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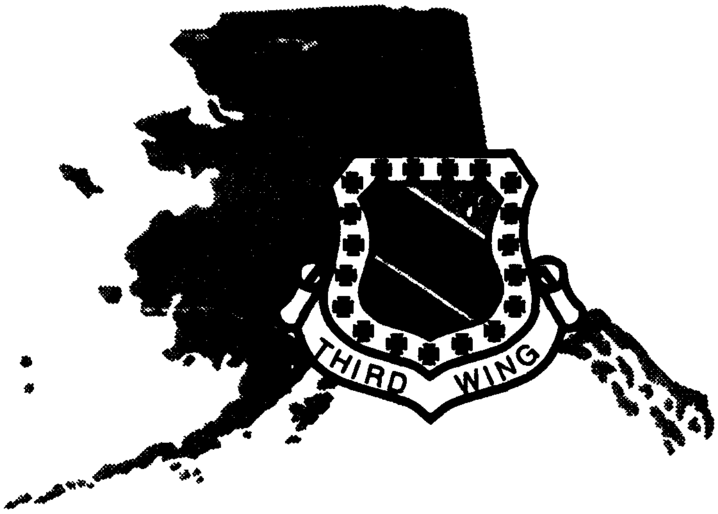

UNITED STATES AIR FORCE
ELMENDORF AIR FORCE BASE, ALASKA

ENVIRONMENTAL RESTORATION PROGRAM

OPERABLE UNIT 5
REMEDIAL INVESTIGATION/FEASIBILITY STUDY

VOLUME 1 - TEXT

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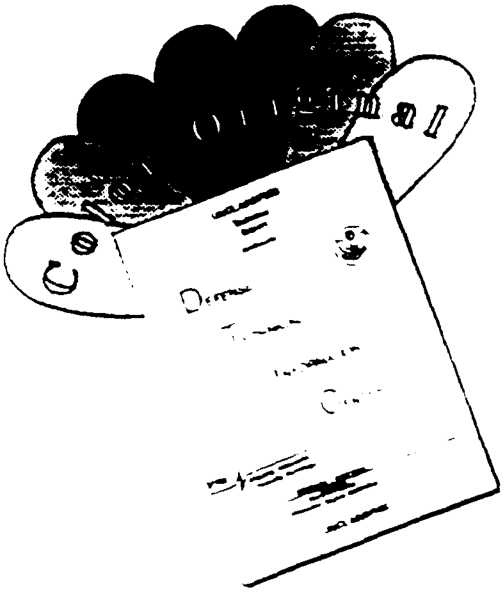

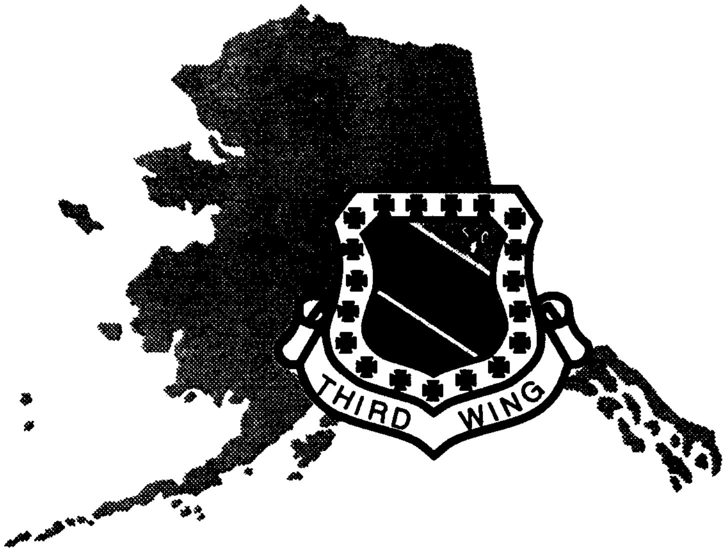

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This Final Report for Operable Unit 5 (OU 5) is provided per the statement of work for the Remedial Investigation/Feasibility Study for (RI/FS) OU 5. The RI portion of the report covers the site background, field investigations, nature and extent of contamination, conceptual model, and baseline risk assessment. The purpose of the RI is to define the contamination at OU 5 and the effects of the contamination on human health and the environment. The FS covers: 1) remedial action objectives, 2) an identification and screening of potentially applicable technologies, 3) a development and screening of alternatives which combine these technologies, and 4) a detailed analysis of the most applicable alternatives. The analysis considers the nine CERCLA evaluation criteria. The alternatives are evaluated according to their combined effectiveness, implementability, and cost scores. Based on the analysis, the most cost-effective alternatives are identified.

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EXECUTIVE SUMMARY

This report presents the results of the remedial investigation/feasibility study (RI/FS) of Operable Unit (OU) 5 on Elmendorf Air Force Base (AFB), Alaska by the U.S. Air Force. The RI report describes the results of the field investigations and provides an evaluation of the data and a risk assessment. The FS evaluates remedial action alternatives for the contaminants in OU 5.

E.1 Remedial Investigation

Objectives

The investigation of OU 5 had the following objectives:

- Provide sufficient data to develop source-specific and OU-specific conceptual models;
- Determine the potential for off-site migration of OU 5 contaminants and impacts on Ship Creek;
- Determine the influence of upgradient contaminant sources on the OU 5 areas;
- Collect sufficient data to determine the approximate extent and nature of contamination;
- Collect sufficient data to determine the risks to human health and the environment; and
- Prepare an RI report with results of the field investigation to provide a basis for the feasibility study (FS).

In accordance with the OU 5 *Management Plan*, the RI report also presents preliminary recommendations for remedial technologies and remedial action objectives.

Site Background and History

OU 5 is located at the southern perimeter of Elmendorf AFB just north of Ship Creek. The topography is dominated by a bluff that rises approximately 30 feet above beaver ponds at the eastern end of the OU and 60 feet above railroad tracks at the western end. Three fuel pipelines and associated storage tanks and distribution systems are located on top of the bluff. Numerous groundwater seeps that are exposed along the bluff flow into ponds, wetlands, and drainage ditches, and eventually into Ship Creek. Land uses between the base of the bluff and Ship Creek include designated open areas, a railroad right-of-way, picnic area and golf course, fish hatchery, and an off-base commercial/industrial area.

The USAF has identified six potential source areas through record searches of spills, pipeline leaks, and fuel seeps.

- Source ST37—In the late 1950s, several thousand gallons of diesel fuel leaked from a fuel line south of the U.S. Army Corps of Engineers (COE) building. The exact location of the leak is not known. The fuel seeped out of the ground near the railroad tracks, and thousands of gallons of fuel were recovered.
- Source ST38—In the mid-1960s, a leak in a JP-4 jet fuel pipeline led to seepage out of the bank southeast of Building 22-010. The exact location or volume of the leak is not known and no fuel was recovered.
- Source SS42—An estimated 8000-gallon, one-time spill of diesel fuel occurred near Building 22-010 in March 1976. Most of the fuel was recovered off the frozen ground.
- Source SD40—During the late 1960s, oil was reported seeping out of the bank near the railroad and flowing through a marsh into Ship Creek. The source of this oil is unknown.
- Source ST46—A cracked pipeline in 1978 allowed JP-4 jet fuel to seep into wetlands and Ship Creek. After the pipe was repaired, fuel continued to seep from the bank and into a beaver pond.
- Source SS53—A fuel seep of unknown origin was observed during the spring thaw for an unspecified number of years. This seep was noted

south of Post Road, north of the golf course pro shop, and flowed into a drainage ditch parallel to Post Road.

All six source areas have undergone previous investigations under USAF environmental programs in the 1980s. Total petroleum hydrocarbons (TPH) were found in soil samples at each source area, with the highest concentrations observed in soil at the groundwater table. The maximum TPH concentration in soil was approximately 10,000 mg/kg at a 30-foot depth at ST38. Groundwater samples from monitoring wells had TPH concentrations up to 160 milligrams per liter (mg/L) at ST37. Benzene was found in groundwater samples above the federal and state drinking water standard of 5 micrograms per liter (μg/L) at ST37 (13 μg/L) and SD40 (27 μg/L). Trace levels of TCE and other solvents were also detected in groundwater samples. In addition, previous investigations found that fly ash deposits had been used to extend the bluff at ST37 and ST38. A summary of results of all previous investigations is provided in the RI report.

