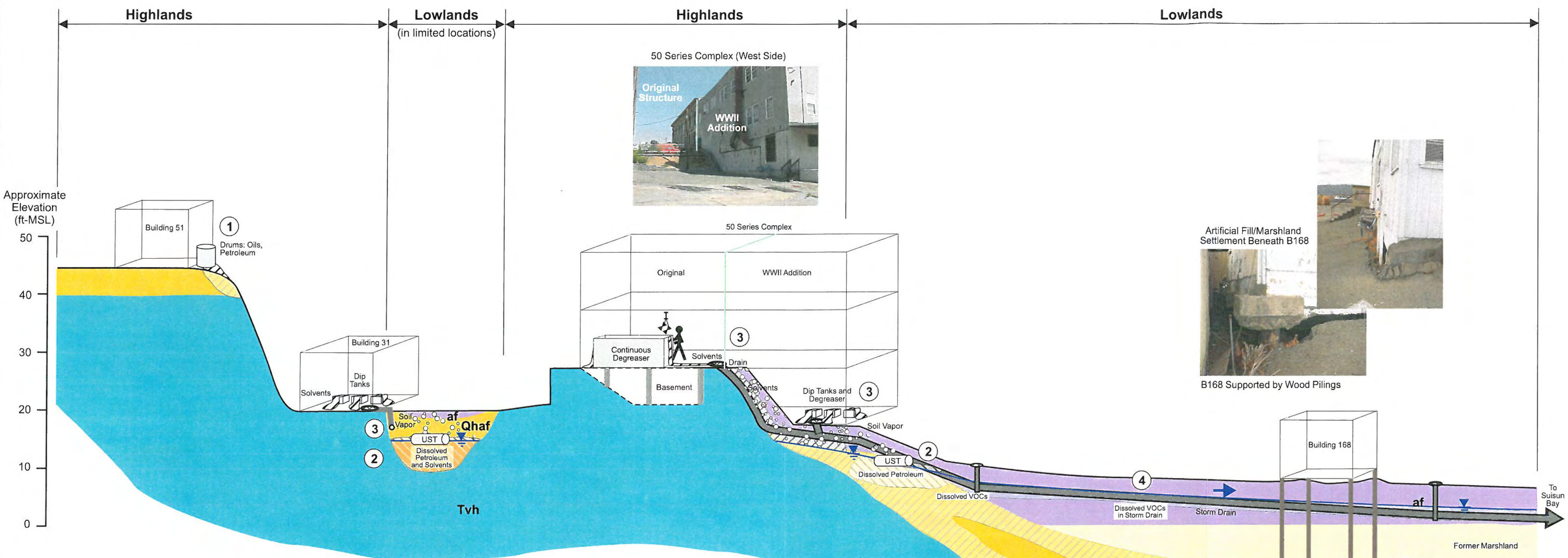
2.3.1 Release Mechanisms

A variety of chemicals were used for the servicing of arms, maintenance of vehicles, assembly and preservation of parts, and fueling of vehicles and boilers. Chemicals may have leaked, spilled, discharged, or been dumped to the surrounding soil and groundwater, see Figure 2-2. From fueling operations, USTs may have leaked or overfilled causing fuel to penetrate surrounding soil and groundwater. Degreasing, paint stripping, and tar removal chemicals were stored in tanks in the 50 Series Complex and surrounding buildings and usually emptied every two to three weeks (Jacobs, 1999). Metal shavings, such as lead and copper, were also by-products in the Arsenal's machining operations and were possibly dumped into the nearby fillsites (FA/BC, 2004b and FA/BC, 2004c). Used liquid materials may have been discharged into the storm/sewer system, a common practice prior to the 1970s.

2.3.2 Pathways and Mobility

Migration pathways for contamination include migration of chemicals in liquid, gaseous, or vapor form from soil to groundwater. After contaminants infiltrate soil, they may migrate further downward into groundwater or be transported laterally as vapor. Once in groundwater, dissolved contaminants migrate primarily in the direction of groundwater flow by advection unless a more permeable path is intercepted (i.e., storm water drain system). In the industrial area, the storm water drain system, specifically in the Lowlands, where catch basins are up to 8 feet deep and groundwater is as shallow as 3 feet deep, may intercept shallow groundwater.

Migration pathways expected at the Arsenal based on DoD activities (e.g., servicing, maintenance, assembly and preservation of parts, and fueling of vehicles) occurred in areas where asphalt pavement or concrete covered exposed soil. Pavement eliminates the possibility of widespread contamination to soil, unless the source of the contamination pathway was beneath the pavement, like, a leak from a UST. Additionally, in the Lowlands, where groundwater is close to the surface (less than 10 feet bgs) and where most of these activities occurred, a subsurface release, for example from a hole in a UST, may impact groundwater immediately as shown on Figure 2-2. Residual contaminants in groundwater may impact soil secondarily when contaminated groundwater adsorbs onto soil particles when groundwater naturally rises and falls. Therefore, any impacted soil found is expected to be the result of a release directly to the surface soil, for example, spills or disposal in unpaved areas as shown on Figure 2-2.



Types of Contaminant Release Mechanisms and Migration Pathways

1. **Release Mechanism:** Spill or leak on unpaved soil
   Migration Pathway: Soil and soil vapor
2. **Release Mechanism:** Leak from partially submerged UST
   Migration Pathway: Groundwater
3. **Release Mechanism:** Spill waste onto floor that drains into storm drain system
   Migration Pathway: Leaks in system impacts soil, soil vapor, and groundwater
4. **Release Mechanism:** Secondary release of contaminated groundwater infiltrates storm drain system
   Migration Pathway: Contaminants conveyed through the system and leaks from system into groundwater downstream of source area

Hydrostratigraphic Units	Geologic Units
Relatively Permeable Units	Artificial Fill (af)
	Alluvium (Qhaf) -fining upwards sequences of silt to silty clay with some lenses of sand and clay
Relatively Non Permeable Units	Bay Mud (Qhbm) - clays and sensitive fines
	Bedrock (Tvh) - Vine Hill Sandstone

Explanation

Storm Water Catch Basin	Petroleum
UST Underground Storage Tank	VOC's
Groundwater Table	Soil Gas
Groundwater Flow Direction	
Storm Water Drain Line	
Drain Inlet	

Figure 2-2
Groundwater Conceptual Site Model
Expanded Site Inspection Report
Former Benicia Arsenal

The site geology influences contaminant mobility. In the CSM, Figure 2-2, Pleistocene-age alluvial and fluvial deposits are shown overlying and inter-fingering the Bay Mud or lying directly on sandstone bedrock. The alluvial and fluvial deposits may be relatively permeable or nonpermeable depending on the ratio of gravel, silt, sand and clay. The Bay Mud and sandstone bedrock units are relatively nonpermeable.

Air. COIs may be transported in the air via dust or volatilization. Examples of airborne transport of chemicals in dust include metals from discharged bullets in the former firing range or burnt wastes discarded or scattered. Nonvolatile chemicals may be transported by air when wind suspends dust in the air and distributes the chemicals throughout the area. The fine particles of dust could contain COIs, such as lead from ammunition.

Solvents (e.g., TCE and cis-1,2-DCE) may be present in surface soil from spills from the vats or dipping tanks. Volatile chemicals may be released to the air via evaporation when solvents are dumped into the fillsites. Another possible pathway for volatiles to contaminate air is by volatization from contaminated soil. Volatile chemicals in soil and dissolved in groundwater may migrate vertically upward and eventually reach the surface and enter the atmosphere.

Surface Water. Released chemicals may be transported by surface water either by dissolving or physically mixing with the fine sediment in surface water. Petroleum hydrocarbons could have dissolved and floated along surface water eventually deposited in the low-lying areas (Figure 2-2).

Soil. Potential mobility of a contaminate in soil is by volatilization or percolation/infiltration. Discarded volatile chemicals may volatilize in the silt, sand and poorly graded gravel creating soil vapor. Spilled waste solvents or spent fuels may percolate or infiltrate into the subsurface soil or into groundwater. Infiltration of surface water through surface soil may also carry contaminants downward into subsurface soil and groundwater. The contaminant may not mobilize in soil if conditions are inadequate (e.g. oxidizing or reducing environments and solubility). An example of this condition is common with metals.

2.3.3 Arsenal Contaminant Migration in the Lowlands

Four hypotheses were developed about how contaminants may be migrating once reaching the shallow groundwater in the Lowlands since a majority of the Expanded SI sites are located in these areas (37 of 53 sites) and more specifically in the industrial area (30 of 37 sites) where previous investigations have indicated the highest contaminant concentrations in soil and groundwater.

In the first hypothesis, low-density contaminants such as dissolved petroleum migrate along the top of the water table (Figure 2-2). In the second hypothesis, shown in Figure 2-2, dissolved VOCs could migrate preferentially in lenses of permeable alluvium that interfinger within the Bay Mud. The continuity of these lenses would likely dictate the extent of contaminates since the surrounding Bay Mud would prohibit migration due its very low permeability. The third hypothesis is that contaminants could migrate along the top of sandstone in weathered sandstone or overlying alluvium (Figure 2-2). The fourth hypothesis is an extension of the first and second hypotheses, such that the dissolved petroleum and VOCs in shallow groundwater intercept a more permeable path, like the storm water drain system and then are carried away from the source area.

Once released into the environment, several mechanisms can transport the chemicals. Advection and convection, the processes that transport chemicals in flowing water, could transport the fuels, metals, and solvents released throughout the former marshland and other downgradient areas of the Arsenal. Another process affecting the distribution of contaminants within the environment is dispersion; as the contaminants are transported, the contaminant may become dispersed. Molecular diffusion or mechanical dispersion can occur as molecules of the contaminant adhere to particles or spread throughout media. Groundwater is not present in the foothills such as at Buildings 42 and 51 or former Buildings TO131, 171, 172, T222 and TO73 or the Firing Range; therefore, groundwater is not a considered pathway at these locations.

The CSM is an important and dynamic tool that aided the sampling strategy and helped to achieve the project objectives during this investigation. Establishing potential contaminants, media that may be contaminated, and pathways of migration were necessary to determine sampling locations and sample depths. The CSM guided the investigation by establishing the source areas, types of contamination and probable plume paths. For example, cone penetrometer technology (CPT) logs were used to determine if there were lenses of permeable alluvium that interfinger within the Bay Mud and groundwater samples were collected at multiple depths based on the hypotheses described above.

SECTION 3
FIELD METHODS AND SAMPLING RATIONALE

This section describes the field methods used, the rationale for selecting the number and location of samples, analytical parameters, and IDW management procedures for the Expanded SI.

3.1 Field Methods

A geophysical survey was conducted as an initial step to clear boring locations of utilities and any underground obstruction. After the geophysical clearance, drilling and sampling activities began. The field techniques are described in detail in the FSIP (BC, 2004a). A total of 14 soil samples, 16 soil gas samples, 117 Hydropunch® groundwater samples, 15 storm water catch basin samples, and 14 groundwater well samples were collected during this investigation.

3.1.1 Geophysical Survey

Ground penetrating radar and electromagnetic line locating methods were used to clear boring locations for subsurface obstructions and utilities. NORCAL Geophysical Consultants, Incorporated (NORCAL) of Petaluma, California performed the geophysical investigations on April 22 through 28, 2004.

3.1.2 Soil Samples

A total of 14 soil samples (5 composite samples and 9 discrete soil samples) were collected during this investigation (excluding quality assurance/quality control (QA/QC) samples). Soil samples were collected at limited locations where releases of non-mobile contaminants may have occurred or further delineation of previously detected contaminates is needed. PAHs and metals, relatively immobile chemicals, are suspected at various locations such as the firing range and Buildings 51 and 58(A). Therefore, soil samples were collected at these locations. Previously, investigations were performed at former UST locations, Buildings 53 and 103, where regulatory agencies had requested further delineation. Soil samples were also collected at these locations.

Hand augered soil borings, surface soils, and composite soil samples were collected during field activities and are described below.

Hand Auger Soil Borings. Soil borings were hand augered at three locations, Building 51, the Firing Range, and Spur E.

The purpose of the hand augered soil borings was to collect soil samples for chemical analyses in areas of limited vehicle access, where a CPT rig could not be used. The borings were augered to the desired sampling depth and then withdrawn. To collect the soil sample, a manual slide impact sampler with a sample sleeve was pounded into the soil to a depth of 6 inches (the length of the sample sleeve). If additional soil samples were needed, the boring was advanced to the next interval and the drive sampling process was repeated.

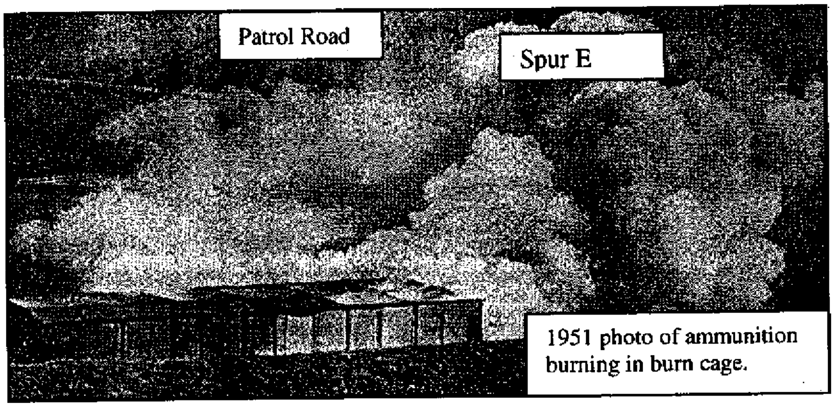
3.1.3 Surface Soil

For areas where surface release was suspected, soil samples were collected at various depths depending upon surface conditions (e.g. asphalt paved versus non-asphalt paved surfaces). Soil samples collected at B58(A)SB001, B65ASB001, B118AHP001, and B120HP002 were collected at asphalt-paved surfaces; therefore, the soil samples were collected 2 and 5 feet below subgrade materials (e.g. aggregate, base rock) to minimize the possible impact from leaching of the asphalt into the underlying soil. At non-asphalt paved surfaces, B051HP001 and B103SB001, soil samples were collected at 0.5 foot and 5 feet below subgrade materials.

3.1.4 Composite Soil Samples.

Composite soil samples were collected at SPUR E and the Firing Range.