In August 1990, Elmendorf AFB was listed by the U.S. Environmental Protection Agency (U.S. EPA) on the National Priorities List. This listing designated the facility as a federal Superfund site subject to the remedial response requirements of the Comprehensive Environmental Response, Compensation, and Liability Act, as amended by the Superfund Amendments and Reauthorization Act of 1986. On November 22, 1991, the USAF, EPA, and the Alaska Department of Conservation signed the Federal Facilities Agreement (FFA) for Elmendorf AFB. Under the terms of the agreement, all remedial response activities will be conducted to protect the public health and welfare, and the environment, in accordance with applicable federal and state law.

OU 5 is one of seven operable units to be investigated under the Elmendorf FFA. The source areas included in OU 5 are grouped together because of similar petroleum-like contaminants, potential for off-site migration of the contaminants, potential impacts to Ship Creek, and potential risks to receptors.

In late 1991, CH2M HILL began preparing a management plan that served as a planning document for all OU 5 RI activities. The final management plan includes all field, laboratory, and quality assurance procedures for the RI.

Field Investigations

Field investigations began in May 1992 and continued into December 1992. The scope of the field investigations is summarized in the following paragraphs by specific task.

Monitoring Well Inspection. Seventeen existing monitoring wells were evaluated for usability in the RI, and were repaired as necessary.

Mapping of Groundwater Seeps. Thirty-one seeps at the base of the bluff were located, and general observations of water quality were recorded. Several seeps had discernable petroleum odors and a sheen indicative of either petroleum contamination or biological growth. Some of the seeps were associated with stressed vegetation.

Mapping of Surface Water Drainage. Drainage from the OU 5 bluff source areas travels through ponds, wetlands, open drainage ditches, and buried culverts, until the runoff reaches Ship Creek and flows west into Knik Arm. A tracer-dye study was performed to determine the direction of flow in buried culverts. Drainage to Ship Creek occurs as point source discharges rather than sheet runoff.

Review of Elmendorf AFB Bioenvironmental Engineering Services Group (BESG) Data. The BESG routinely collects water samples from two lower aquifer supply wells (BW2 and BW52) in OU 5 and from a drainage ditch as it exits Elmendorf AFB. These data are summarized in the RI report.

Water Use Survey. A survey of 30 off-base property tenants, computer searches of available groundwater data bases, and interviews were conducted to determine water use at and downgradient of OU 5 and to identify the potential receptors of groundwater and surface-water contaminants. Surface water from Ship Creek is diverted for cooling water at the Elmendorf AFB power plant and for fish production at the hatchery. The upper aquifer groundwater was not found to be used by Elmendorf AFB or adjacent properties. Two Elmendorf base wells, two fish hatchery wells, and four off-site industrial area wells that draw groundwater from the lower aquifer were identified. These wells are used for drinking water, fish production, and cooling water. Most of the tenants off-base do not have supply wells on their property, but are connected to Municipality of Anchorage water supplies.

Soil Gas and Groundwater Screening Survey. A soil gas and groundwater screening survey was used to collect screening-level data on the extent of organic contamination in soil and groundwater, and to guide the placement of soil borings and monitoring wells for the RI field investigation. Samples were analyzed on site with a gas chromatograph (GC) for five chlorinated solvents; benzene, toluene, ethylbenzene, and xylene (BTEX); and total volatile hydrocarbons.

Soil Investigation. Soil sampling was conducted within OU 5 to define the extent of soil contamination around source areas and to characterize soil types. Soil samples were collected from 31 boring locations. A total of four deep borings were advanced to the Bootlegger Cove Formation using continuous split-barrel sampling to log the soil stratigraphy and verify the depth of the Bootlegger Cove Formation. Other borings were sampled at 5-foot intervals and advanced only to the top of the water table, unless the boring was designated to be completed as a monitoring well. Each soil sample was classified by a field geologist following standard procedures.

Soil samples for chemical analyses were collected at regular, predetermined intervals in the borings and at the groundwater/unsaturated zone interface. An additional soil sample was collected from the bottom of each boring that had been advanced to the Bootlegger Cove Formation to analyze for sinking contaminants. Samples were analyzed for BTEX, halogenated volatile organics, and diesel-, gasoline-, and JP-4-range hydrocarbons. In addition, selected soil samples were analyzed for semivolatile organics, metals, and physical parameters, including grain-size distribution, liquid and plastic limits, and total organic carbon.

Groundwater Investigation. Nineteen groundwater monitoring wells were installed into the upper aquifer. Monitoring well locations were selected to confirm the presence of contamination identified during the groundwater screening survey to provide groundwater data in areas of known or suspected leaks, and to allow the groundwater directly upgradient and downgradient of OU 5 to be sampled. Water level measurements in existing and new wells and at temporary piezometers installed during the soil gas survey were measured four times during the field season at approximately 3-week intervals. No floating product layers were detected in the monitoring wells. All new monitoring wells were developed with a combination of surging and bailing or pumping. Slug tests were completed on 11 of the new monitoring wells to allow measurement of hydraulic conductivity values.

Groundwater samples from a total of 17 existing and 19 new monitoring wells were collected and analyzed to evaluate upper aquifer groundwater quality. Samples were tested for halogenated volatile organics, BTEX, semivolatile organics, and diesel-, gasoline-, and JP-4-range hydrocarbons. Monitoring wells near fly ash deposits (east of source ST37) were additionally sampled for total and dissolved metals. General water-quality parameters (alkalinity, hardness, and anions) were analyzed in five randomly chosen sample locations. Results of the general water-quality analysis were used to perform a geochemical comparison of water collected from the shallow and deep aquifers.

Four active water-supply wells were also sampled to determine lower aquifer groundwater quality. Samples were analyzed for volatile organics, semivolatile organics, and diesel/gasoline/JP-4-range hydrocarbons. Samples from selected wells were also analyzed for selected cations, anions, and metals.

Coordinates and elevations for monitoring wells, soil borings, piezometers, water supply wells, and stream gages were surveyed and referenced to published control points. Both were used to map sampling locations and provide common reference points for water-level measurements used to evaluate site hydrology.

Surface Water and Sediment Investigation. Surface water and sediments were sampled from Ship Creek, the golf course beaver pond, and selected surface water impoundments and drainage ditches downgradient of the OU 5 bluff. Sample locations were chosen based on strategic points of inlet or discharge to receiving waters, or where stressed vegetation was apparent.

Surface-water samples were analyzed for volatile organics, semivolatile organics, total and dissolved metals, diesel-, gasoline-, and JP-4-range hydrocarbons, and alkalinity. In-situ field measurements included pH, temperature, specific conductance, and dissolved oxygen. Sediment samples were analyzed for volatile organics, semivolatile organics, diesel/gasoline/JP-4 hydrocarbons, and total metals. PCB samples were included in selected sediment samples.

Ecological Surveys. Aquatic and terrestrial ecological surveys were performed to describe the biological characteristics of OU 5, identify receptors and important habitats, determine if there is evidence of stress on the ecosystems in the area, and assess toxicity of water and sediments in the study area to fish and benthic macroinvertebrates. In-situ physical measurements of surface-water quality and habitat observations were made to provide a qualitative habitat assessment for comparison of each sampling location. The RI report contains the results of both the aquatic and terrestrial surveys.

The following tasks were part of the ecological investigations. Benthic macroinvertebrates were sampled using both quantitative and qualitative methods. Fish were sampled qualitatively using electroshocking at Ship Creek and pond locations. Acute and chronic toxicity tests were conducted on selected surface-water and sediment samples to assess the potential for stress to aquatic organisms. Plant and soil samples were also collected for chemical analyses to determine whether plant stress observed during the terrestrial field survey was directly related to contaminant exposure or to nutritional deficiencies and imbalances induced by contaminants.

Analytical Laboratory Program. The analytical program used both 48-hour turnaround time analyses at the CH2M HILL Corvallis, Oregon, Close Support Laboratory (CSL) and standard turnaround time analyses at the CH2M HILL Redding, California, laboratory. Additional contract laboratories to support add-on work included Superior Analytical, ENSECO, and the CH2M HILL Milwaukee, Wisconsin, aquatic biology laboratory.

Data Validation and Management. The laboratories generated EPA Level III data with documentation equivalent to EPA Level IV data. All data packages from the investigation were reviewed for adherence to quality assurance limits defined in the OU 5 *Management Plan*. An additional 10 to 20 percent of the data was validated using raw data according to EPA functional guidelines. Validation reports are included in the RI report. Generally, the data met the project quality assurance objectives. Standard procedures were also followed for entering the data into a data management system that met USAF requirements.

Nature and Extent of Contamination

The OU 5 sampling locations are divided into seven subareas based on the geographic relationship to the suspected pipeline sources, and habitat and land use characteristics. The subareas studied during the RI are designated upgradient, pipeline corridor, waste paint tank, lower bluff, Post Road corridor, golf course beaver pond, and Ship Creek. The industrial area along Post Road was not investigated under this RI.

Soil. Three source areas had soil petroleum hydrocarbons greater than 100 mg/kg: the pipeline corridor and lower bluff subareas south of the COE building (Source ST37), the lower bluff subarea below Building 22-010 (Source ST38), and the pipeline corridor near a low-point water drain valve at the junction of Post Road and Second Avenue (Source SS53). Petroleum hydrocarbons generally increased with depth with very little upper vadose zone contamination. The highest concentration of petroleum hydrocarbons at OU 5 was 1160 mg/kg diesel in a soil boring at the 10- to 12-foot depth at Source ST37. Halogenated organics were not detected in any soil samples.

Upper Aquifer Groundwater. Halogenated volatile organic compounds (VOCs) were detected in the upgradient subarea of OU 5 (TCE concentrations between 5.2 μg/L and 52 μg/L), and at lesser concentrations in the pipeline corridor and lower bluff subareas. The fuel hydrocarbons observed in OU 5 groundwater include BTEX compounds, PAHs, gasoline, JP-4, and diesel-range organics. Several of the fuel hydrocarbons were also observed in upgradient monitoring wells, but generally at lower concentrations than found downgradient of the pipelines. Comparison of metals in groundwater near the fly ash deposits with regional background data indicates that concentrations for several metals are elevated. Additional sampling upgradient and downgradient of the fly ash deposit is being performed to further evaluate the potential impact of the source.

Surface Water and Sediment. In the surface water sampling program, fuel hydrocarbons, BTEX, PAHs, volatiles, and semivolatiles were detected, to some degree, in each pond, except the beaver pond at seep SL29, and in drainage ditches. These organics, with the exception of an diesel-range organic detected at a culvert outfall outside OU 5 (sampling station SW11), were not detected in the Ship Creek surface waters. The chemical analyses results indicate that organic contaminants in the surface water, for the most part are confined to the OU 5 lower bluff ponds, and are either biodegraded/absorbed in soils or vegetation along the drainage pathways, or are diluted to a level below detection limits before reaching Ship Creek.

In the sediment sampling program, organics were detected, to some degree, in the water-body sediments sampled along the OU 5 runoff pathway (ponds, drainage ditches, creek). However, the potential contaminant concentrations detected in Ship Creek sediments are below those detected upgradient/upstream, indicating the potential contaminants are somewhat confined to the upgradient lower bluff pond sediments in the OU 5 transport pathway. PCBs (Aroclor 1260) were detected in one sediment sample (sampling station SB07); however, the source of the PCB is uncertain.

Aquatic Biota. Macroinvertebrate community structures in the ponds at the base of the bluff were restricted. The golf course beaver pond was the most biologically affected sampling station. The presence of organic compounds in the pond surface water and sediments suggests a potential cause for this condition. Laboratory toxicity tests indicated that the golf course beaver pond sediments are acutely toxic to *Chironomus tentans* at the southwest end of the pond, and chronically toxic to *Hyalella azteca* at the northeast end of the pond; however, additional quantitative sampling would be required to better characterize community structure.

Ship Creek was not observed to be affected by any of the OU 5 source areas. Resident fish are present in Ship Creek in limited numbers within the study area, and do not appear to be in the pathway of OU 5 contaminants of concern that could have an adverse effect. No fish were observed to inhabit the OU 5 study area ponds.

Terrestrial Plants and Animals. Several species of plants exhibited signs of stress, including interveinal chlorosis. This suggests that some stressor found in the soils in various areas of OU 5 has altered the photosynthetic rate of affected plants. Because the signs of stress were similar to those induced by iron deficiency, the chemical analyses of plants and soils focused on factors that may affect iron uptake and availability, in addition to analyses for previously identified contaminants for OU 5. Elevated soil manganese, phosphorus, and pH may cause mineral imbalances to occur in plants. Based on the data from this exploratory study, a definitive cause for the plant stress cannot be determined.

Bird eggs that failed to hatch were found in four nests, and five of the six eggs had dead embryos. The affected nests included mew gulls, American widgeon, and spotted sandpiper. The limited observations of water fowl, shorebird, and gull nests did not indicate that eggs were becoming oiled by transfer of oil from the parents' feathers, and oil was not observed on the birds' plumage. These findings are inconclusive, however, because the number of nests being observed was small.

Conceptual Model

A conceptual model was established as a means of defining contaminant migration pathways into, through, and away from OU 5. The primary media of concern in OU 5 include the vadose zone soils, groundwater, surface water, and sediment.

Three areas (Sources ST37, ST38, and SS53) were identified during the investigation as having fuel contaminated soils. Because no ongoing or recent leaks were identified during the investigation, contaminated soils probably represent residual contamination from past reported leaks and spills. The current contamination is located in the capillary fringe of the water table.

Groundwater contamination observed in OU 5 wells occurred exclusively in the upper aquifer. Halogenated VOCs and fuel hydrocarbons were the principal contaminants detected in the groundwater. Concentration patterns suggest that the halogenated VOCs are migrating into OU 5 from upgradient sources via groundwater transport. Fuel hydrocarbon concentration patterns confirm that sources are along the pipeline corridor, but low concentrations indicate that these are relatively old spills and leaks.

The Bootlegger Cove Formation between the upper and lower aquifers is thought to prevent any significant exchange of contaminants between the two aquifers.

Groundwater flow within OU 5 is generally toward the Ship Creek valley. Water table elevation contours indicate that groundwater enters Ship Creek as base flow. The elevation of the ponds and seeps along the base of the bluffs and the presence of halogenated VOCs in both groundwater and seeps further indicate that these surface waters are fed by groundwater. These surface-water bodies are also fed by storm-water runoff from the base.

Baseline Risk Assessment

The baseline risk assessment evaluates the potential threat to human health and the environment posed by actual or potential releases of hazardous substances from OU 5 under the no-action alternative (no remedial action).

Human Health Evaluation. The human health evaluation consists of four steps: identification of contaminants of concern, toxicity assessment, exposure assessment, and risk characterization. For each step, assumptions and uncertainties in the process are discussed. The risks for OU 5 are evaluated under both current and potential future land uses. Contaminant concentrations are assumed to remain constant during the duration of the assumed exposures.

A maximum concentration screening approach was used to eliminate pathways of low risk to human health. Pathways eliminated included subsurface soil, surface water, sediment, and some surface soil. A fish ingestion pathway was eliminated because of the lack of contamination in Ship Creek. The remaining pathways, groundwater, air (dust), and some soil, were evaluated under reasonable maximum- and average-case exposure scenarios.

The estimated risk values were compared to EPA bench marks. The upper aquifer groundwater pathway generated noncancer hazard index values exceeding unity and total excess lifetime cancer risks equal to one in ten thousand (1 x 10^{-4}). The groundwater pathway assumed future residential exposures through ingestion, inhalation of vapors, and dermal contact with upper aquifer groundwater over a lifetime. Total metals (arsenic and manganese) are the largest contributors to the groundwater risk estimates. Exposure by ingestion of the groundwater yields the highest risk values.

Under reasonable maximum exposure assumptions, organic contaminants contribute between 10^{-5} and 10^{-6} excess lifetime cancer risks for future residents through ingestion of groundwater and inhalation of volatiles during showering. That level of risk occurs as a result of organic contaminants in all OU 5 subareas. The organic contaminants contributing to the estimated risks include gasoline- and diesel-range organics, benzene, and TCE.

A future residential scenario for the upper aquifer groundwater is highly conservative. The upper aquifer at OU 5 is unlikely to be used for domestic purposes because of low yield and the availability of other piped water supplies. The aquifer is not currently being used at OU 5.

Environmental Evaluation. Assessment endpoints (the environmental values to be protected) considered in the risk assessment for aquatic and terrestrial receptors include the integrity of wildlife habitats in OU 5, no significant impacts of environmental contaminants in OU 5 on wildlife species, and compliance with potential federal and state applicable or relevant and appropriate requirements (ARARs). Measurement endpoints include general habitat conditions as assessed through qualitative surveys, evidence of impaired ecosystem health, and comparison of observations and contaminant concentrations to potential ARARs.