Two composite surface soil samples (less than 0.5 foot bgs) were collected near Spur E. One composite sample was collected approximately 60 feet in the upwind direction of the former Spur E and one composite sample was collected approximately 100 feet in the downwind direction (photo, to the right) of the former Spur E. These surface soil samples were collected from native soil or just below any aggregate or paving materials. Each sample was composed of five soil samples composited into one soil sample. The downwind soil sample (SPURECS002) was used to determine if there was an impact to surface soil from particulates produced during burning which were blown downwind of the former burn cage. The upwind sample (SPURECS001), collected in the same manner as the downwind sample, was used to determine the ambient concentrations of the area.



1951 photo of ammunition burning in burn cage.

Three composite soil samples were collected at the Firing Range. The samples were collected from the berm. A composite of five soil samples was collected every 50 cubic yards along the berm (50 cubic yards is the industry standard for obtaining representative soil composition). The berm comprised approximately 150 yards; therefore, three five-point composite soil samples were collected. Bullet and bullet fragments were removed from the sample using a No. 10 sieve (0.0787-inch opening).

3.1.5 Cone Penetrometer Technology (CPT) Borings and Groundwater Sampling

A total of 117 Hydropunch® groundwater samples and 11 groundwater well samples were collected during this investigation (excluding QA/QC samples).


CPT rig positioned at TO-131.

The CPT can provide a large amount of data for geotechnical analysis of the soil, our primary objectives were simpler:

- Push every boring to refusal or to the maximum depth of the device,
- Record the lithology, and
- Establish location of significant water bearing units.

During the planning stages, the depth to the sandstone bedrock was considered a critical component of the investigation to determine the vertical extent of the contaminants, especially in the industrial area where the contaminants had already been found. By pushing to refusal, we assumed that bedrock was encountered. All of these measurements were used to map the surface of the sandstone. This led us into determining contaminant migration pathways and correlating them with significant water bearing zones.

Borings were advanced with a CPT rig to first collect lithologic data and then a Hydropunch® was advanced to collect either a soil and/or groundwater sample. The purpose of the Hydropunch® was to collect a grab sample to obtain information on contaminants from previous facility use.

The CPT is performed with a cylindrical penetrometer with a conical tip (cone) penetrating into the ground at a constant rate. During the penetration, the forces on the cone and the friction sleeve are measured. The measurements are carried out using electronic transfer and data logging, with a measurement frequency that can secure detailed information about the soil conditions. The results from a cone penetration test can in principle be used to evaluate stratification, soil type, soil density and in situ stress conditions, and shear strength parameters.

The CPT probe also had the capability to acquire pore pressure data verses time. At anytime during a CPT test, the push can be paused to record pore pressure dissipation as it approaches static equilibrium also known as a dissipation test. The data is viewed in real time to determine depth to groundwater. In combination with these tests and a relative readout of negative pore pressures, the location of significant water bearing zones can be determined.

At the Post Dumpsite, the depth to the top sandstone bedrock was greater than amount of CPT rod available (130 feet) at PD001HP006.

3.1.6 Groundwater Monitoring Wells

Up to 13 monitoring wells (piezometers) were planned during the Expanded SI. The purpose of these wells was to obtain water-level elevations and groundwater samples. After completion of the fieldwork, the project team believed these wells were not necessary at this time.

Fourteen groundwater samples were collected from existing piezometers PZ-1, PZ-2, PZ-3, PZ-5, PZ-6, PZ-12, PZ-20, Valero Well #117, B057AHP003, B057AHP005, and B057AHP006. Piezometers PZ-2, PZ-5 and B057AHP005 were sampled twice. These piezometers were purged of three casing volumes before samples were collected. Field instruments were calibrated prior to daily sampling activities according to manufacturer's guidelines. Instrument measurements were recorded in the field notebooks. Samples were collected using disposable bailers and placed into containers supplied by the analytical laboratory.

3.1.7 Soil Gas Sampling

A total of 16 soil gas samples were collected during this investigation (excluding QA/QC samples). The purpose of the soil gas samples was to evaluate areas near current buildings where VOCs have potential to impact indoor air quality. Soil gas samples collected during this project were collected from the CPT borings if either no groundwater was encountered and the sampling location was near an existing building, or groundwater was encountered, key indicator chemicals were present at detectable concentrations, and the location was near an existing building.

In addition, a soil gas sample was collected adjacent to Building TO131 since sandstone is close to the surface (less than 7 feet bgs), it was assumed that no groundwater would be encountered; this was confirmed during field work. Soil gas samples were also collected at Building 31, 42, 51 90, 93, 156, 171, 172, T222, and TO73 and at boring SWAMPAHP001 due to shallow bedrock and no groundwater.

3.1.8 Storm Drain Catch Basin Sampling

Three existing piezometers (PZ-2, PZ-5 and B057AHP005) and 15 storm water catch basins were sampled in September 2004 and October 2004. These water samples were collected to determine if the storm water drain system in the industrial area is intercepting shallow contaminated groundwater. In order to determine if groundwater was entering in the catch basin, the nearest catch basin downgradient from a piezometer screened across shallow groundwater was sampled. Other catch basins were also sampled upstream, within and downstream of the industrial area to determine the lateral extent of the contaminated water within the system.

3.2 Sample Locations and Analytical Parameters

The boring locations and chemical parameters were selected based on site-specific historical records and information obtained during previous investigations. The Expanded SI site, boring/piezometer ID, matrix sampled and depth, and analyses performed are shown on Table 3-1. Red text indicates step locations sampled or additional samples/analyses collected per the decision criteria. Purple indicates the additional analysis performed to further define the discrete peaks on fuel chromatographs. Storm drain catch basins and selected piezometers sampled in September and October 2004 are listed on Table 3-2.

Table 3-1. Sample IDs, Matrix, and Analysis

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	B004HP001	GW	5-10	26.74	TPHG/VOCs (8260B), TPHD/MO (8015B), Metals
			23-27		TPHG/VOCs (8260B), TPHD/MO (8015B)
	B004HP002	GW	5-10	72.51	TPHG/VOCs (8260B), TPHD/MO (8015B), Metals
			68-72		TPHG/VOCs (8260B), TPHD/MO (8015B)
	B004HP003	GW	5-10	74.64	TPHG/VOCs (8260B), TPHD/MO (8015B)
			68-72		
	B154HP001	GW	5-10	33.96	TPHG/VOCs (8260B), TPHD/MO (8015B), lead, PAHs (8310)
			30-34		TPHG/VOCs (8260B), TPHD/MO (8015B)
31	B031HP001	GW	5-10	15.91	TPHG/VOCs (8260B), TPHD/MO (8015B), Metals
	B031HP002	SG	3-4	7.71	TPHG/VOCs (8260B)
	B031HP003	GW	5-10		TPHG/VOCs (8260B), TPHD/MO (8015B), Metals
42	B042HP001	SG	3-4	5.09	TPHG/VOCs (8260B)
	B042HP002	SG	1-2	1.48	TPHG/VOCs (8260B)
50	B050HP001	SG	3-4	45.44	TPHG/VOCs (8260B)
		GW	5-15		TPHG/VOCs (8260B), TPHD/MO (8015B), Lead (6010B)
51	B051HP001 (Hand Auger)	S	0.5-1	NA (hand augered - TD 2 feet)	TPHD/MO (8015B), TPHG/VOCs (8260B), PAHs (8310), SVOCs (8270C), Metals
			1.5-2		
53	B053SB003	S	4.5-5	NA (used geoprobe - 5.5 feet TD)	TPHD/MO (8015B), lead (6010B), PAHs (8310)
	B053HP001	GW	7-9	24.44	TPHG/VOCs (8260B), TPHD/MO (8015B), Lead (6010B)
55	See B120HP003 at Site 120	GW	5-10	21.49	TPHD/MO (8015B), TPHG/VOCs (8260B)
	B057AHP003 (piezometer)		11-18.5	NA	
56	B057AHP003 (piezometer)	GW	11-18.5	NA	TPHD/MO (8015B), TPHG/VOCs (8260B)
56A	B056AHP001	GW	5-10	46.10	TPHD/MO (8015B), TPHG/VOCs (8260B)
	B057AHP005 (piezometer)		3-13.5	NA	

Table 3-1. Sample IDs, Matrix, and Analysis

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	B057AHP006 (piezometer)			NA	
57	See B161HP002 at Site 161	GW	19-23	23.46	TPHD/MO (8015B), TPHG/VOCs (8260B)
	See B031HP002 at Site 31	SG	3-4	7.71	TPHG/VOCs (8260B)
	B057AHP006 (piezometer)	GW	3-13.5	NA	TPHD/MO (8015B), TPHG/VOCs (8260B)
58(A)	B058ASB001	S	2.5-3	NA (hand augered - TD 5 feet)	TPHD/MO (8015B), TPHG/VOCs (8260B), Lead (6010B), PAHs (8310)
	B056AHP001	GW	5-10	46.10	TPHD/MO (8015B), TPHG/VOCs (8260B)
	B057AHP005 (piezometer)		3-13.5	NA	
	B057AHP006 (piezometer)		3-13.5	NA	
59	B059HP001	GW	2.5-4.5	12.96	TPHD/MO (8015B), TPHG/VOCs (8260B)
			5-10		PAHs (8310)
	B053HP001		7-9	24.44	TPHD/MO (8015B), TPHG/VOCs (8260B), Lead (6010B)
59(A)	B059(A)HP001	GW	5-10	42.81	TPHD/MO (8015B), TPHG/VOCs (8260B)
65(A)	B065ASB001	S	2-2.5	NA (hand augered - TD 5 feet)	TPHD/MO (8015B), TPHG/VOCs (8260B), Lead (6010B), PAHs (8310)
	B057AHP006 (piezometer)	GW	3-13.5	NA	TPHD/MO (8015B), TPHG/VOCs (8260B)
90	B090HP001	SG	3-4	13.12	TPHG/VOCs (8260B)
		GW	8-13		TPHD/MO (8015B), TPHG/VOCs (8260B)
91	B091HP001	GW	5-10	31.99	TPHD/MO (8015B), TPHG/VOCs (8260B), Metals
91A	B091AHP001	GW	5-10	23.62	TPHD/MO (8015B), TPHG/VOCs (8260B), Metals
93	B093HP001	SG	2.5-3.5	4.96	TPHG/VOCs (8260B)
101	B101HP001	GW	5-10	22.47	TPHD/MO (8015B), Metals
	B101HP002			20.83	

Table 3-1. Sample IDs, Matrix, and Analysis

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
103	B103SB001	S	5-6	16.90	TPHD/MO (8015B), TPHG/VOCs (8260B)
111	B111HP001	SG	3-4	17.55	TPHG/VOCs (8260B)
		GW	5-14		TPHG/VOCs (8260B), TPHD/MO (8015B)
118(A)	B004HP002	GW	5-10	72.51	TPHD/MO (8015B), TPHG/VOCs (8260B), Metals
			68-72		TPHD/MO (8015B), TPHG/VOCs (8260B)
	B118AHP001	S	4.5-5	7.05	TPHD/MO (8015B)
	B118AHP002	GW	5-10	27.56	TPHG/VOCs (8260B), TPHD/MO (8015B)
120	B120HP001	GW	2-5	24.44	TPHG/VOCs (8260B), TPHD/MO (8015B)
	B120HP002	S	3-3.5	42.81	cadmium, chromium, copper and nickel (6010B) (Note: cyanide was requested but was inadvertently not analyzed at the lab)
		GW	5-10		TPHG/VOCs (8260B), TPHD/MO (8015B), cadmium, chromium, copper and nickel (6010B)
			34-42		TPHG/VOCs (8260B), TPHD/MO (8015B)
	B120HP003	GW	5-10	21.49	TPHD/MO (8015B), TPHG/VOCs (8260B)
	B120HP004	SG	3-4	54.46	TPHG/VOCs (8260B)
		GW	5-10		TPHD/MO (8015B), TPHG/VOCs (8260B)
	B120HP005	No sample collected – no groundwater due to shallow sandstone		11.48	--
154	B154HP001	GW	5-10	33.96	TPHD/MO (8015B), TPHG/VOCs (8260B), Lead (6010B), PAHs (8310)
			30-34		TPHD/MO (8015B), TPHG/VOCs (8260B)
	B154HP002	GW	5-10	52.16	TPHD/MO (8015B), TPHG/VOCs (8260B), Lead (6010B)
			42-52		TPHD/MO (8015B), TPHG/VOCs (8260B)
	B154SB001	S	4.5-5	5.5	TPHD/MO (8015B), TPHG/VOCs (8260B)
156	B156HP001	SG	3-4	7.71	TPHG/VOCs (8260B)
	B156HP002			16.24	

Table 3-1. Sample IDs, Matrix, and Analysis

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
161	B161HP001	GW	9-13	56.27	TPHD/MO (8015B), TPHG/VOCs (8260B), Metals
			49-56		TPHD/MO (8015B), TPHG/VOCs (8260B)
	B161HP002	GW	5-10	23.46	TPHD/MO (8015B), TPHG/VOCs (8260B)
			19-23		TPHD/MO (8015B), TPHG/VOCs (8260B), Metals
165	B165HP001	SG	3-4	44.62	TPHG/VOCs (8260B)
		GW	5-10		TPHD/MO (8015B), TPHG/VOCs (8260B), Metals
			36-43		TPHD/MO (8015B), TPHG/VOCs (8260B)
	B165HP002	GW	5-14	29.69	TPHD/MO (8015B), TPHG/VOCs (8260B), Metals
	B165HP003	No sample collected – no groundwater due to shallow sandstone		6.73	--
	B165HP004	GW	5-10	92.68	TPHD/MO (8015B), TPHG/VOCs (8260B)
			53-62		
	B165HP005	GW	2-5	57.74	
			49-58		
	PZ-2 (piezometer)	GW	6-15	NA	
	PZ-3 (piezometer)	GW	54-64	NA	
165A/T199	B165AHP001	GW	5-10	49.21	TPHD/MO (8015B), TPHG/VOCs (8260B)
	B165AHP002	GW	10-20	92.03	
166	SWAMPAHP003	GW	5-10	35.76	TPHD/MO (8015B), TPHG/VOCs (8260B)
	SWAMPAHP006	GW	5-10	63.81	TPHD/MO (8015B), TPHG/VOCs (8260B)
			56-63		
167	B167HP001	GW	5-10	52.16	TPHD/MO (8015B), TPHG/VOCs (8260B)
	B167HP002	GW	5-10	104.82	
168	B168HP001	GW	5-10	67.26	TPHD/MO (8015B), TPHG/VOCs (8260B), SVOCs (8270C)
	B168HP002	GW	5-10	36.58	TPHD/MO (8015B), TPHG/VOCs (8260B)
171	B171HP001	SG	3-4	40.19	TPHG/VOCs (8260B)
172	B172HP001	SG	5-6	32.97	TPHG/VOCs (8260B)
194	B194HP001	GW	Not conducted due to lack of right-of-entry		
CL1	CL1HP001	GW	Not conducted due to lack of right-of-entry		
	CL1HP002	GW	Not conducted due to lack of right-of-entry		
CL2	CL2HP001	GW	Not conducted due to lack of right-of-entry		

Table 3-1. Sample IDs. Matrix. and Analysis

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fillsite 1 (Formerly Landfill 1)	FS001HP001	GW	3.6-10	13.29	TPHD/MO (8015B), TPHG/VOCs (8260B)
			5-10		PAHs (8310)
	FS001HP002	GW	5-10	52.49	TPHD/MO (8015B), TPHG/VOCs (8260B)
			46-54		
	FS001HP003	GW	0-10	85.46	TPHD/MO (8015B), TPHG/VOCs (8260B)
			76-85		
	FS001HP004	GW	0-10	54.79	TPHD/MO (8015B), TPHG/VOCs (8260B)
	FS001HP005	GW	0-10	50.52	TPHD/MO (8015B), TPHG/VOCs (8260B), SVOCs (8270C)
	FS001HP006	GW	5-10	51.51	TPHD/MO (8015B), TPHG/VOCs (8260B)
	FS001HP007	GW	5-10	27.89	TPHD/MO (8015B), TPHG/VOCs (8260B)
			18-27		
	FS001HP008	GW	5-10	43.14	TPHD/MO (8015B), TPHG/VOCs (8260B)
			37-42		
	FS001HP009	GW	5-10	16.40	TPHD/MO (8015B), TPHG/VOCs (8260B)
	FS001HP010	GW	5-10	41.01	TPHD/MO (8015B), TPHG/VOCs (8260B)
			32-41		
	FS001HP011	GW	5-10	10.17	TPHD/MO (8015B), TPHG/VOCs (8260B)
	FS001HP012	GW	5-10	27.07	TPHD/MO (8015B), TPHG/VOCs (8260B), PAHs (8310)
			23-27		TPHD/MO (8015B), TPHG/VOCs (8260B)
	FS001HP013	GW	5-10	13.29	TPHD/MO (8015B), TPHG/VOCs (8260B)
Fillsite 3 (formerly the Dumpsite)	FS003HP001	GW	6.4-9.4	26.57	TPHD/MO (8015B), TPHG/VOCs (8260B)
	FS003HP002	GW	10-15	34.28	
Firing Range	FR01CS001	S	0	NA	Antimony, Copper, Lead, Zinc (6010B), Arsenic (7060A)
	FR01CS002	S	0	NA	Antimony, Copper, Lead, Zinc (6010B), Arsenic (7060A)
	FR01CS003	S	0	NA	Antimony, Copper, Lead, Zinc (6010B), Arsenic (7060A)
Post Dumpsite (Formerly Landfill 3)	PD001HP001	GW	5-15	103.67	Metals
	PD001HP002		5-10	108.59	
	PD001HP003		5-10	107.77	
	PD001HP004		8-23	109.91	

Table 3-1. Sample IDs, Matrix, and Analysis

Inspection Site	Boring / Piezometer ID	Matrix (SG/S/GW)	[illegible]	[illegible] (feet bgs)	[illegible] EPA [illegible]
	PD001HP005		5-15	130.41	
	PD001HP006		5-15	108.92	
Popping pot (formerly the Incinerator and also known as the Armored Fighting Vehicle)	AFVSB002	GW	5-10	37.57	Explosives (8330), TPHD/MO (8015B), TDS (E160.1), Anions (E300), barium (6010B), cadmium (6010B), chromium (6010B), lead (6010B), silver (6010B), zinc (6010B), arsenic (7060A), mercury (7470A), selenium (7740)
		GW	18-25		
Salvage yard	OS29HP001	GW	5-15	87.76	TPHD/MO (8015B), TPHG/VOCs (8260B)
			86.5-87		
	OS29HP002	GW	5-15	75.62	TPHD/MO (8015B), TPHG/VOCs (8260B)
			73.5-74		TPHD/MO (8015B), TPHG/VOCs (8260B), SVOCs (8270C)
	OS29HP003	GW	5-10	36.74	TPHD/MO (8015B), TPHG/VOCs (8260B)
			32-35		TPHD/MO (8015B), TPHG/VOCs (8260B), SVOCs (8270C)
Spur E	SPURECS001	S	0.3-0.8	NA	Metals, Explosives (8330)
	SPURECS002			NA	
	SPUREHP001	GW	40-45	42.98	TPHD/MO (8015B), Metals, Explosives (8330), SVOCs (8270C)
	SPUREHP002		12-22	22.8	TPHD/MO (8015B), Metals, Explosives (8330)
T221	PZ-20 (piezometer)	GW	18-34.5	NA	TPHD/MO (8015B), TPHG/VOCs (8260B)
T222	T222HP001	SG	5-6	33.14	TPHG/VOCs (8260B)
TO73	TO73HP001	SG	3-4	30.51	TPHG/VOCs (8260B)
TO131	TO131HP001	SG	4-5	6.56	TPHG/VOCs (8260B)
Swamp	SWAMPAHP001	No sample collected – no groundwater due to shallow sandstone		6.07	--
	SWAMPAHP002	GW	5-15	52.98	TPHD/MO (8015B), TPHG/VOCs (8260B)
Swamp	SWAMPAHP003	GW	5-10	35.76	TPHD/MO (8015B), TPHG/VOCs (8260B)
	SWAMPAHP004	GW	5-10	92.03	TPHD/MO (8015B), TPHG/VOCs (8260B)
			61-70		
	SWAMPAHP005	GW	5-10	48.56	TPHD/MO (8015B), TPHG/VOCs (8260B)
	SWAMPAHP006	GW	5-10	63.81	TPHD/MO (8015B), TPHG/VOCs

Table 3-1. Sample IDs, Matrix, and Analysis

[illegible]	Boring/Piezometer ID	[illegible] (SOIL/GW)	[illegible] Depth (feet bgs)	[illegible] (feet bgs)	[illegible] (EPA Method)
			56-63		(8260B)
	SWAMPAHP007	GW	5-10 78-87	87.11	TPHD/MO (8015B), TPHG/VOCs (8260B)
	SWAMPAHP008	GW	5-10 77-85	85.46	TPHD/MO (8015B), TPHG/VOCs (8260B)
	SWAMPBHP001	GW	20-30	75.62	TPHD/MO (8015B), TPHG/VOCs (8260B)
	SWAMPBHP002	GW	5-10	66.44	TPHD/MO (8015B), TPHG/VOCs (8260B), SVOCs (8270C)
	SWAMPBHP003	GW	5-10 91-100	103.51	TPHD/MO (8015B), TPHG/VOCs (8260B)
	SWAMPBHP004	GW	5-10	82.84	TPHD/MO (8015B), TPHG/VOCs (8260B)
	SWAMPBHP005	GW	5-10	59.55	TPHD/MO (8015B), TPHG/VOCs (8260B)
	SWAMPBHP006	GW	0-10	62.83	TPHD/MO (8015B), TPHG/VOCs (8260B)
	PZ-1 (piezometer)	GW	6-15	NA	TPHD/MO (8015B), TPHG/VOCs (8260B)
	PZ-2 (piezometer)	GW	10-20	NA	TPHD/MO (8015B), TPHG/VOCs (8260B)
	PZ-3 (piezometer)	GW	54-64	NA	TPHD/MO (8015B), TPHG/VOCs (8260B)
	PZ-5 (piezometer)	GW	5-15	NA	TPHD/MO (8015B), TPHG/VOCs (8260B)
	PZ-6 (piezometer)	GW	25-34	NA	TPHD/MO (8015B), TPHG/VOCs (8260B)
Waste Areas/Open Ditch	WA001HP001	GW	5-10 16-25 63-73	75.29	TPHD/MO (8015B), TPHG/VOCs (8260B)
	WA001HP002	GW	40-50	67.09	TPHD/MO (8015B), TPHG/VOCs (8260B)
	WA001HP003	GW	7-12 43-50	62.01	TPHD/MO (8015B), TPHG/VOCs (8260B)
	OD01HP001	GW	1-3	NA (hand augered – TD 3 feet	TPHD/MO (8015B), TPHG/VOCs (8260B)
Waste Areas/Open Ditch	OD01HP002	GW	2-2.5	NA (hand augered – TD 2.5 feet	TPHD/MO (8015B), TPHG/VOCs (8260B)
	OD01HP003	GW	4-5.5	NA (hand augered – TD 5.5 feet	TPHD/MO (8015B), TPHG/VOCs (8260B)

Table 3-1. Sample IDs. Matrix. and Analysis

Inspection Site	Boring/ Piezometer ID	Matrix (S/SG/GW)	[illegible]	[illegible]	Analysis (EPA Method)
	PZ-12 (piezometer)	GW	7.9-15	NA	TPHD/MO (8015B), TPHG/VOCs (8260B)
	Valero Well #117	GW	9.4-18.3	NA	TPHD/MO (8015B), TPHG/VOCs (8260B), SVOCs (8270C)

Notes:

1. Unless otherwise noted,
   a. Analytical methods for metals in soil consists of antimony, barium, beryllium, total chromium, cobalt, copper, manganese, molybdenum, nickel, selenium, silver, tin, vanadium and zinc by 6010B, cadmium and lead by 6010B ICP trace, arsenic by 7060A, thallium by 7841 and mercury by 7471A.
   b. Analytical methods for metals in groundwater consist of antimony, arsenic, barium, beryllium, total chromium, cobalt, copper, manganese, molybdenum, nickel, selenium, silver, thallium, tin, vanadium and zinc by 6010B, and cadmium and lead by 6010B ICP trace.
2. Red indicates step locations sampled or additional samples/analyses collected per the decision criteria (Diagram 1-1).
3. Purple indicates analysis added to further define discrete peaks on fuel chromatographs indicating low-level diesel and motor oil detections.

Anions = chloride (as CL), nitrate (as N), nitrogen, nitrite (as N), and sulfate (as SO4)
AST = aboveground storage tank
bgs = below ground surface
GW = groundwater
NA = not applicable
PAHs = polyaromatic hydrocarbons
S = soil
SG = soil gas
SVOCs = semivolatile organic compounds
TDS = total dissolved solids
TPHD = total petroleum hydrocarbons as diesel fuel
TPHG = total petroleum hydrocarbons as gasoline
TPHMO = total petroleum hydrocarbons as motor oil
UST = underground storage tank
VOCs = volatile organic compounds

Table 3-2. Storm Drain Catch Basin Sample IDs and Analyses

[illegible]	[illegible]	[illegible]
PZ-2*	10-20	VOCs (8260B), Anions (E300), TDS (E160.1), Calcium, Magnesium, Potassium and Sodium (6010B)
PZ-5*	5-15	
B057AHP005*	2.5-12.5	
B56ASD01*	4.1	
B56ASD02*	4.1	
B089SD01*^	8.05	VOCs (8260B), Anions (E300), TDS (E160.1), Calcium, Magnesium, Potassium and Sodium (6010B), TPHD/MO (8015B), SVOCs (8270C)
B089SD02^	8.05	
B091SD02^	5.6	
B091SD04^	3	
B116SD01^	7.58	
B161SD02^	3.35	
B165SD01*^	4.6	
B165SD02*	4.91	VOCs (8260B), Anions (E300), TDS (E160.1), Calcium, Magnesium, Potassium and Sodium (6010B)
B165SD03*^	5.2*, 4.7^	VOCs (8260B), Anions (E300), TDS (E160.1), Calcium, Magnesium, Potassium and Sodium (6010B), TPHD/MO (8015B), SVOCs (8270C)^
B165SD05^	4.65	
B165SD20^	5.9	
CITYSD02^	3.48	
SUMP01^	12.6	

Notes:
*Samples collected on September 17, 2004.
^Samples collected on October 28, 2004.

bgs = below ground surface
Anions = chloride (as CL), nitrate (as N), nitrogen, nitrite (as N), and sulfate (as SO4)
TDS = total dissolved solids
TPHD = total petroleum hydrocarbons as diesel fuel
TPHMO = total petroleum hydrocarbons as motor oil
VOCs = volatile organic compounds
SVOCs = semi-volatile organic compound

As stated in Section 1.1, Problem Definition and Scope, additional groundwater samples were collected for PAH analysis. The location of the additional PAH samples were determined solely on the results from the Hydropunch® samples and therefore, we could not forecast which borings to leave open for these samples. It was safer to grout up all the borings as the investigation proceeded and redrill for these samples. A total of four locations (B059HP001, B154HP001, FS001HP001 and FS001HP012) met this criterion. The analysis PAHs (8310) is highlighted in red on Table 3-1 to indicate the location of these analyses.

The chromatography of groundwater samples at seven locations (B168HP001-A-W01, FS001HP005-A-W01, OS29HP003-A-W01, OS29HP002-A-W01, SPUREHP001-A-W01, SWAMPBHP002-A-W01, and Valero117-A-W01) indicated low-level (less than 300 μg/L) diesel range and motor oil range organics with several distinct peaks on the chromatographs. These peaks had the potential to be other organics and not fuel. In an attempt to speciate these peaks, the remaining groundwater samples were sent for semi-volatile organic compound (SVOC) analysis by EPA Method 8310 to EMAX laboratories. Results from the speciation and its impact on the fuel concentrations for these samples are described in Section 5.0 Data Usability.

3.3 Investigation Derived Waste

IDW generated as part of the field effort included soil from drilling out a cone penetrometer tool that broke, decontamination rinsate from drilling, and purge water from monitor well sampling.

Table 3-3 presents the quantities of IDW generated during this investigation. The soil from drilling out the broken cone penetrometer was stored at a temporary waste staging area at 3800 Industrial Way. The area at 3800 Industrial Way is a secure site with perimeter fencing and lockable gates. Decontamination of drilling equipment was also staged at 3800 Industrial Way. All decontamination was performed as specified in the QAPP (FA/BC, 2001).

Table 3-3. Quantities of IDW

Media	Quantity
Soil from drilling out cone penetrometer	One 55-gallon drum
Water (decontamination and purge water)	550 gallons

Based on analytical results, soils from this investigation contained low levels of petroleum hydrocarbons. Integrated Waste Management of Milpitas, California transported the soil, classified as non-hazardous, to the Chemical Waste Management facility located in Kettleman Hills, California. Also classified as non-hazardous, the water was transported to Seaport Environmental in Redwood City, California. IDW manifests are included in Appendix C.