The risk characterization indicated that the most likely impacts of contaminants on aquatic receptors in OU 5 would be caused by dermal contact, absorption, or ingestion of fuel hydrocarbons, and/or BTEX and PAHs, by benthic macroinvertebrates in the golf course beaver pond, wetland pond, and lower bluff pond. Impacts to aquatic bed plants in the golf course beaver pond and wetland pond hydrophytes by metabolic uptake of contaminants may also be a limiting factor to aquatic vegetation viability. Furthermore, PCBs (Aroclor 1260) were detected in the near-shore sediment of the snowmelt pond above criteria for sediment level of concern. The presence of chironomids at the water/sediment interface, however, suggests that the contaminant in this near-shore environment is not biologically available, or that the taxa present are highly resistant to the contaminant.

Fish and invertebrates in Ship Creek do not appear to be at significant risk from OU 5 contaminants.

Plant stress, and possibly the reduced egg-hatching success in semiaquatic birds that nested near several surface-water bodies, provided evidence of impaired ecosystem health. Causes of the plant stress could not be identified definitively, but they appear to be something other than fuel hydrocarbons. The most likely cause seemed to be mineral imbalances related to elevated manganese, and potentially cobalt, phosphorous, and pH in areas where plants showed signs of stress. The number of bird nests was not adequate to determine causes of nesting failure.

The risk characterization indicated that the most likely impacts of contaminants on terrestrial ecological receptors in OU 5 would be caused by the following:

- Inhalation exposure of small mammals to fuel hydrocarbon vapors when the animals were in their burrows;
- Dermal contact/absorption of fuel hydrocarbons by semiaquatic mammals, birds, and wood frogs in the golf course beaver pond (or elsewhere when surface sheens are present); and

- Metabolic uptake/inhibition effects of inorganics by plants near seeps and wetlands where plants exhibited signs of stress.

The limitations of the above conclusions are discussed in the RI report.

Comparing observed contaminant levels to potential ARARs indicates that federal ambient water-quality criteria and the Alaska water-quality standards for fuel hydrocarbons are being exceeded in the lower bluff pond and the golf course beaver pond.

Snowmelt Pond. Three studies of the snowmelt pond have been performed. The first study indicated that PCBs may be present in the sediment of the pond. The second study confirmed the presence of the PCBs in the sediment. The third study evaluated the risk to aquatic life posed by the PCBs.

Water samples from snowmelt pond contained concentrations of 1.4 to 2.5 μg/L of three VOCs that have been detected in groundwater. Analysis of a composite sediment sample from the pond detected 0.057 to 0.240 mg/kg of 11 different polycyclic aromatic hydrocarbons (PAH) compounds and 1,600 μg/kg of PCBs (Arochlor 1260). Additional sediment samples were collected in June 1993 and were analyzed for PCB concentrations. The reported PCB concentrations in these samples ranged from "not detected" to 1,460 μg/kg.

Sediment and surface water samples were collected at the three locations where PCBs were detected during the second round of sampling. The sediment samples were analyzed for total organic carbon (TOC) because PCB toxicity in sediments is dependent on the TOC concentration in the sediments. The water samples were analyzed to determine if PCBs are present in the water phase.

The PCB concentrations do not exceed any potential ARARs for human exposure. There is potential risk to aquatic life in sediments at two locations. Also a sheen is found on the water near a seep. The sediment impacts and the sheen are evaluated in the FS.

Beaver Pond. The beaver pond is a potentially sensitive receptor of contaminated groundwater. Because of the sensitivity, two studies of the pond have been conducted. The first study focused on the identification of contamination in the water and sediment in the pond. The second study evaluated the ability of the pond to naturally attenuate the known types and concentration of contaminants.

Based on analysis of data collected during the investigation, the following conclusions have been made.

- The beaver pond is within Section 404 jurisdiction; however, a 404 permit would not be required for allowing the wetland to continue natural degradation of contaminants.
- The assessment of functions suggests that the beaver pond is capable of treating contamination in excess of that currently discharging into the system.

Any Remedial Action involving earth moving, capture of surface water, or capture of groundwater that naturally discharges to the pond would not require a 404 permit, although the intent and substantive requirements of this permit would have to be met. A 404 permit would also not be required for allowing Beaver Pond to continue natural degradation of contaminants, although again, the intent and substantive requirements of this permit would have to be met. Continuation of natural degradation would not entail any alteration of the system whatsoever, and therefore, would cause no impacts to the hydrology. A long-term monitoring program would be needed to ensure continued effective water treatment and to track potential impacts to the ecosystem.

Seeps. Three seeps not related to the beaver pond were evaluated in the beaver pond study. These seeps discharge impacted groundwater, and the discharge typically collects in puddles and flow from the puddles into damage ditches. The potential exists for exposing wildlife and humans to the impacted groundwater.

Based on the analysis of data collected for these seeps, the following conclusions can be drawn:

- The seeps not related to the beaver pond contain hydrocarbon-degrading bacteria, yet residence time in the system is probably not sufficient for complete degradation; and
- The water quality improves as the water flows away from the point of discharge.

E.2 Feasibility Study

The results of the remedial investigation (RI) of Operable Unit (OU) 5 indicate areas of soil, sediment, groundwater, and surface water contamination. To determine which media and which contaminants need to be remediated, the RI results were compared to potential ARARs, human health risks posed by the contaminants, and ecological risks. The comparison with these three criteria determined:

- Which contaminants exceeded the criteria. These became the contaminants of concern (COCs).
- The concentrations of the COCs that may require remediation.
- Which media may require remediation.
- The migration pathways affected.

These four factors — COCs, concentrations media, and migration pathways — in turn form the basis of the Feasibility Study. The most important factors are the identification of COCs and the concentrations of COCs that may require remediation. In this report, the concentrations above which COCs may need to be remediated are referred to as interim remediation goals (Table 1). They are called interim because, while they are based on regulatory requirements and site data, they are not the negotiated clean-up levels for OU 5.

The COCs for OU 5 are:

Water COCs

- Fuel hydrocarbons (JP-4, TFH-diesel, TFH-gasoline);
- Halogenated volatile organic compounds (VOCs); and
- Aromatic volatile organic compounds (BTEX).

Soil and Sediment COCs

- Fuel hydrocarbons (JP-4, TFH-diesel, TFH-gasoline);
- BTEX compounds; and
- PCB (Arochlor 1260).

Remedial actions considered for groundwater and surface seeps in OU 5 must also accommodate contaminants that may migrate in groundwater from all upgradient sources. Therefore, the list of COCs may be expanded in the future, if new COCs are identified during groundwater characterization investigations in areas upgradient from OU 5.

One inorganic compound has not been made a COC. The RI found that arsenic is a major contributor to both carcinogenic and non-carcinogenic risk in the soil and groundwater. However, an increasing body of data indicates that arsenic is not a contaminant in OU 5. Arsenic occurs naturally in soil and water of OU 5 at concentrations greater than those detected in uncontaminated media throughout the U.S. These greater background concentrations in Elmendorf AFB soils provide a natural source of arsenic in

Table 1

Interim Remediation Goals

Medium	Potential Contaminant of Concern	Interim Remediation Goal		Rationale/Comments
		Goal	Reference	
Soil (includes sediments)	TFH - diesel	200 mg/kg	ACM	The ACM, a TBC, specifies a procedure to calculate these goals on a site-specific basis. For all areas of concern at OU 5, the indicated goals were calculated.
	TFH - gasoline	100 mg/kg	ACM	
	Benzene	0.5 mg/kg	ACM	
	BTEX	15 mg/kg	ACM	
	All potential COCs (i.e., PCBs, PAHs, TFHs, VOCs, and inorganics [except arsenic]) at a specific location	Total carcinogenic risk of 1 x 10^{-6}	EPA Risk Assessment Guidelines for Superfund	Upper value of 1 x 10^{-4} to 1 x 10^{-6} EPA acceptable carcinogenic risk range.
		Total noncarcinogenic Hazard Index of 1	EPA Risk Assessment Guidelines for Superfund	EPA acceptable noncarcinogenic risk value
	PCBs	1,900 µg/kg (if TOC equals 10%) 190 µg/kg (if TOC equals 1%)	PCB SQCs	EPA recommends that SQCs be considered in establishing remediation goals for sediments. The goal is proportional to the TOC concentration as indicated.
	Arsenic	9–13 mg/kg	Average surface soil background levels at EAFB	Arsenic can result in a high level of risk, even at background levels. Remediation to below background levels is unreasonable; therefore, arsenic would only be a COC if background levels are exceeded.