Excess disposable wastes derived from sampling, such as personal protective equipment (PPE), gloves, and bailers were disposed by BFI, which provides local garbage disposal service for the area.

SECTION 4
GEOLOGY AND HYDROGEOLOGY

The geology and hydrogeology of the former Benicia Arsenal are discussed in the CHM report (FA/BC, 2003b), and summarized in this section. The regional geology is described in Section 2.1 while the geology and hydrogeology of the Arsenal are described below. The site lithologic data and groundwater quality parameters are also discussed.

4.1 Geology of the Arsenal

As discussed in the PCHM (FA/BC, 2003b), the former Arsenal was divided into two hydrogeologic areas: the Highlands and the Lowlands (Figure 4-1).

The Highlands are the foothill areas of the former Arsenal. Groundwater is found mostly within the alluvial valleys and the weathered bedrock within these alluvial valleys. At the IT Panoche facility, bedrock weathering extends from 1 foot on the valley edges to 27 feet in the center of the valley, but typically averages 10 to 20 feet thick within the central drainage areas (IT Corporation, 2001). These valleys in the Highland areas drain into the Lowlands of the Sulphur Springs Creek drainage area, or to the Lowlands of southern Area I. The boundary between the Highland and the Lowland areas in the Sulphur Springs Creek drainage area is approximately the break in slope between the flat Lowlands and the foothills of the Highlands, and roughly the extent of the Holocene Bay Mud in the Lowlands (Figure 4-1). The Highlands in Area I are the foothills above the filled former marshlands or swamp.

The geology of the Highland area is characterized by a relatively thin veneer (usually less than 50 feet thick) of Pleistocene alluvial and fluvial deposits over the bedrock (the Vine Hill Sandstone or the Great Valley Sequence). The alluvial material consists of sandy silt interbedded with clay, or as cemented sand with seams of gravel layers. Unconsolidated fluvial deposits of clay, silt, sand and gravel cover the bedrock along the creek valleys.

The Lowland area, as shown on Figure 4-1 is the flatlands associated with the Sulphur Springs Creek drainage channel, and the former marshlands in the industrial area. The geology of the Lowland area is characterized by artificial fill and/or Holocene alluvial and fluvial deposits overlying the Bay Mud. The Bay Mud may lie directly on the bedrock, or older alluvial and fluvial deposits may be present on the bedrock surface below the Bay Mud.

In the industrial area, the boundary between the Lowlands and the Highlands is boundary of the former marshland (Figure 4-1). This boundary was changed slightly based on the CPT lithologic data. The previous boundary was based on photographs and a drawing of the former marshland and was fairly accurate. The CPT data changed the boundary slightly in the area of the Bottle Hill and the east side of the 50 Series Complex. At the eastern extent of the Bottle Hill, the edge of the former marshland is farther east and does not extend beneath the nearby buildings. On the east side of the 50 Series Complex, the former marshland swings around the complex toward the hillside to the north. This inland embayment matches a similar embayment on the east side of the 50 Series Complex. Essentially, the hill on which the 50 Series Complex sits, at one time, overlooked water on three sides.

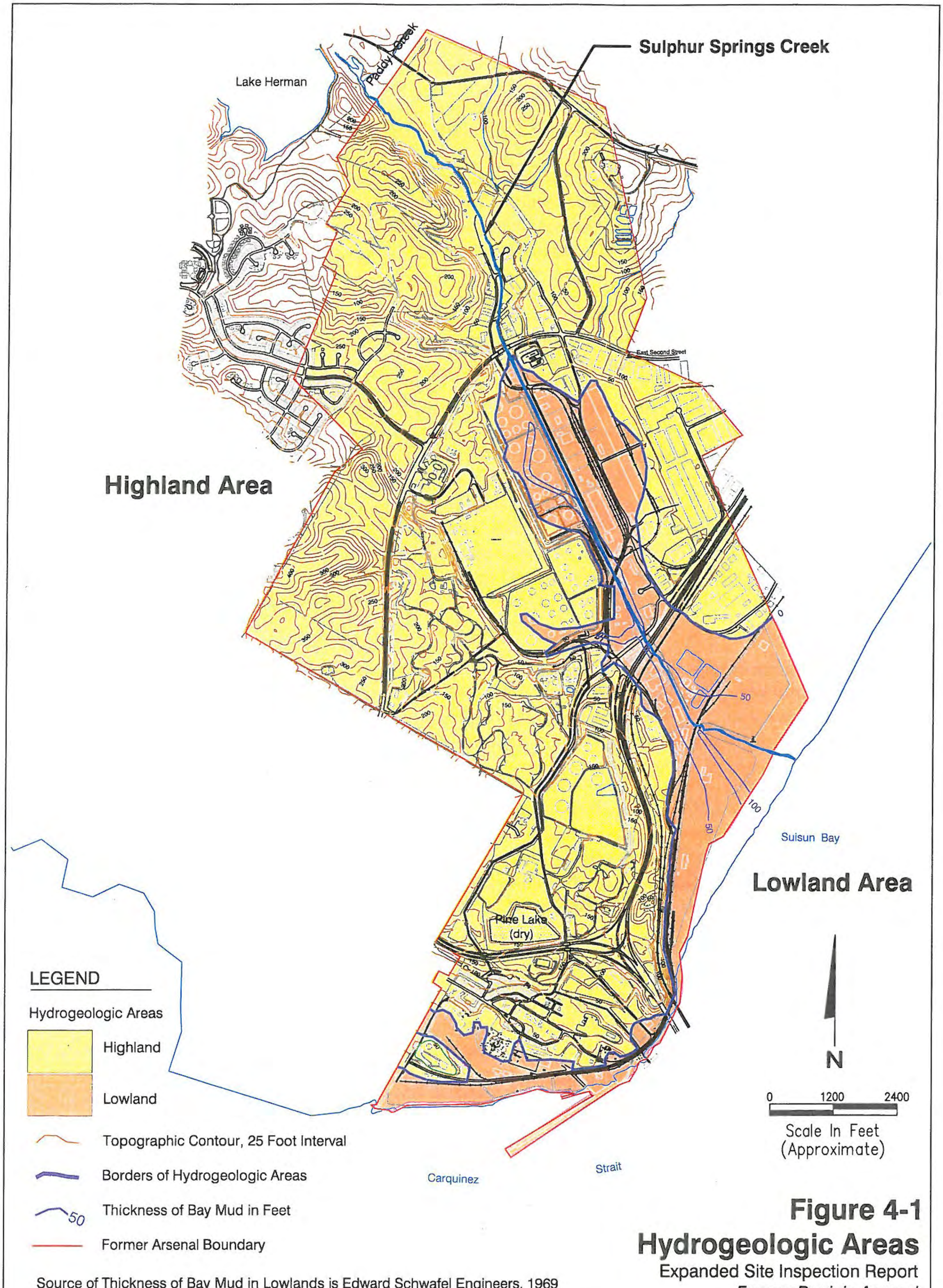


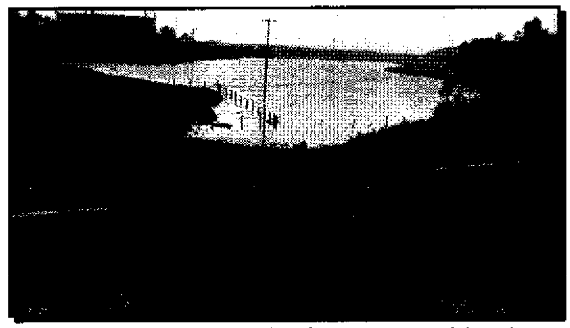
Figure 4-1
Hydrogeologic Areas
Expanded Site Inspection Report
Former Benicia Arsenal

4.2 Site-Specific Geology of the Industrial Area

CPT and soil boring logs advanced during this field investigation are documented in Appendix D. Figures 4-2 and 4-3 contain cross sections showing the geology beneath the industrial area. From oldest to youngest, the Vine Hill Sandstone (Tvh) is overlain by alluvial sediments (Qhaf), then Bay Mud (Qhbm) and lastly artificial fill (af) covering most of the area.

Depth to the Vine Hill Sandstone ranges from 6 feet bgs at SWAMPAHP001 near Building 116, to 3 feet bgs to almost 105 feet at B167HP001 at the southeast corner of Building 167. The shallow occurrences of sandstone are found adjacent to bedrock knobs. The topography of the top of the Vine Hill Sandstone indicates several valleys that have been partially filled with alluvium. They are oriented northwest to southeast shown in cross-sections E-E' at boring B165HP004, B-B' at borings B004HP002 and FS1HP003, and C-C'.

A rise in sea level beginning between 11,000 and 8,000 years ago inundated the region. Deposited on top of these alluvial sediments was an estuarine mud known as the Bay Mud. Marshlands formed as the valleys were filled with the unconsolidated mud in these quiet water environments (see photo to right).



Looking southeast at the former marshland, photo taken around 1915 to 1920.

Most soil borings in the area include artificial fill consisting of sandy silt, silt, clayey silt and sand overlying the Bay Mud (clays and sensitive fines). The thickness of the fill increases as the distance from bedrock highs increase; the thickness ranges from 2 feet to 13 feet.

The photo above provides a look into the past regarding the location of the former marshland. Recently, an 1856 hand drawn map and a 1928 aerial photo were found that also located the former marshland. This map and photo were used to compare existing features and refine the location of the former marshland.

In 1856, the US Army drew a map of the outpost (Figure 4-4). Low-lying hills are indicated on the 1856 map with hatching around the sides indicating a slope. The former marshland is marked like tules and the location of the coastline is distinct. This map was orientated to present features by scanning the 1856 map and electronically stretching it to fit known key points of reference (i.e. the hill of the 50 Series Complex, an exaggerated valley east of the 50 Series Complex [found during an investigation by another consultant] and the location of Building 91). The entire map is not proportional to existing features but portions were able to fit. Figure 4-4 concentrates on the former marshland area, but as stated above the area of the Clock Tower and Jefferson Street does not correlate well.

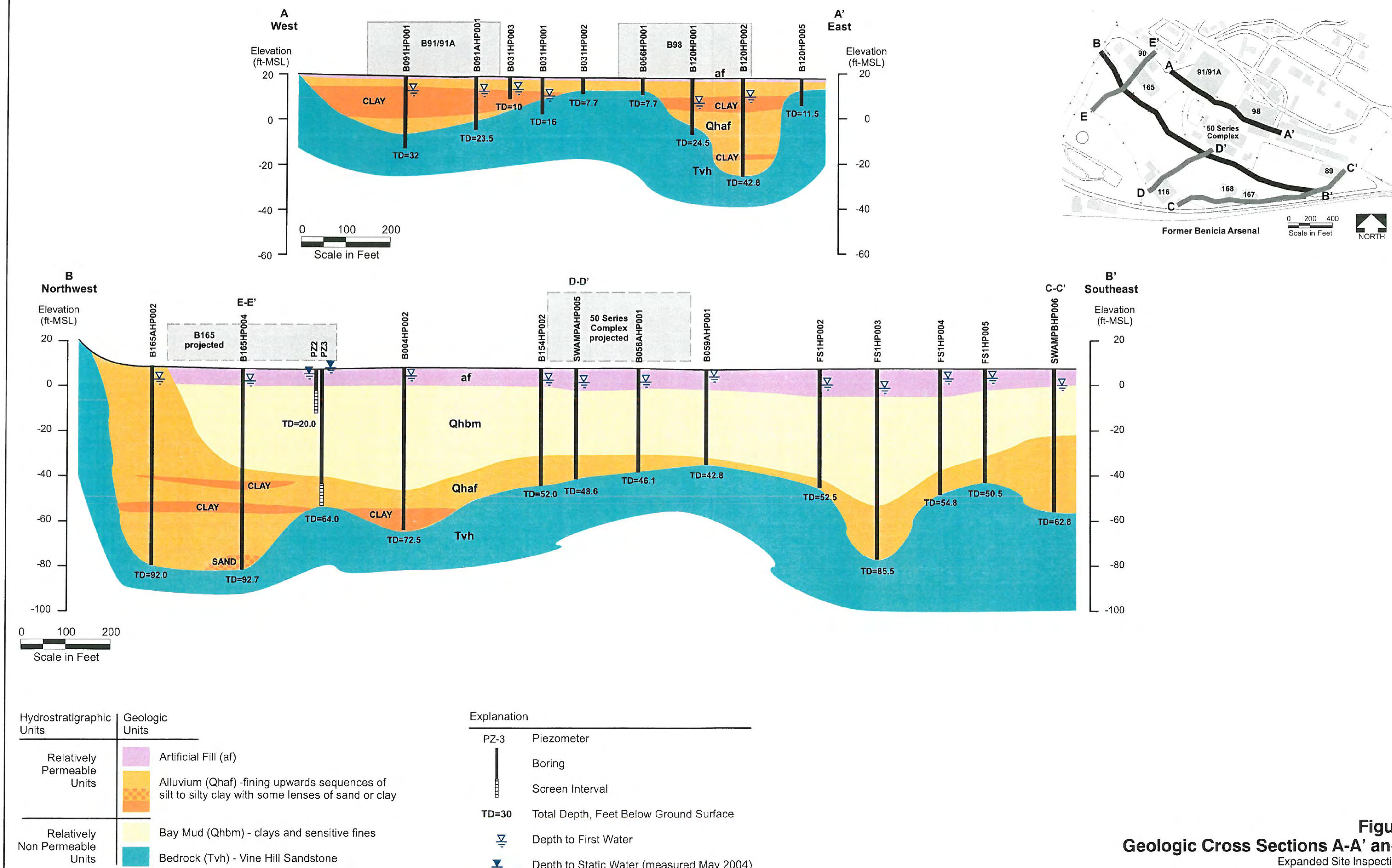


Figure 4-2
Geologic Cross Sections A-A' and B-B'
Expanded Site Inspection Report
Former Benicia Arsenal

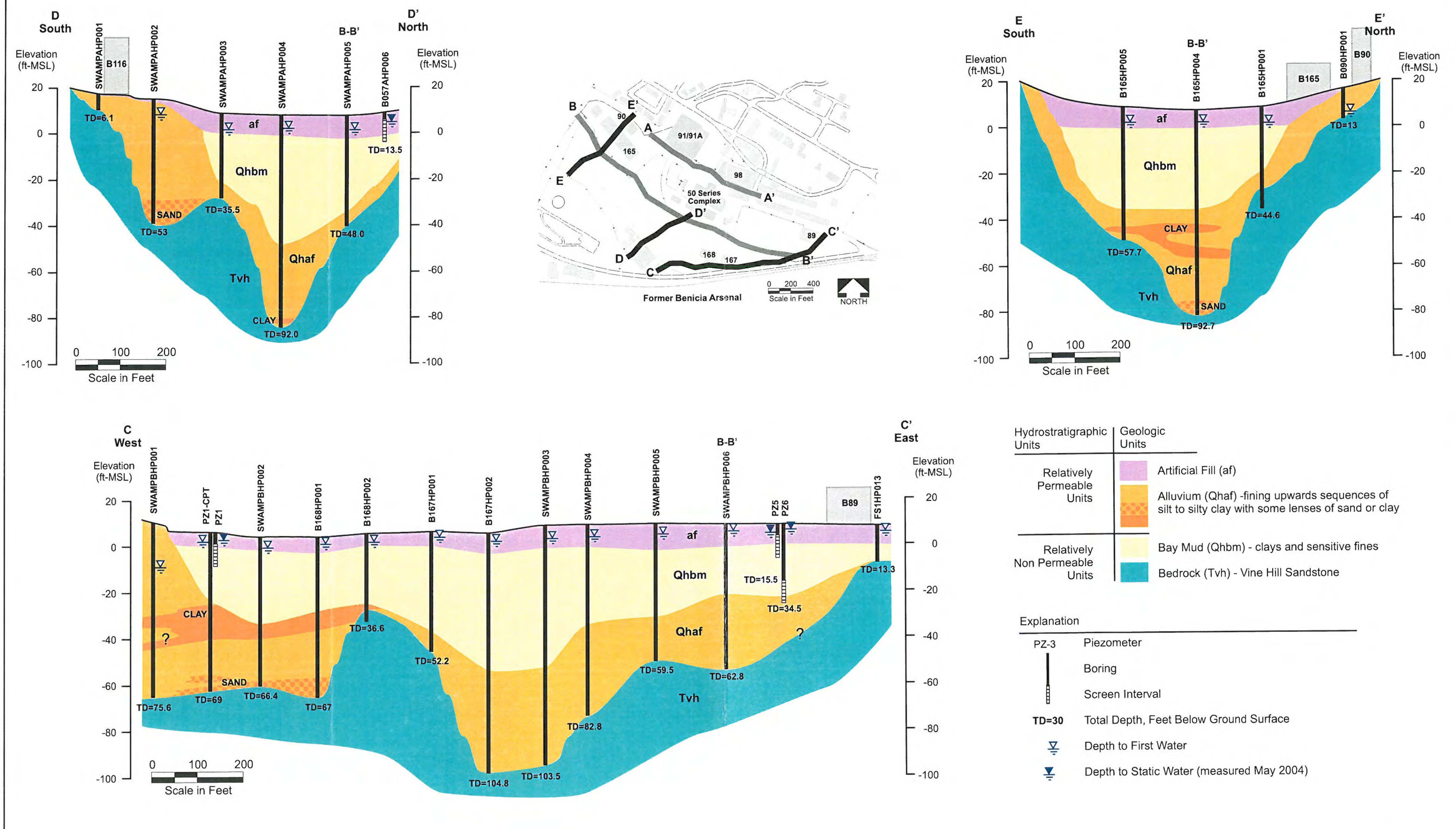


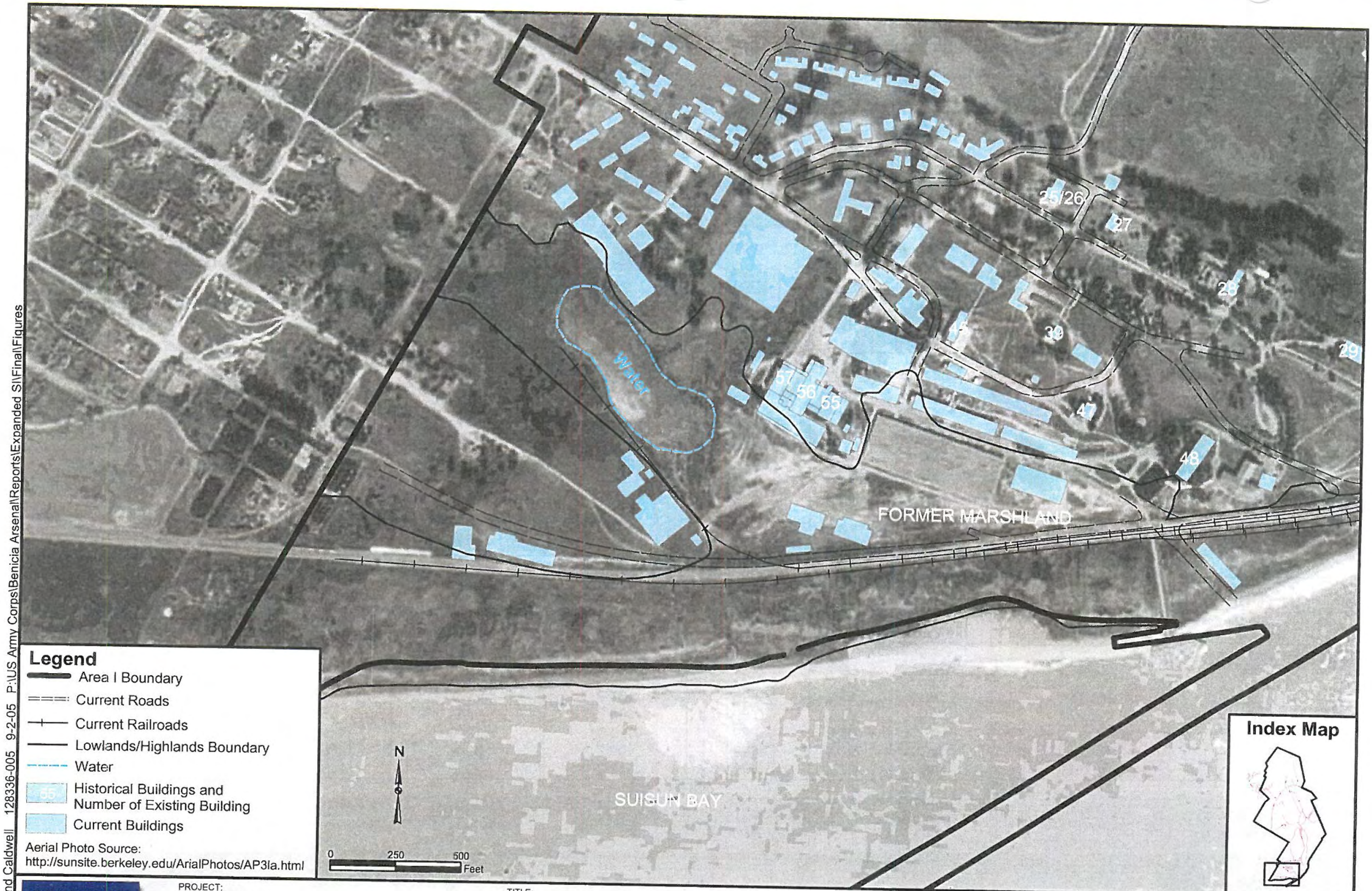
Figure 4-3
Geologic Cross Sections C-C', D-D', and E-E'
Expanded Site Inspection Report
Former Benicia Arsenal

In 1928, an aerial photo was taken of the Suisun area and in particular the industrial area could be seen very clearly (Figure 4-5). This photo correlates well with existing features (Figure 4-5). Buildings that existed in 1928 still exist today are labeled on the figure. A remnant of the former marshland as water is outlined on the figure. The Army had filled in most of the marshland shown as a disturbed area, new roads were built around the coastline and the railroad trestle over the Carquinez Strait was being built. The outline of the former marshland was revised based on the 1856 map and the 1928 photo.

4.3 Hydrogeology of the Industrial Area

Grab groundwater samples were collected from CPT borings and selective storm drain catch basins to assess groundwater impacts from previous facility use and water quality measurements were collected to determine the salinity of the groundwater and assist in future biodegradation assessments. Groundwater samples were also collected from the existing piezometers (PZ-1, PZ-2, PZ-3, PZ-5, PZ-6, B057AHP003, B057AHP005 and B057AHP006) that surround or are located within the known groundwater plumes. There are over 200 groundwater locations or samples that have been measured for depth to water or water quality parameters (temperature, pH, ORP, electrical conductivity and total dissolved solids) in the industrial area. Table 4-1 is a snapshot of this data such that only measurements were included from piezometers and storm drain catch basins since May 2004. Depth to water was measured at the top of the grate covering the catch basin. This location is assumed to be equal to ground surface.

Locations of the storm drain catch basins were then identified in the field, if possible, and are shown on Figure 4-6 in gray.



Brown and Caldwell 128336-005 9-2-05 P:\US Army Corps\Benicia Arsenal\Reports\Expanded SI\Final\Figures

BROWN AND CALDWELL

PROJECT: 24785-007

DATE: 10/20/2004

TITLE: 1928 Aerial Photo

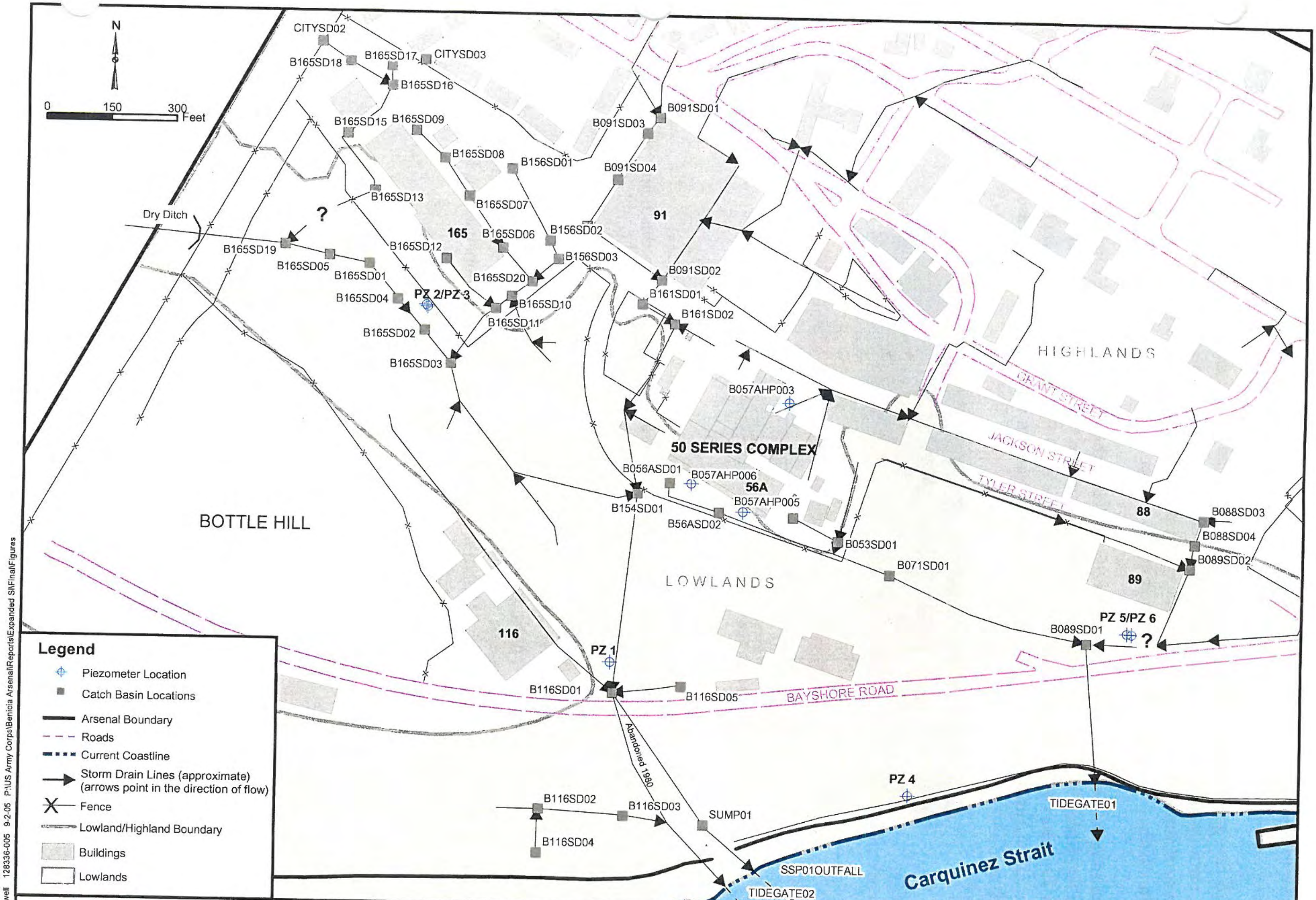
SITE: Benicia Arsenal, Benicia, California

Figure 4-5

Table 4-1. Water Quality Parameters from Industrial Area Piezometers and Storm Drain Catch Basins (May 2004, September 2004 and October 2004)