Table 1

(Continued)

Medium	Potential Contaminant of Concern	Interim Remediation Goal		Rationale/Comments
		Goal	Reference	
Water (surface and groundwater)	Benzene	5 μg/L	MCLs (federal and Alaska)	MCLs are enforceable ARARs under the Safe Drinking Water Act.
	TCE	5 μg/L		
	Toluene	1,000 μg/L		
	bis(2-Ethyl hexyl-phthalate)	6 μg/L		
	Ethyl benzene	700 μg/L		
	Xylenes (total)	10,000 μg/L		
	Copper	1,300 μg/L		
	Arsenic	50 μg/L		
	Lead	15 μg/L		
	Total hydrocarbons	10 μg/L	ASWQ standards	ASWQ states that level is lesser of 10 μg/L or 0.01 times the lowest measured 96 hour LC50 for most sensitive species at the particular location. Level is 15 μg/L for species not designated by the state as "most sensitive." 10 μg/L is selected as the conservative value.

Table 1

(Continued)

Medium	Potential Contaminant of Concern	Interim Remediation Goal		Rationale/Comments
		Goal	Reference	
Water (cont.)	Hydrocarbons, oil, and grease	Not cause visible sheens or discoloration	ASWQ standards	Sheens must be from COCs and not natural sources.
	All potential COCs (i.e., PCBs, PAHs, TFHs, VOCs, and inorganics [except arsenic]) at a specific location	Total carcinogenic risk of $< 1 \times 10^{-6}$	EPA Risk Assessment Guidelines for Superfund	Upper value of 1×10^{-4} to 1×10^{-6} EPA acceptable carcinogenic risk range.
		Total noncarcinogenic Hazard Index of < 1	EPA Risk Assessment Guidelines for Superfund	EPA acceptable noncarcinogenic risk range
	PCBs	0.014 μg/L	NAWQC	This goal is more conservative than the MCLs.

TFH = Total fuel hydrocarbons
ACM = Alaska Cleanup Matrix for non-UST soils
ASWQ = Alaska Surface Water Quality Standards
MCL = Maximum concentration level
TBC = To be considered
COC = Contaminant of concern
TCE = Trichloroethylene
PAH = Polycyclic aromatic hydrocarbons
VOC = Volatile organic compounds
PCE = Tetrachloroethylene
BTEX = Sum of benzene, toluene, ethylbenzene and xylene
PCB = Polychlorinated biphenyls
NAWQC = National Ambient Water Quality Criteria
SQC = Sediment Quality Criteria
TOC = Total organic carbon

other media because the arsenic in soil may be leached to groundwater and surface water or suspended as sediment from soil erosion. Arsenic concentrations in OU 5 groundwater samples are less than federal and Alaskan MCLs for drinking water. Manganese is also found in soil; however, the analytical data show a high bias suggesting the manganese concentrations are lower than shown by the data. For this reason, manganese is not considered a COC.

Areas Recommended for No Further Action

No further action is recommended for the following source areas or specific pathways in each of the three geographic areas of OU 5 because remedial actions are not warranted.

Central OU 5

Source Areas ST38 and SS42 — No further action for the soil, surface water, and sediment pathways are warranted for the following reasons:

- TFH diesel, JP-4, and BTEX compounds were only detected in soil 10 to 60 feet below surface SB23, MW11, SP2/6-10, and SP2/6-04 and are not in a surface soil pathway accessible by residents or terrestrial animals;
- Detected contaminant concentrations pose less than 1 x 10^{-4} cancer risk and have a Hazard Index less than 1 for non-cancer risks;
- COC concentrations do no exceed ARAR or TBC levels; and
- There are no identifiable affects of contaminants on aquatic biota or terrestrial plants and animals.

Eastern OU 5

Source Area SS53 — No further action is warranted for the soil pathway for the following reasons:

- TFH diesel, JP-4, and BTEX compound concentrations were detected in SB26 at a depth of 25 to 27 feet; TFH diesel concentration in near surface soil at SL20 was only 2 mg/kg;
- Detected contaminant concentrations pose less than 1 x 10^{-6} cancer risk and have a Hazard Index less than 1 for non-cancer risk; and
- Contaminant concentrations do no exceed ARAR or TBC levels.

Source Areas SD40 and ST46 — No further action is warranted for the soil pathway for the following reasons:

- Detected contaminant concentrations in all soil samples pose less than 1 x 10^{-6} cancer risk and have a Hazard Index less than 1 for non-cancer risk;
- COC concentrations do no exceed ARAR or TBC levels; and
- There are no identifiable affects of contaminants on aquatic biota or terrestrial plants and animals.

Areas and Media Evaluated in the Feasibility Study

Remedial actions for COCs in specific pathways were be evaluated in the feasibility study because contaminants exceed potential ARARs or TBC regulatory levels or pose cancer risks greater than 1 x 10^{-6} or non-cancer risks with a Hazard Index greater than 1. The pathways that were evaluated in each geographic area and the reasons for selecting the pathway are explained below.

Western OU 5

Source Area ST37 — Remedial actions were evaluated for the soil pathway for the following reasons:

- TFH diesel and gasoline concentrations exceed the interim remediation goals of 200 mg/kg and 100 mg/kg, respectively, in a sample from 10 to 12 below ground surface at SB29.

Remedial actions were evaluated for the surface water pathway for the following reason:

- The concentrations of JP-4 (770 μg/L) and TFH gas (320 μg/L) exceed the Alaska Surface Water Quality (ASWQ) ARAR of (10 μg/L) at location SW08.

The surface water is a puddle caused by seep water. This pathway was evaluated in the FS as a seep of groundwater.

Remedial actions were evaluated for the groundwater pathway for the following reasons:

- Potential federal and state ARARs for groundwater are exceeded for benzene (5 μg/L) at SP1-01, for TCE (5 μg/L), and TFH (10 μg/L) at SP1-01, MW15, and MW16A; and
- Excess lifetime cancer risks to a future residential receptor exceed 1×10^{-6} in groundwater at wells MW02, SP1-01, and SP1-02 locations even if arsenic is deleted as a contributor to risk.

Central OU 5

Outside of Source Areas — Remedial actions were evaluated for the soil pathway for the following reasons:

- The TFH diesel concentration exceeds the interim remediation goal of 200 mg/kg in a small volume of soil south of ST38 at SL16 and the sediments at SE06.

This soil is contaminated by groundwater seeps. Because the soil is impacted as a result of a seep, the remediation of soil was not considered independently, without evaluation of alternatives for seeps.

Remedial actions were evaluated for the groundwater pathway for the following reasons:

- Interim remediation goals based on potential ARARs for JP 4 and TFH gasoline (10 μg/l) are exceeded in MW 13.
- Excess lifetime cancer risks to a future residential receptor exceed 1 x 10^{-4} in groundwater at well MW13.

Remedial actions are evaluated for the Snowmelt Pond for the following reasons:

- PCB in sediment may pose a risk to aquatic life; and
- A surface sheen near the seeps exists.

Eastern OU 5

Beaver Pond

Remedial actions were evaluated for the surface water pathway for the following reason:

- A TFH gasoline concentration of 52 μg/L exceeds the Alaska Surface Water Quality (ASWQ) ARAR of 10 μg/L and TCE exceeds the MCL ARAR of 5 μg/L.

Groundwater Outside of Source Areas

Remedial actions were evaluated for the groundwater pathway for the following reasons:

- Interim remediation goals for groundwater are exceeded for TCE (5 μg/L) at MW06 and for TFH gasoline (10 μg/L) at GW5A; and
- Excess lifetime cancer risks to a future residential receptor exceed 1 x 10^{-6} at wells MW06, MW07, and GW5A.

Remedial Action Objectives

Remedial action objectives (RAOs) are the goals that the remedial action alternatives proposed in the feasibility study (FS) are designed to achieve.

Overall goals for the remedial actions at Operable Unit (OU) 5 are to:

- Protect human health by reducing the risk from the potential exposures identified in the human health evaluation;
- Protect environmental receptors;
- Restore contaminated media for present and future land use;
- Protect uncontaminated media by preventing releases from sources;
- Expedite site cleanup by applying the U.S. EPA Superfund Accelerated Cleanup Model goals; and
- Use permanent solutions and alternative treatment technologies to the maximum extent practicable.

Specific remedial action objectives derived from these goals are listed in Section 8.0 of the RI/FS.

Remedial Action Alternatives

Based on the remedial action objectives, the interim remediation goals, and the COCs, general response actions were identified for both water and soil contamination.

The general response actions for water are:

- Natural attenuation;
- Institutional actions;
- Containment;
- Extraction/treatment/discharge; and
- In-situ treatment.

The general response actions for soil are:

- Natural degradation;
- Institutional controls;
- Excavation and disposal;
- Containment;
- Excavation/treatment/disposal; and
- In-situ treatment.