Locations	Date	Screen Interval (feet btoc)	Groundwater Elevation (feet msl)	Depth to Water (feet btoc or gs)	Temperature (Fahrenheit)	pH	ORP (millivolts)	Electrical Conductivity (µS/cm)	Total Dissolved Solids (mg/L)
May 2004									
PZ-1	5/7/04	5-15	3.58	2.51^	68.1	7.25	-344	63,300	NM
PZ-2	5/6/04	10-20	5.46	2.56^	68.4	6.88	-310	49,140	NM
PZ-3	5/10/04	54-64	9.03*	+0.98*^	68.9	6.20	15.4	74,800	NM
PZ-5	5/6/04	5-15	5.79	2.96^	68.0	7.12	-110	6,733	NM
PZ-6	5/7/04	24-34	5.50	2.95^	66.6	7.19	-96	20,290	NM
B057AHP003 (piezometer)	5/26/04	7-17	15.08	11.58^	67.2	7.80	-12.3	843	NM
B057AHP005 (piezometer)	5/26/04	2.6-12.6	5.92	4.27^	69.6	6.85	-172.5	8,181	NM
B057AHP006 (piezometer)	5/26/04	3-13	6.29	3.02^	70.5	7.16	-137.4	5,234	NM
September 2004									
PZ-2	9/17/04	10-20	5.24	2.78^	77.9	6.65	NM	20,160	8,750
PZ-5	9/17/04	5-15	5.60	3.15^	77.2	6.91	NM	8,304	6,400
B057AHP005 (piezometer)	9/17/04		6.60	3.59^	77.7	6.83	NM	7,007	6,050
B56ASD01	9/17/04	NA	NC	2.10	81.3	8.16	NM	506	240
B56ASD02	9/17/04	NA	NC	3.86	77.4	8.41	NM	14	318
B089SD01	9/17/04	NA	NC	2.69	76.5	7.41	NM	2,892	1,470
B165SD01	9/17/04	NA	NC	4.41	79.9	7.03	NM	12,530	7,950
B165SD02	9/17/04	NA	NC	4.10	80.8	6.84	NM	22,330	14,900
B165SD03	9/17/04	NA	NC	3.87	79.7	7.80	NM	13,190	11,200
October 2004									
B089SD01	10/28/04	NA	NC	2.89	65.8	7.54	NM	1,118	660
B089SD02	10/28/04	NA	NC	5.98	70.0	8.16	NM	NM	204
B091SD02	10/28/04	NA	NC	5.35	64.6	7.61	NM	1,479	986
B091SD04	10/28/04	NA	NC	2.75	63.7	6.72	NM	1,360	910
B116SD01	10/28/04	NA	NC	4.08	67.1	7.75	NM	NM	114
B161SD02	10/28/04	NA	NC	5.92	65.5	6.82	NM	1,683	970
B165SD01	10/28/04	NA	NC	4.40	67.5	7.87	NM	NM	564
B165SD03	10/28/04	NA	NC	3.90	72.0	7.65	NM	NM	1,210
B165SD05	10/28/04	NA	NC	4.60	65.8	7.58	NM	NM	1,270
B165SD20	10/28/04	NA	NC	5.25	67.6	6.54	NM	1,336	682
CITYSD02	10/28/04	NA	NC	3.0	56.7	7.75	NM	NM	114
SUMPGR01	10/28/04	NA	NC	6.8	61.0	7.57	NM	NM	928

btoc = feet below top of casing
gs = ground surface
msl = mean sea level
mg/l = milligrams per liter
NA = not applicable
NC = not collected
PZ = piezometer
µS/cm = microsiemens per centimeter
* = artesian
^ - Measured from btoc



BROWN AND CALDWELL

PROJECT: 124785-005

DATE: 3/24/2005

TITLE: Storm Water Drain System in the Industrial Area

SITE: Benicia Arsenal, Benicia, California

Figure 4-6

Depth to first groundwater in the industrial area is less than 12 feet deep (Table 4-1). At deeper depths, static groundwater is under confined conditions such that water levels rise to within 10 ft bgs and sometimes above the ground surface (artesian conditions). PZ-3 had groundwater flowing out of its casing. This piezometer is located in the former marshland.

Between sampling events, up to 3.59 inches of rain fell in the area between the catch basin sampling and the Expanded SI. Approximately 0.4 inches of rain was recorded during September 2004, and about 3.19 inches of rain was recorded during October 2004 (National Climatic Data Center, San Francisco Airport). As a result, the salinity of the water in the catch basins decreased after the precipitation.

Table 4-2. Groundwater Salinity Classification

Category	Total Dissolved Solids (mg/L)	Electrical Conductivity (µS/cm)*
Fresh water	0 – 1,000	0 – 1,800
Brackish water	1,000 – 10,000	1,800 – 13,000
Saline water	10,000 – 100,000	13,000 – 130,000
Brine water	More than 100,000	More than 130,000

Source: Driscoll, 1986.
* EC = TDS/conversion (between 0.55-0.75 depends on ionic composition of solution). 0.55 conversion factor used for fresh water and 0.75 conversion factor used for brackish, saline and brine waters.

EC readings from the grab groundwater samples were plotted on Figure 4-7. On this figure, the upper half of the circle represents EC concentrations for groundwater samples collected at depths less than 15 feet bgs and represents first water located in the artificial fill or the alluvial sediments north of the 50 Series Complex. The lower half of the circle represents groundwater samples collected at depths greater than 15 feet bgs. The color in each half of the circle represents the groundwater classification: fresh water (green), brackish water (yellow) or saline water (pink). Each classification corresponds to a range of concentrations for TDS (Table 4-2). EC is proportional to the amount of dissolved minerals (i.e., TDS) in the sample (Table 4-2). The colors used on Figure 4-7 are also used in the other tables in this section.

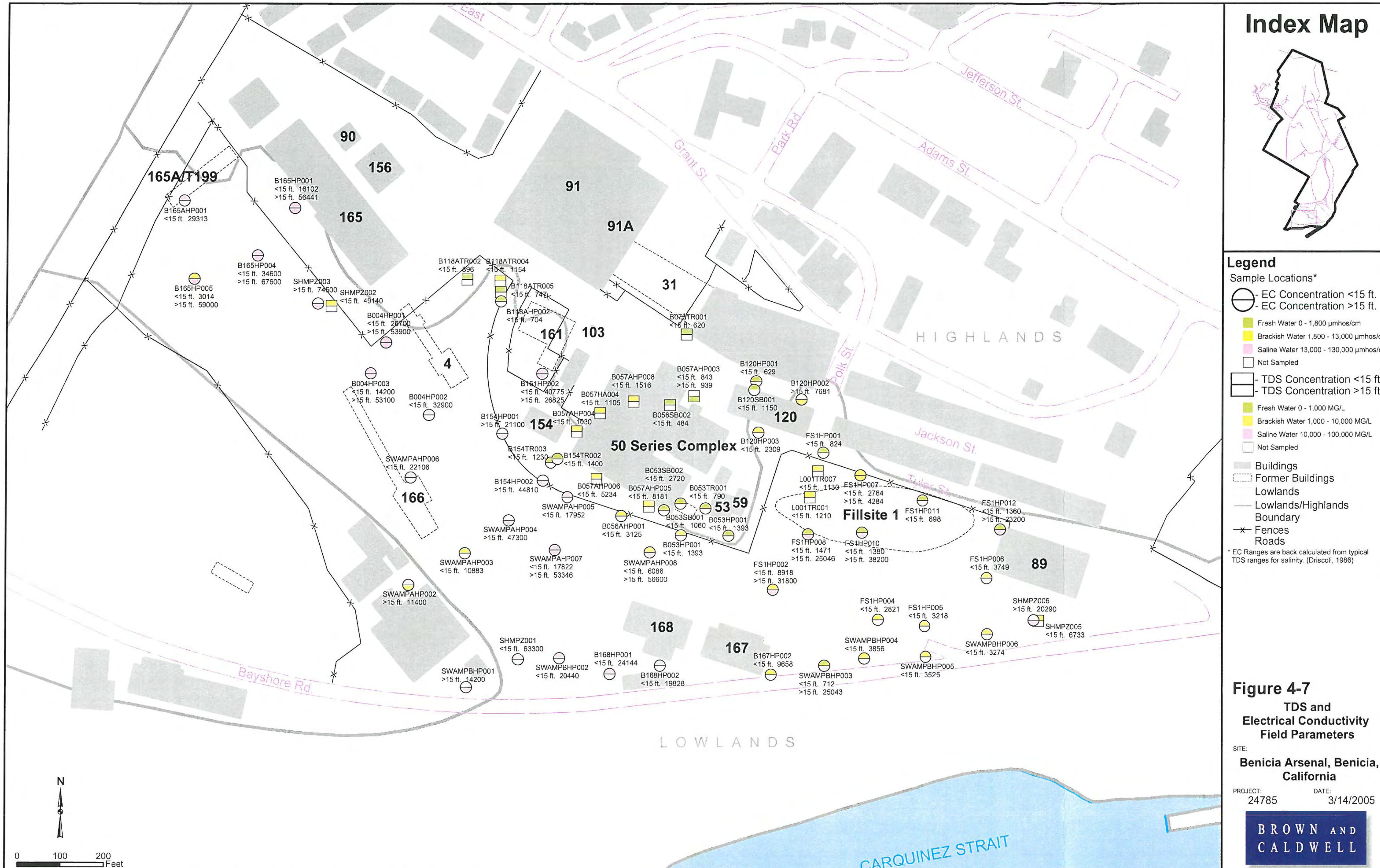


Figure 4-7
TDS and Electrical Conductivity Field Parameters

Benicia Arsenal, Benicia, California

In the industrial area, fresh to saline groundwater is present (Table 4-1). TDS values were collected in 2001 for the investigation at Fillsite 1 and during the Expanded SI during the storm catch basin sampling. All results were below 1,000 mg/L (Table 4-3) at Fillsite 1. The TDS values suggest the shallow groundwater at Fillsite 1 is freshwater. EC concentrations from the grab groundwater samples in the same area also confirm this classification. The deeper groundwater in the area, based on EC, is saline (Figure 4-7).

Table 4-3. Water Quality Parameters at Fillsite 1 (February 2001)

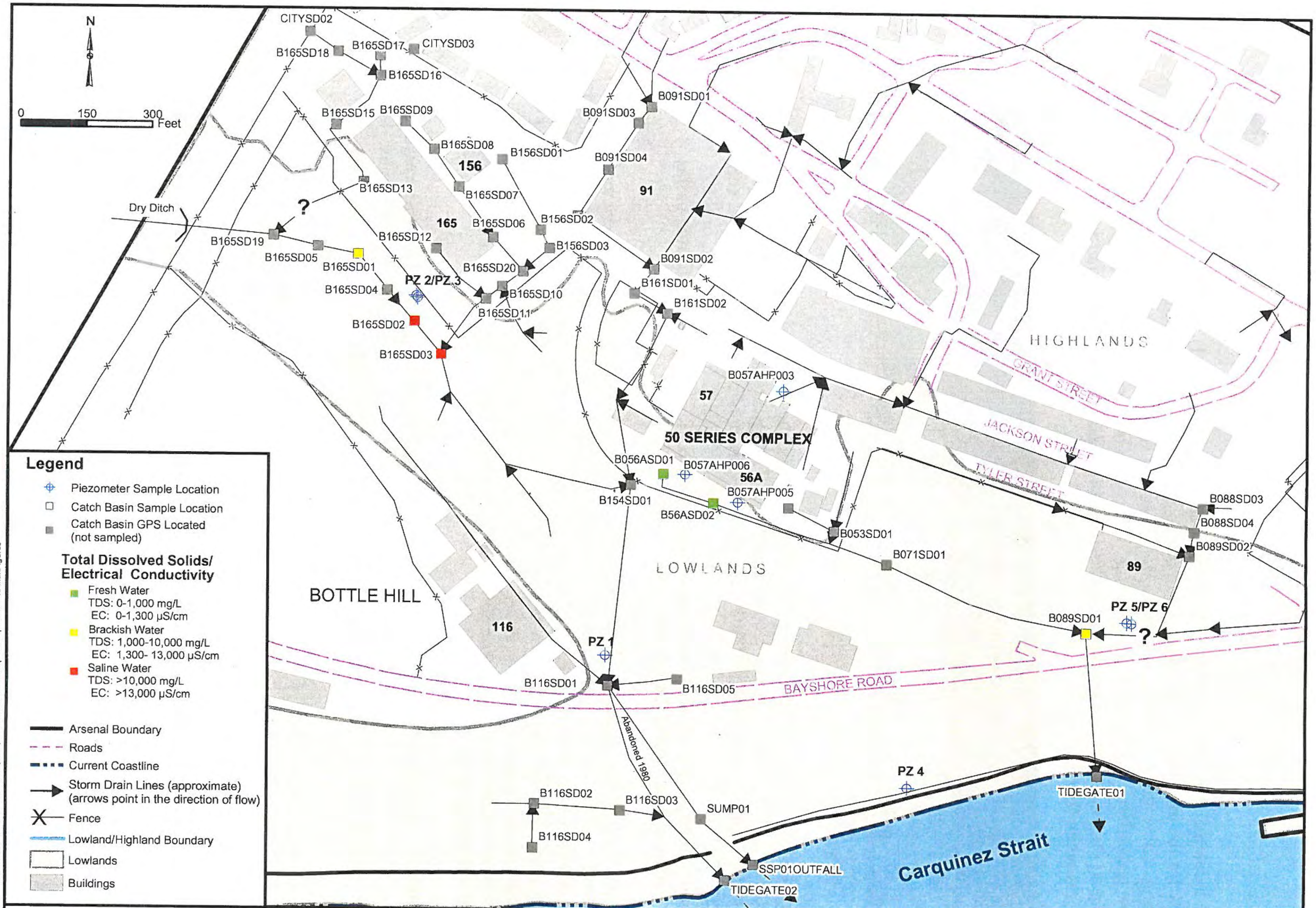
Trench	Depth (feet bgs)	Temperature (Fahrenheit)	pH	TDS (mg/L)	Electrical Conductivity (µS/cm)
L001TR001	3	59.1	6.16	564	1,210
L001TR007	3	63.8	8.9	795	1,130
L001TR008	3	56.5	6.42	735	1,040

bgs = below ground surface
mg/L milligrams per liter
µS/cm microsiemens per centimeter

During the May 2004 and September 2004 sampling event, the catch basin water samples collected were all brackish to saline based on a concentration of TDS greater than 1,000 mg/L except for fresh water in piezometer B057AHP003 and two storm drain catch basins (B56ASD01 and B56ASD02 (Table 4-1). The border between the fresh and brackish groundwater, or the Lowland/Highland boundary, is estimated to be just north of, or upgradient of catch basins B56ASD01 and B56ASD02 (Figure 4-8).

The catch basin water samples collected during the October 2004 sampling event were mostly fresh (<1,000 mg/L TDS) to brackish water (Figure 4-9). As shown on Table 4-1, concentrations of TDS dropped between the May/September 2004 and October 2004. The change from more saline in May/September 2004 to less saline or fresh in October 2004 can be attributed to the 3 inches of precipitation that occurred between the two sampling events. More details about the water quality measurements collected in September 2004 and October 2004 for the storm water drain sampling is included as Appendix E in this report.

These results are supported by the CHM which stated that groundwater in the Lowland areas is brackish to saline and the groundwater in the Highland areas is fresh (FA/BC, 2003b). Figure 4-6 approximates the line that separates the Highlands from the Lowlands.