For sediment in the Snowmelt Pond, reasonable alternatives are linked. Excavation of the sediment would be difficult because of the standing water and the potential to spread impacted sediment. Also, capping would not be feasible because of the saturated conditions and the probability that a cap would be breached by hydraulic forces. Therefore, a presumptive remedy that isolates the sediment and converts the Snowmelt Pond into a constructed wetland has been selected to remediate impacts on sediment in the central area.

From these media-specific general response actions, technologies were identified and screened for effectiveness, implementability, and cost.

Those technologies that passed this initial screening were combined into media-specific alternatives that, based on professional judgment, were most applicable to the setting and contaminants at OU 5. These alternatives were screened for effectiveness, implementability, and cost in a process similar to the evaluation of technologies. Alternatives that passed this second screening (Table 2) were evaluated in detail.

However, any remedial action alternative evaluated in the FS must address all of the contamination in the operable unit. In the case of OU 5, that meant developing multi-media alternatives that each address the main body of impacted groundwater, seeps, and soil. Even with only a few remedial alternatives for each medium, the potential plausible combinations of multi-media alternatives is very large.

To reduce the number of repetitive alternative descriptions, an approach was developed where the media-based alternatives were evaluated individually according to the nine CERCLA criteria using a numerical scoring system. Multi-media alternatives were then developed; the multi-media scores for each CERCLA criterion were calculated by averaging individual component scores for a total comparative score. For example, if the long-term effectiveness scores for these components are 4, 5, and 3, the average score for the long-term effectiveness of this multi-media alternative would be 4 (12 ÷ 3). The average scores for the multi-media alternatives were evaluated in the comparative analysis. This approach streamlined the detailed analysis effort by not creating repetitive analyses for similar combinations of alternatives. Each media-specific component was evaluated for protection provided to human health and the environment, compliance with the remedial action

Table 2

Media-Specific and Applicable Pathway Remedial Action Alternatives for OU 5

WATER TREATMENT ALTERNATIVES	Groundwater	Seeps	SOIL TREATMENT ALTERNATIVES
Alternative #1 — Natural Attenuation	✓	✓	Alternative #7 — Natural Degradation
Alternative #2 — Institutional Controls	✓		Alternative #8 — Institutional Controls
Alternative #3 — Passive Extraction with Constructed Wetlands Treatment		✓	Alternative #9 — Excavation, Biopiling and Backfilling
Alternative #4 — Passive Extraction with Carbon Treatment		✓	Alternative #10 — Bioventing
Alternative #5 — Air Sparging with Soil Vapor Extraction	✓	✓	
Alternative #6 — Active Extraction with Air Stripping and Carbon Treatment	✓	✓	

objectives and potential ARARs, effectiveness, and implementability. For example, a combined multi-media alternative might be:

- Passive extraction and activated carbon treatment for seeps;
- Bioventing for soil; and
- Natural attenuation with institutional controls for groundwater.

Finally, a cost-to-effectiveness quotient was calculated for each multi-media alternative. The cost-to-effectiveness quotient is the sum of the five effectiveness criteria scores divided by the cost (in millions of dollars). The higher the quotient, the more cost effective the alternative.

Comparative Analysis Results

While the purpose of this FS is not to recommend the "best" remedial alternative, an analysis of effectiveness/cost quotient can give an indication of the most promising alternatives. Below are indicated the three alternatives that scoped highest for each area, with their attendant effectiveness/cost quotients.

Western Area

Effectiveness/Cost Quotient

1) 6.3 Passive extraction with constructed wetlands for seeps/natural attenuation with institutional controls for groundwater/bioventing for soils;

2) 6.2 Passive extraction with constructed wetlands for seeps/natural attenuation for groundwater/bioventing for soils; and

3) 5.9 Passive extraction with activated carbon for seeps/natural attenuation with institutional controls for groundwater/bioventing for soils;

5.9 Passive extraction/activated carbon treatment for seeps, natural attenuation with institutional controls for groundwater, and bioventing for soil.

Central Area

Effectiveness/Cost Quotient

1) 7.7 Passive extraction with constructed wetlands for seeps/natural attenuation for groundwater/bioventing for soils; and

2) 7.6 Passive extraction with constructed wetlands for seeps/natural attenuation with institutional controls for groundwater/bioventing for soils;

3) 7.1 Four multimedia options tied, all of which include passive extraction with either constructed wetlands or activated carbon.

Eastern Area

Effectiveness/Cost Quotient

1) 8.9 Passive extraction with constructed wetlands for seeps/natural attenuation with institutional controls for groundwater;

2) 8.8 Passive extraction with constructed wetlands for seeps/natural attenuation for groundwater;

3) 8.1 Passive extraction with activated carbon for seeps/natural attenuation with institutional controls for groundwater; and

4) 8.0 Passive extraction with activated carbon for seeps/natural attenuation for groundwater.

As stated earlier, the evaluation of alternatives by using effectiveness/cost quotients cannot be relied on to select the "best" alternative due to the numerous assumptions made (e.g., assigning equal weight to each criteria). However, it can provide a useful cut of

the more preferable alternatives. The remainder of the CERCLA process (i.e., Proposed Plan, agency/public input, and Record of Decision) will determine the preferred alternative.

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1.0 INTRODUCTION

This report presents the results of the remedial investigation (RI) of Operable Unit (OU) 5 on Elmendorf Air Force Base (AFB), Alaska, conducted by the U.S. Air Force (USAF). The site location is shown on Figure 1-1. The RI report describes the results of field investigations and provides an evaluation of the data and a risk assessment. The RI activities took place during summer and fall 1992.

In August 1990, Elmendorf AFB was listed by the U.S. Environmental Protection Agency (EPA) on the National Priorities List (NPL). This listing designated the facility as a federal Superfund site subject to the remedial response requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986.

As a result of Elmendorf AFB being listed on the NPL, the USAF, the EPA, and the Alaska Department of Environmental Conservation (ADEC) negotiated the Federal Facility Agreement (FFA) for Elmendorf AFB, which all three parties signed on November 22, 1991. Under terms of the agreement, all remedial response activities will be conducted to protect the public health and welfare, and the environment, in accordance with CERCLA, the National Contingency Plan (NCP), the Resource Conservation and Recovery Act (RCRA), and applicable state law. The purpose of the FFA and its requirements are summarized in *Elmendorf Air Force Base, Alaska, Basewide Investigation Work Plan* (CH2M HILL, 1992b).

1.1 Objectives

In response to the FFA, the USAF prepared a management plan for OU 5 (CH2M HILL, 1992d) that served as a planning document for the OU 5 RI activities. The OU 5 Management Plan met the requirements of CERCLA and the FFA.

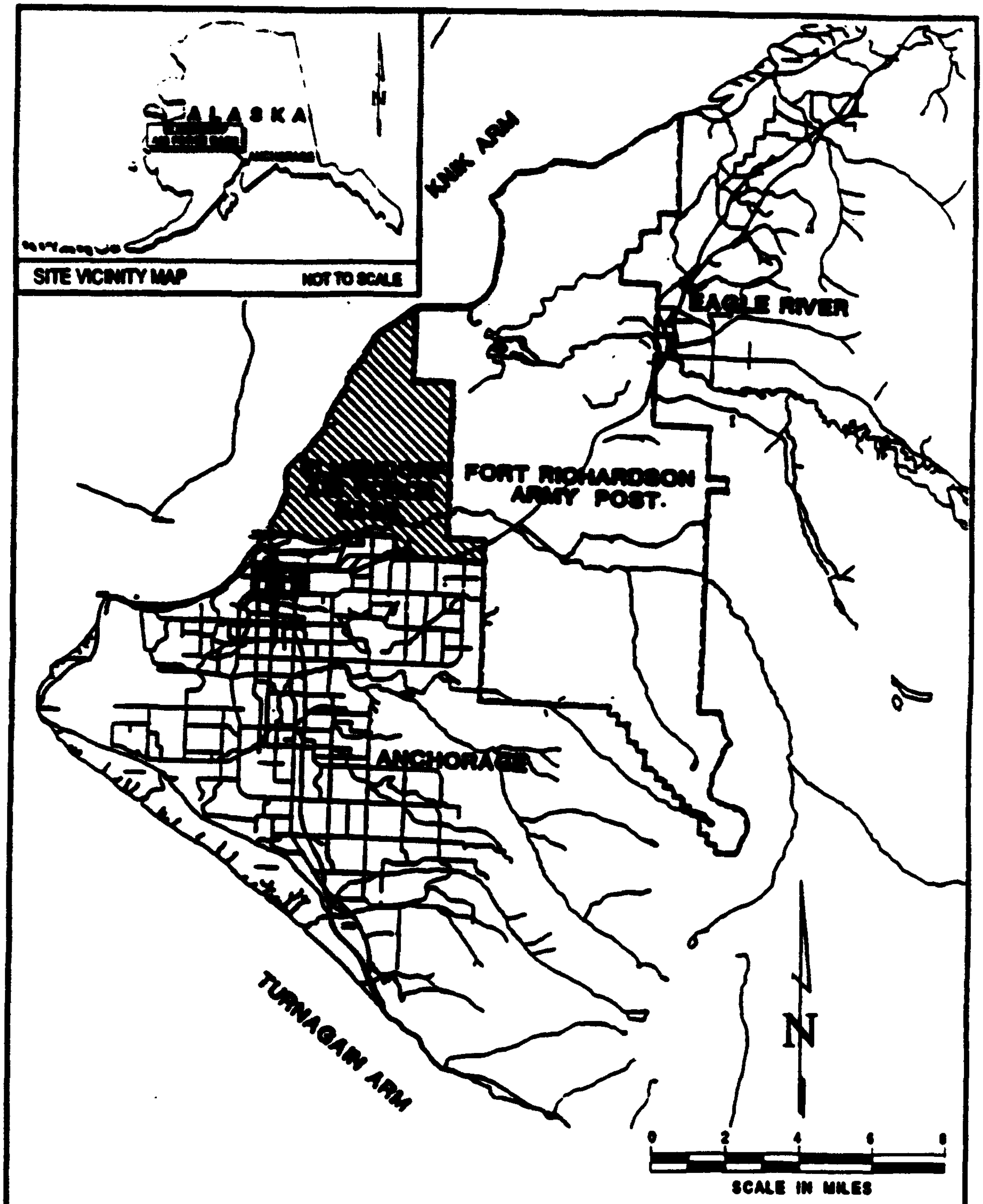

FIGURE 1.1
SITE LOCATION MAP
ELMENDORF AFB
ANCHORAGE, ALASKA

The investigation of OU 5 had the following objectives:

- Provide sufficient data to develop source-specific and OU-specific conceptual models.
- Determine the potential for offsite migration of OU 5 contaminants and impacts on Ship Creek.
- Determine the influence of upgradient contaminant sources on the OU 5 areas.
- Collect sufficient data to determine the approximate extent and nature of contamination.
- Collect sufficient data to determine the risks to human health and the environment.
- Prepare an RI report with results of the field investigation to provide a basis for the feasibility study (FS). In accordance with the OU 5 Management Plan, the RI report will also present preliminary recommendations for remedial technologies and remedial action objectives.

1.2 Operable Unit 5 Background

OU 5 is one of the areas on Elmendorf AFB that has been identified in the FFA as a source of environmental contamination. The location of OU 5 and other operable units at the site is shown on Figure 1-2.

Throughout this RI report, "the site" refers to Elmendorf AFB; areas of contamination or potential contamination within Elmendorf AFB are referred to as "source areas" or "sources."

1.2.1 Operable Unit 5 Description

OU 5 is located just north of Ship Creek at the southern perimeter of Elmendorf AFB. The FFA lists six potential source areas in OU 5 that were identified by

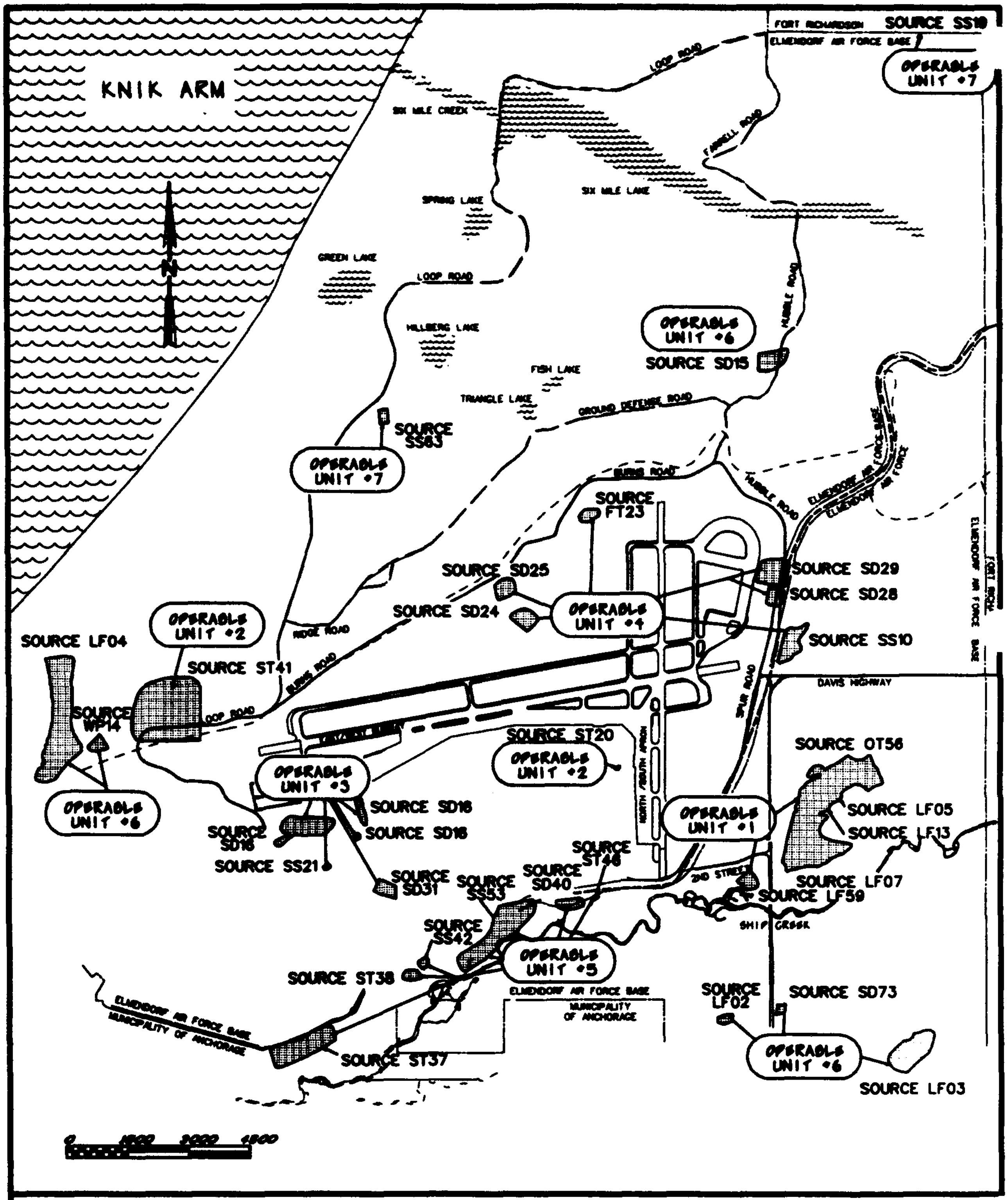

Figure 1-2. CERCLA Sites at Elmendorf AFB

the USAF through records searches of spills and fuel seeps. Figure 1-3 shows the locations of the OU 5 source areas. The source areas included in OU 5 are grouped together because they share similar petroleum-like contaminants, potential for offsite migration of the contaminants, potential impacts to Ship Creek, and potential risks to receptors. All six sources have undergone previous investigations. It is not certain whether these sources are the only sources of petroleum contamination in OU 5. Figure 1-3 also shows the location of coal fly ash deposits that were observed in borings installed during previous investigations. Fly ash was a residual waste of the coal-burning Elmendorf AFB power plants until the plants switched to natural gas in the 1960s. The extent of fly ash deposits on the bluff area is unknown.

Figure 1-4 shows the locations and concentrations of selected contaminants (total petroleum hydrocarbons [TPH]; benzene; total benzene, toluene, ethylbenzene, and xylene [BTEX]; and trichloroethene [TCE]) found within OU 5 during previous investigations. Figure 1-4 also shows a larger study area surrounding the OU 5 sources that includes upgradient and downgradient areas where sampling activities occurred during the RI. The boundaries of this study area are loosely defined as 500 to 1000 ft. north of the petroleum, oil, and lubricants (POL) pipelines, to include open areas where upgradient wells were placed, and along Ship Creek to the south, to include downgradient sampling areas and surface water and sediment sampling along Ship Creek. An offsite industrial area west of Reeve Boulevard and south of Post Road was not included in the proposed study area because of the known and potential sources for soil and groundwater contamination that exist in this area (such as the Standard Steel Superfund site). The known and potential sources in the industrial area are not expected to impact Elmendorf AFB and the OU 5 source areas since they are located hydraulically downgradient from the site. Industrial area sources may cause impacts to Ship Creek that are separate from potential impacts caused by Elmendorf AFB sources; however, this RI is not designed to evaluate impacts caused by offsite industrial area sources.