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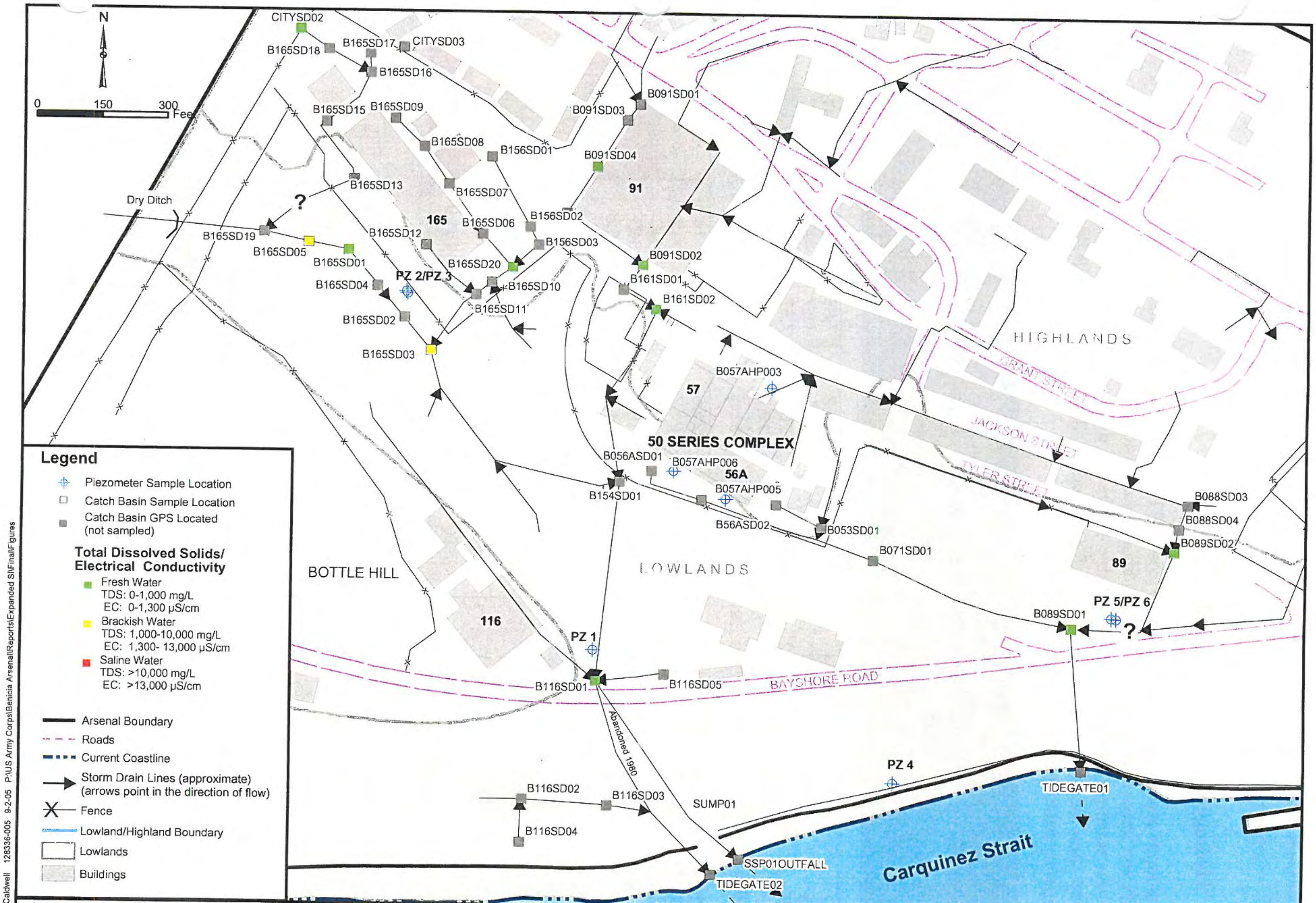
PROJECT: 124785-005
DATE: 3/24/2005

TITLE: September 2004 Stormwater Quality
SITE: Benicia Arsenal, Benicia, California

Figure 4-8



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BROWN AND CALDWELL

PROJECT: 124785-005
DATE: 3/24/2005

TITLE: October 2004 Stormwater Quality
SITE: Benicia Arsenal, Benicia, California

Figure 4-9

4.4 Hydrogeology of the Non-Industrial Areas

Grab groundwater samples were collected from CPT borings in the non-industrial areas to assess groundwater impacts from suspected DoD facility use. Additionally, water quality was measured from these samples (see Appendix F and Table 4-4 for the data). Groundwater samples were also collected from the two existing piezometers (PZ-12 and PZ-20) and Valero Well #117 and their water quality parameters are listed in Table 4-4.

Table 4-4. Water Quality Parameters in the Non-Industrial Areas (April/May 2004)

Locations	Screen Interval (feet bgs)	Groundwater Elevation (feet msl)	Depth to Water (feet btoc or gs)	Temperature (Celcius)	pH	ORP (millivolts)	Electrical Conductivity (µS/cm)
HIGHLANDS							
PZ-12	5-15	6.64	7.95^	19.8	7.85	207	1,417
PZ-13	10-20	28.97*	11.08*^	NC	NC	NC	NC
PZ-20	24.5-34.5	145.52	18.02^	20.0	7.57	160	1,088
SPUREHP002	12-22	NC	NC	19.7	7.10	199.3	1,141
B050HP001	5-15	NC	NC	22.7	7.25	232	1,484
LOWLANDS							
FS003HP001	6.4-9.4	NC	6.4	21.6	7.19	-14	10,865
FS003HP002	10-15	NC	7.1	21.7	6.89	-12	4,349
OD01HP002	0-5	NC	1.25	17.2	6.70	NC	>20,000
OD01HP003	0-5	NC	4.0	18.0	6.76	NC	18,500
OS29HP001	87	NC	NC	21.4	6.34	70.6	34,454
OS29HP002	74	NC	NC	22.3	6.32	46	19,560
PD001HP002	5-10	NC	NC	24.1	6.35	-73	10,813
PD001HP003	5-10	NC	NC	22.5	6.99	-163	10,921
PD001HP004	8-23	NC	NC	21.8	6.58	-64	10,264
PD001HP005	5-15	NC	NC	21.8	7.44	-137	10,504
PD001HP006	5-15	NC	NC	21.6	6.23	-52	4,268
Valero Well #117		7.80	7.80^	19.4	7.73	-181.0	36,469

btoc – feet below top of casing
gs = ground surface
msl – mean sea level
µS/cm – microseimens per centimeter
NC – not collected
* - Measured on 11/26/02
^ - Measured from btoc

Depth to water measured in the piezometers located north of the industrial area, range from approximately 5 feet to 20 feet deep. The EC results indicate fresh to saline water. These results are supported by the CHM that stated that groundwater in the Highland areas are fresh, represented by the locations at PZ-20 and SPUREHP002 and water is brackish to saline in the Lowlands, represented by the locations at PZ-12 and Valero Well #117 (FA/BC, 2003a). The table has been divided to reflect the locations in the Highlands and the Lowlands.

SECTION 5
DATA USABILITY

This section summarizes the data quality assessment of analytical results reported for soil, soil gas and groundwater samples collected during this investigation. Only significant data quality issues are summarized. More detailed information and discussions, including verification/validation of the analytical results, are found in the Quality Control Summary Report (QCSR). Validation and/or verification of the laboratory analytical data was performed per the criteria specified in the Benicia QAPP (FA/BC, 1999a).

Soil, water, and soil gas samples were collected by Brown and Caldwell (BC) in three mobilizations (April, May, August, and October 2004). Transglobal Environmental Geochemistry Laboratory - Sacramento (TEG) performed 20 field days of analysis in April 2004 through May 2004. During the end of the April/May sampling event and in August and October 2004, soil and water samples were delivered by overnight courier to EMAX Laboratories, Inc. (EMAX). Data was received in both hard copy and electronic formats. In general, the data collected in support of this investigation are considered usable for the purpose of engineering decision making.

The following were the most significant data quality issues identified in the data quality assessment. A summary of primary samples and associated quality control (QC) samples are included in Table 5-1.

- The results of the TPH-extractable analysis performed by TEG are qualified as estimated with a possible low bias due to QA/QC deficiencies. Split samples were sent to the USACE QA lab. These samples were: B051HP001-A-S01, B053HP001-A-W01, B120HP001-A-W01, B154HP001-A-W01, B154HP002-A-W01, B165HP001-A-W02, SPUREHP001-A-W01, SWAMPBHP006-A-W01, and FS001HP010-A-W01. Diesel fuel concentrations from these samples have replaced the TEG diesel fuel concentration data. The remaining TEG diesel fuel results will be considered usable for screening and not as definitive data.

- Discrete low level peak were identified in the diesel range on chromatographs for seven water samples. The peaks were not part of the diesel fuel pattern and likely represented other organic compounds. An attempt was made to have EMAX identify them. These samples were OS29HP003-A-W01 (32-35 ft bgs), OS29HP002-A-W01 (74 ft bgs), SWAMPBHP002-A-W01 (5-10 ft bgs), B168HP001-A-W01 (5-10 ft bgs), SPUREHP001-A-W01 (40-45 ft bgs), VALERO117-A-W01 (9.4-18 ft bgs), and FS001HP005-A-W01 (0-10 ft bgs). Of these samples OS29HP003-A-W01, OS29HP002-A-W01, and B168HP001-A-W01, the chromatography did not resemble a diesel or motor oil pattern. The sample extracts from TEG for these seven water samples were sent to EMAX for EPA Method SW8270C analysis including tentatively identified compounds (TICs) for use in evaluation of the low level diesel range organic detects. Detected compounds included bis (2-ethylhexyl) phthalate (BIS2EHP), diethylphthalate, ethanol, benzoic acid, 4-methyl benzenesulfanomide, n-hexadecanoil acid, octadecanoil acid, 2-Methylphenol, phenol, toluene, benzeneacetic acid, and several unknown compounds.

- Most (248 of 357) of the results from the seven environmental water samples analyzed for SVOCs by Method SW8270C were rejected due to missed analytical holding time, which resulted in low technical and analytical completeness. There were no other systematic deficiencies noted. However, the results from these samples were not intended to be used quantitatively but qualitatively.

Lessons learned from this investigation were that the TPH-extractable diesel analysis as performed by the mobile laboratory did not provide definitive analytical data. This is due in part in the difficulty in performing the extraction and concentrations steps in the mobile setting. In the future, samples for TPH-extractable analysis that are analyzed by a mobile laboratory will also be analyzed by a fixed laboratory to provide definitive analytical results.

Overall, the non-rejected data are of acceptable quality and are suitable for the purposes of this project.

Table 5-1. QC Sample Summary Expanded SI

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
VOCs (8260B)	7	1	1	115	9	7	16	2	0
SVOCs (8270C)	2	1	0	7	0	0	NC	NC	NC
PAHs (8310)	5	1	0	4	0	0	NC	NC	NC
Explosives (8330)	2	0	0	2	0	0	NC	NC	NC
TPHG (8015B)	4	0	0	6	0	0	NC	NC	NC
TPHD/TPHMO (8015B)	8	1	1	112	9	7	NC	NC	NC
Metals (6010B/7000)	11	1	0	35	2	1	NC	NC	NC
Cyanide (9014)	NC	NC	NC	1	0	0	NC	NC	NC
Total Dissolved Solids (E160.1)	NC	NC	NC	9	0	0	NC	NC	NC
Anions (E300)	NC	NC	NC	9	0	0	NC	NC	NC
Total number of analyses	39	5	0	300	20	0	16	2	0

NC – None Collected

SECTION 7
CONCLUSIONS AND RECOMMENDATIONS

The objectives of the Expanded SI were to use a dynamic sampling strategy to 1) identify DoD-related contamination based on the highest risk to human and/or the environment; 2) determine if additional data is necessary to characterize potential impacts; and 3) delineate the extent of the contamination (if additional data was necessary) (BC, 2004a.). The investigation had to be completed in 21 field days. These objectives were almost achieved. All 53 sites in the Expanded SI were investigated. The initial sampling did reveal sites that needed additional sampling (e.g. impacted groundwater found in the deeper groundwater in the industrial area, and diesel fuel identified in the first location at Spur E). Lastly, all but three sites with contaminated soil and or groundwater were delineated. Building 51 [lead and PAH impacted soil] and Building 58A boiler house [lead in soil at B058AHP001] were not fully delineated due to lack of time. The Post Dumpsite data was not delineated because the URS data was not available at the time of the investigation. Even though the objectives were not completely achieved, the process and the strategy was a success.

The conclusions and recommendations are summarized below for the Expanded SI investigation.

7.1 Summary of Conclusions

- The Arsenal is divided into two hydrogeologic areas; 1) the Highlands, which are characterized by the foothill areas and 2) the Lowlands composed of the flatlands characterized by artificial fill and/or Holocene alluvial and fluvial deposits overlying Bay Mud.

- The geology of the Arsenal consists of sandstone or shale bedrock overlain by alluvial sediments, Bay Mud and artificial fill.

- In the lowlands, alluvial sediments mantle the top of the sandstone and are characterized by fining upwards sequences of silt to silty clay ranging from a few feet thick up to 80 feet thick. In the highlands, relatively thin veneers of alluvial and fluvial sediments cover the bedrock.

- In the industrial area, fill, alluvium, and Bay Mud range from 0 feet to over 25 feet thick. Bay Mud is predominately located to the south of the 50 Series Complex coinciding with the location of historical marshlands, while colluvium derived from downslope movement of the residual material eroded from the bedrock fill the slopes and bottoms of ravines in the highlands.

- In the industrial area, groundwater occurs in the artificial fill, the Bay Mud and the alluvium beneath the Bay Mud. Groundwater elevations range from approximately 6 feet to 15 feet above msl. In other portions of the Arsenal, groundwater elevations range from 6 feet to 145 feet msl. On the sandstone slopes in the highlands, groundwater is not present, except for in bottom of ravines.

- The EC and TDS results from the water samples collected support the Arsenal CHM which state that groundwater in the Highland areas is fresh and groundwater in the Lowlands is brackish to saline, indicating influence from former marshlands or the Carquinez Strait.

- Comparisons of groundwater results to MCLs were used as a criterion for possible drinking water sources at sites located in the Highlands since groundwater quality meets the TDS (less than 3,000 mg/L)or 200 gallon per day criteria (State Board Resolution No. 889-63, Regional Board Resolution No. 89-39 , and the Basin Plan). If MCLs were not established for a particular analyte, then the representative RWQCB ESL was used. However, MCLs are not appropriate in the lowland areas, where TDS is high (>3,000 mg/L). In the lowland areas, comparison criteria of RWQCB ESLs (RWQCB, 2005) were used for groundwater categorized as not a source of drinking water. Ambient metal concentrations were also used a comparison criterion for soil.

- USTs and ASTs were used to store diesel fuel, gasoline, and fuel oil at the Arsenal. Diesel fuel was detected as frequently as VOCs in groundwater.

- All metal results in soil at Spur E (Section 6.1.1), and the Firing Range (Section 6.2.1) are lower than the BSLs indicating no significant DoD impact at these locations.

- Another contractor identified TCE, diesel fuel, motor oil, metals, and heptachlor and 4-4'-DDT at concentrations exceeding RWQCB ESLs (Section 6.4.1). These chemicals may have been disposed of at the Post Dumpsite. Additionally, diesel fuel was found in groundwater near the former burn pits. These contaminants may have been associated with former DoD activities..

- Diesel fuel and motor oil was present in the deeper groundwater sample, approximately 300 feet downgradient of the AFV (Section 6.4.2). There is insufficient evidence to eliminate the possibility of a release at the AFV but the Post Dumpsite, located adjacent to the AFV borings, has diesel fuel and motor oil in groundwater at concentrations up to 5,700 μg/L diesel fuel and 1,800 μg/L motor oil. Therefore, the source of the diesel fuel and motor oil could be from the Post Dumpsite.

- No significant DoD impact was reported at the Salvage Yard (Section 6.4.3), Fillsite 3 (Section 6.4.4), the former vehicle maintenance buildings at T222, T221, 171, 172 and TO 73 (Section 6.4.5), the former heavy equipment yard (Buildings 50 and 111)(Section 6.4.6), and the former battery charge building (Building 101)(Section 6.5.14).

- MtBE was detected in the Open Ditch (Section 6.3.1) indicating post-Army use. Diesel fuel is also present in the Open Ditch and Valero Well #117 (Section 6.3.1). Concentration trend of the diesel fuel in Valero Well #117 indicates a recent release not associated with former DoD activities.

- At the eastern Waste Area and CL 1 (Section 6.3.1), TCE was detected in an upgradient boring suggesting there may be another source of contamination. The source area maybe from a nearby site, 4186 Park Road. This site is currently under review with the RWQCB.

- In the industrial area (Section 6.5),
    - There is no evidence of a release at Building 4 (Section 6.5.1), Building 42 (Section 6.5.3), Building 156 (Section 6.5.19), and TO131 (Section 6.5.26),
    - Trace concentrations of TCE were found in soil gas at Building 93 (Section 6.5.13).

- Lead-contaminated soil exists south of the former boiler house (Building 58A) at B058ASB001 (Section 6.5.7). The lateral extent is bounded to the north, west and east but not to the south. Lead and PAHs were reported in soil at the former drum storage area at Building 51 (Section 6.5.4).

- The highest soil detections of TPH as diesel fuel and motor oil is found near the known USTs located southwest and southeast of the 50 Series Complex at Building 53 (Section 6.5.5) and Building 154 (Section 6.5.18), at the former Building 31 UST (Section 6.5.2) and south of Building 120 (Section 6.5.17).

- Also stored in USTs/ASTs was TPH as gasoline. Gasoline was not detected in any soil samples above ESLs. The highest gasoline concentrations in groundwater were reported near the former USTs at Building 53, Building 103, and Building 154 (Section 6.5.5, Section 6.5.15, and Section 6.5.18).

- Releases from the former USTs at Buildings 53, 103, and 154 appear to have impacted groundwater with fuels. The lateral and vertical extent of these fuels in groundwater has been defined (Section 6.5.27).

- Diesel fuel was found in shallow groundwater near Building 168. The source of the diesel fuel was not found (Section 6.5.17).

- MtBE has been detected in shallow groundwater at B057AHP001, B118AHP002, SWAMPAHP003, SWAMPAHP008, B035SB002, L001TR001, and B059HP001 indicating a post Army release of oxygenated gasoline. The highest concentrations were found in 1999 at 17 μg/L beneath Building 57A. Other locations are near the former Building 118A ASTs or south of Building 91, south of the 50 Series Complex and at Building 59 (Section 6.5.27).

- There appears to be separate releases of TCE that have co-mingled into one plume in shallow groundwater that extends from Building 165 to beneath the 50 Series Complex, beneath Building 120, and past Fillsite 1. The source of TCE in this area is likely a combination of Army and post-Army activities (Section 6.5.27).

- In deeper groundwater in the industrial area, solvents are found in the several valleys within the Vine Hill sandstone that have been partially filled with alluvium and beneath the Bay Mud (Section 6.5.27).

- The lateral and vertical extent of solvents in groundwater has been defined in the industrial area (Section 6.5.27.3).

- The data indicate that the storm water drain system intercepts shallow groundwater in the industrial area, and contaminated groundwater is infiltrating into the storm drain system (Section 6.5.29).

7.2 Recommendations – Additional Activities

A summary of the recommendations for the Expanded SI sites is provided in Table 7-1. Based on the findings of this investigation, suspected DoD and non-DoD sources appear to have impacted soil or groundwater in the industrial area and a possibility at the Post Dumpsite. The lateral and vertical extent of impacted groundwater has been delineated in the industrial area. With the exception of a few focused areas, the site investigation at the Arsenal is almost complete. There is further investigation needed at several sites. The location and purpose of the investigations are as follows:

- The former drum storage area at Building 51 – Additional investigation is recommended to determine the source of lead and PAHs found in shallow soil.
- Building 161 UST – The UST was found but the landowner refused right-of-entry to remove the UST. No further action by USACE can be done until access is provided.
- Building 168 – Additional investigation is recommended to determine a source area for the diesel fuel found near the Building 168 at location B168HP001 and SWAMPBHP002.
- South of the 50 Series Complex – Additional investigation is recommended to delineate lead-impacted soil south of B058AHP001.
- Former Septic Tank 194 – The investigation at the Septic Tank 194 remains unfinished per the FSIP due to lack of right of entry. The purpose of the investigation is to determine the presence or absence of a suspected discharge from the CL1. USACE should pursue a right-of-entry agreement with the new landowner.
- CL2 Boiler House – The investigation to determine if a UST is present at the former UST remains unfinished. The landowner refused right-of-entry to USACE. No further action by USACE can be done until access is provided.
- Post Dumpsite –Further investigation is recommended to delineate solvents, fuels, metals, heptachlor, and 4-4'-DDT in soil and groundwater in the area former dumpsite. This investigation will provide the evidence needed to determine if the source of the fuels found in groundwater at the AFV is from the Post Dumpsite. Additionally, further investigation is recommended in the area of the former burn pits for diesel fuel.

The findings from this investigation have provided enough information to proceed into the risk assessment stage and feasibility stage at the former DoD vehicle repair facility at Building 93, the former battery charge building at Building 101, and the industrial area.

Since the site inspection for the Arsenal is focused on the last remaining areas, the Post Dumpsite and the industrial area, there is no further need for all of the piezometers. Therefore, we are recommending the abandonment of the piezometers PZ-9, PZ-10, PZ-11, PZ-12, PZ-13, PZ-14, PZ-17, PZ-18, PZ-19, and PZ-20. The remaining piezometers are located in the industrial area (PZ-1 through PZ-6, B057AHP003, B057AHP005 and B057AHP006).

7.3 Recommendations – No DoD Action Indicated

FUDS policy outlines four categories of NDAI (I, II, III, and IV). A Category I NDAI decision applies to the PA process. Sites are classified as Category I NDAI where USACE has determined that the hazards found were not attributable to DoD. Sites that continue through the CERCLA process could be designated as Category II (after SI efforts), Category III (after RI/FS or Engineering Evaluation/Cost Analysis efforts) and Category IV (after Removal Action [RA] efforts) NDAI decisions.

For the sites included in this report, a Category II NDAI determination is based on the following criteria:

- metals concentrations in soil are below ambient or ESLs concentrations,
- soil and groundwater concentrations are less than ESLs or MCLs based on the location of the site, whether it is located in the lowlands or the highlands, and
- the only detected chemicals can be attributed to a non-DoD source (e.g. MtBE).

The sites recommended for Category II NDAI status are listed in Table 7-1.

Table 7-1. Summary of Recommendations for the Expanded SI Sites

Site	Description	DoD Activity	Recommendation
4	Sandblast Building/Paint Spray	Cleaning, painting	NDAI
26^	Lieutenant's quarters	UST (removed in 2002)	NDAI
28^	Quarter's Commanding Officer	UST (removed in 2002)	NDAI
31	Store House/Engine Rebuild	Degreasing	NDAI
31	Store House/Engine Rebuild	UST (removed)*	Risk Assessment
42	Garage/Repair Shop	Solvent washer, maintenance	NDAI
42	Garage/Repair Shop	Possible UST (not found)*	NDAI
50	Heavy Equipment Yard	Maintenance	NDAI
50	Heavy Equipment Yard	ASTs (removed)	NDAI
51	Stable/ Maintenance	Maintenance	Additional investigation to determine lateral extent of lead and PAHs in soil
53	Dynamometer Shop (motors)/ Engine Testing/Fuel Storage	UST (removed in 2002)	Risk Assessment
55	Blacksmith Shop/ Machine/Welding Shops	Repair/ Maintenance	Risk Assessment
56	Leather & Canvas Shop/ Welding Shop	Dip tanks	Risk Assessment
56A	Small Arms Shop/Leather Canvas Shop	Degreaser	Risk Assessment
57	Small Arms Shop, Firing Range**	Firing ranges**, degreaser	Risk Assessment
58(A)	Small Arms Repair and Retinning/ Boiler Room	Repair, former boiler UST (not found)	Additional investigation to determine lateral extent of lead in soil
59	Tool House/ Degreaser Pit	Cleaning, degreaser	Risk Assessment
59(A)	Tool House	Storage	Risk Assessment
65(A)	Boiler House	Former UST/AST (not found)	Risk Assessment
90	Locomotive Building	Repair/ Maintenance	Risk Assessment
91	Machine Shop/Combat Vehicle and Artillery Repair	Cleaning, Degreasing	Risk Assessment
91A	Temporary Machine Shop/Engine Rebuild	Cleaning, Degreasing	NDAI
93	Truck Storage Building/MMW Repair, Motor Vehicle Maintenance Building	Maintenance, grease tanks	Risk Assessment
101	Battery Charge Building	Steam cleaning battery	NDAI

Table 7-1. Summary of Recommendations for the Expanded SI Sites

Site	DoD Use	DoD Activity	Recommendation
		cases	
103	Service Station/Office Building	UST (removed in 2002)	Risk Assessment
111	Heavy Equipment Shop	Storage	NDAI
118(A)	Diesel Fuel Tank, Fuel Oil Tank, Oil Storage Tank	Former ASTs	Risk Assessment
120	Quartermaster Storage/Shop/Electroplating	Dip tanks, degreaser	Risk Assessment
154	Motor Test Shed/Paint Spray/ Fuel storage	USTs (removed in 2002)	Risk Assessment
156	Locomotive House	Maintenance	NDAI
161	Motor Cleaning Building/Steam Cleaning/Paint Spray/Fuel Storage	Maintenance Storage	Risk Assessment
161	Motor Cleaning Building/Steam Cleaning/Paint Spray/Fuel Storage	UST	Remove existing UST and delineate any soil contamination. UST was found but access to property not permitted by landowner. No further action by USACE can be done until access is provided.
165	Reclamation Building/Transport Vehicle Shop	Degreaser	Risk Assessment
165A	Steam Cleaning Building	Cleaning	NDAI
166	Paint Shop	Grease rack	NDAI
167	Bar Stock Building/Storage/Vehicle Shop for Motor Pool	Maintenance	NDAI
168	Bar Stock Building/Storage/Vehicle Shop for Motor Pool	Maintenance	Additional investigation to determine the source of diesel fuel in groundwater
171	Vehicle Shop	Maintenance	NDAI
172	Vehicle Repair and Maintenance Shop	Maintenance	NDAI
194	Former Septic Tank for CL1	Sewer	USACE to attempt another ROE with new landowner for the investigation of a suspected discharge from CL1 into the former septic tank.
CL1/Eastern Waste Area	Clip-Link and Belt Plant (1942-1944); Guided Missile Shop/Nike Missile Assembly	Assembly area	Wait on 4186 Park Road to delineate downgradient extent of solvents in groundwater.
CL2	Boiler House	Boiler house (former UST? or AST)	Determine if UST is present at site. If so, remove existing UST and delineate any soil contamination. Access to property not permitted by landowner. No further action by USACE can be done until access is provided.
Fillsite 1	Dump	Disposal	NDAI
Fillsite 3	Dump	Disposal	NDAI
Firing range	Test Firing of .45 and .50 Caliber Weapons	Firing Range	NDAI
Popping pot	Incineration	Disposal	See Post Dumpsite
Post Dumpsite	Dump	Disposal	To determine the location of buried ferrous and non-metallic debris. Based on the results of this survey, additional sampling will be performed to determine lateral extent of fuels, solvents, metals and pesticides in groundwater, the source of diesel fuel at AFV boring locations, and the source of diesel fuel at the former burn pits.

Table 7-1. Summary of Recommendations for the Expanded SI Sites

Site	DoD Use	DoD Activity	Recommendations
Salvage yard	Salvage Yard	Disposal	NDAI
Spur A	Revetment and Burn Cage Area/Hydrazine Burn Area (1958/59)	Burn cage	NDAI
Spur E	Revetment and Burn Cage Area	Burn cage	NDAI
Spur G	Revetment and Burn Cage Area	Burn cage	NDAI
T199	Maintenance Building, Body and Radiator Shop	Maintenance	NDAI
T221	Vehicle Maintenance	Maintenance	NDAI
T222	Steam Cleaning	Cleaning	NDAI
TO73	Recreation and Storage Building/ Photo Lab/Depot Facilities Shop	Cleaning	NDAI
TO131	Storehouse/Shop	Degreasing	NDAI
Western Waste Area/ Open Ditch	Western Waste Area/Open Ditch for CL1	Disposal	NDAI

*UST investigated in a separate field event [Fuel Storage Tank Removal Action Plan, BC, 2004b].
** The firing ranges in the basement of Building 57 will be assessed for further action during the feasibility study/remedial action phase.
^GPS coordinates were collected as part of the Expanded SI. These coordinates were required by the RWQCB before closure of the UST tanks sites could be granted.
NDAI - National Pollutant Discharge Elimination System

SECTION 8
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