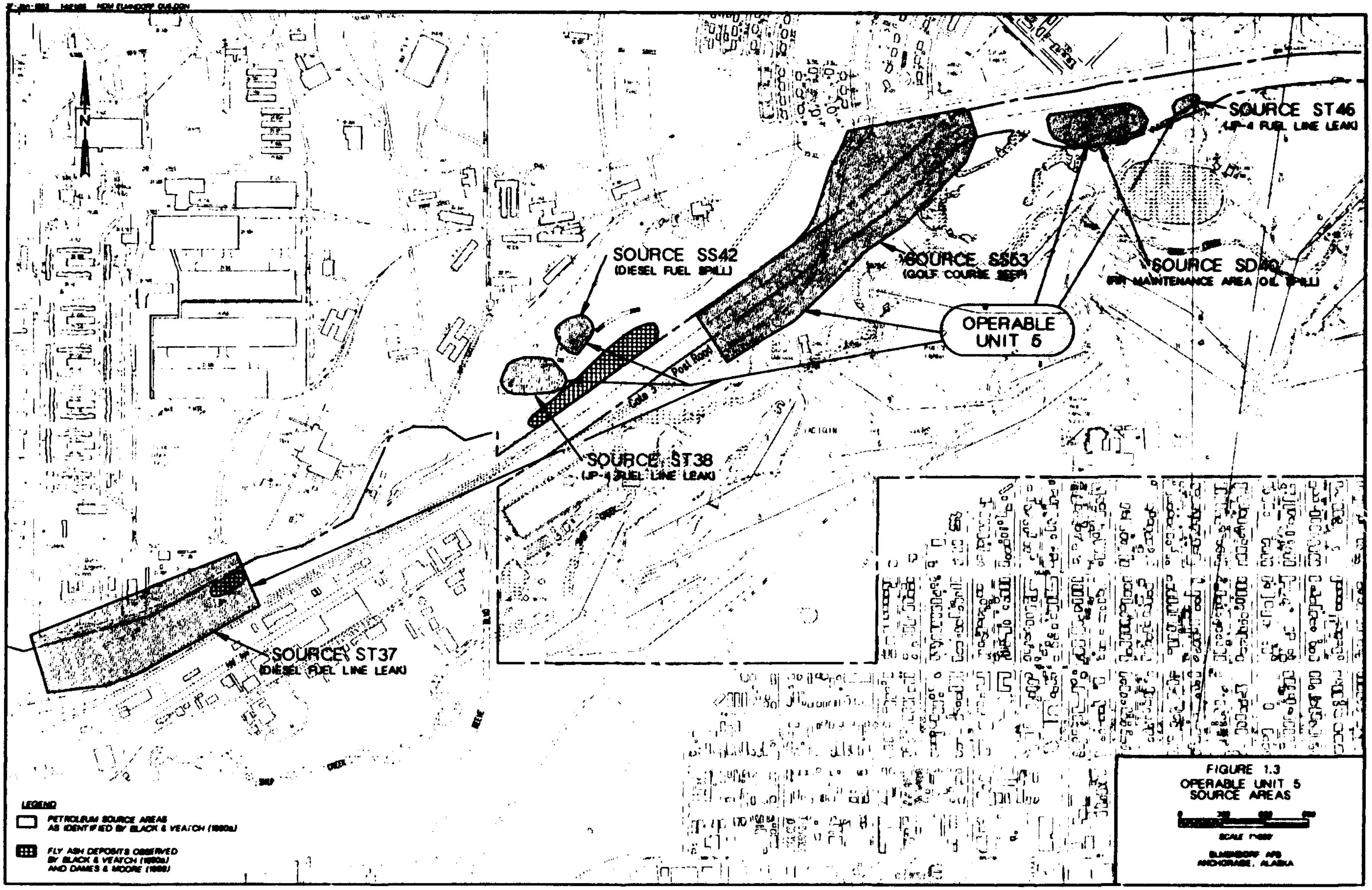

FIGURE 1.3
OPERABLE UNIT 5
SOURCE AREAS

ELMENDORF AFB
ANCHORAGE, ALASKA

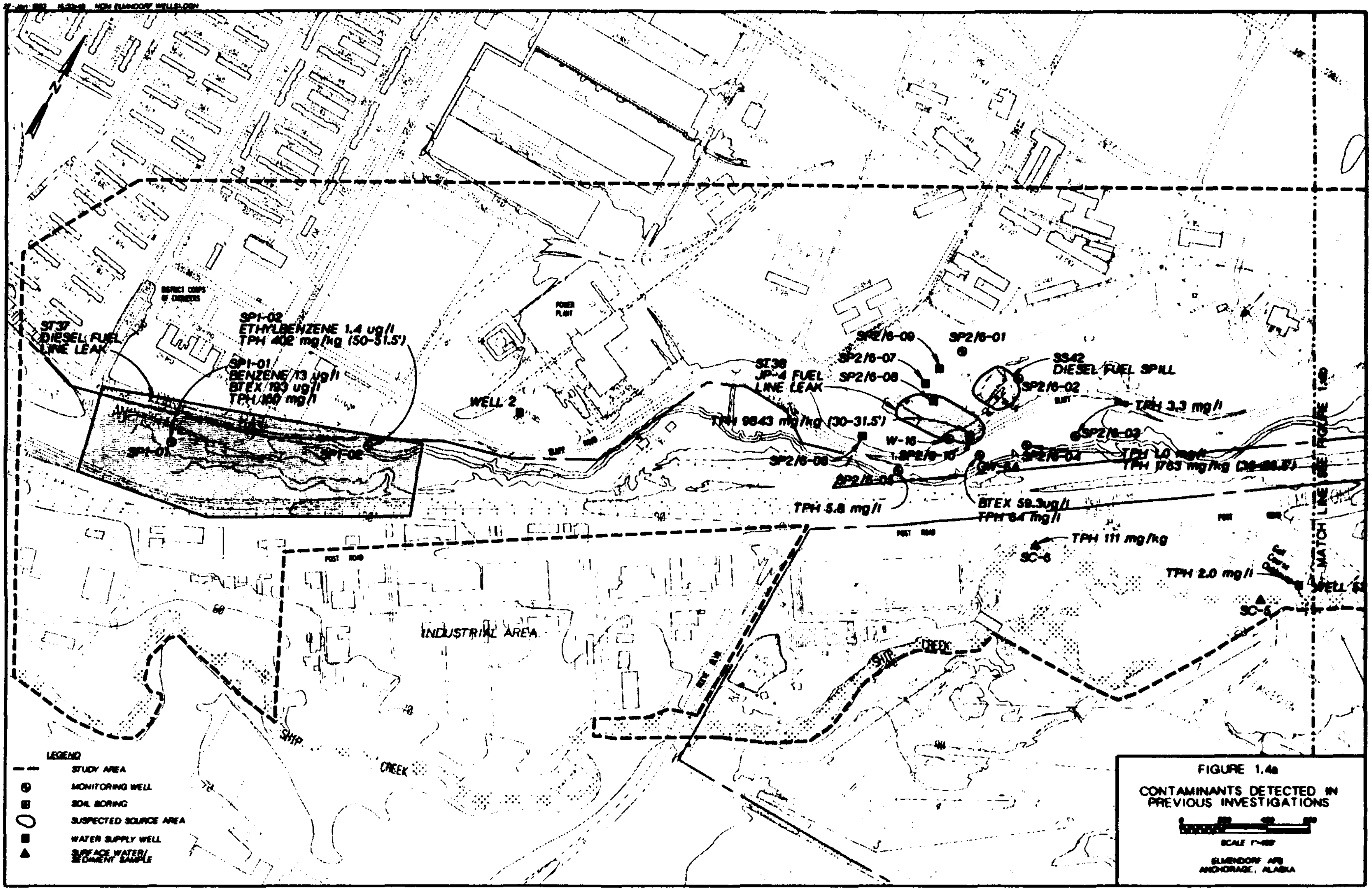

FIGURE 1.4a

CONTAMINANTS DETECTED IN PREVIOUS INVESTIGATIONS

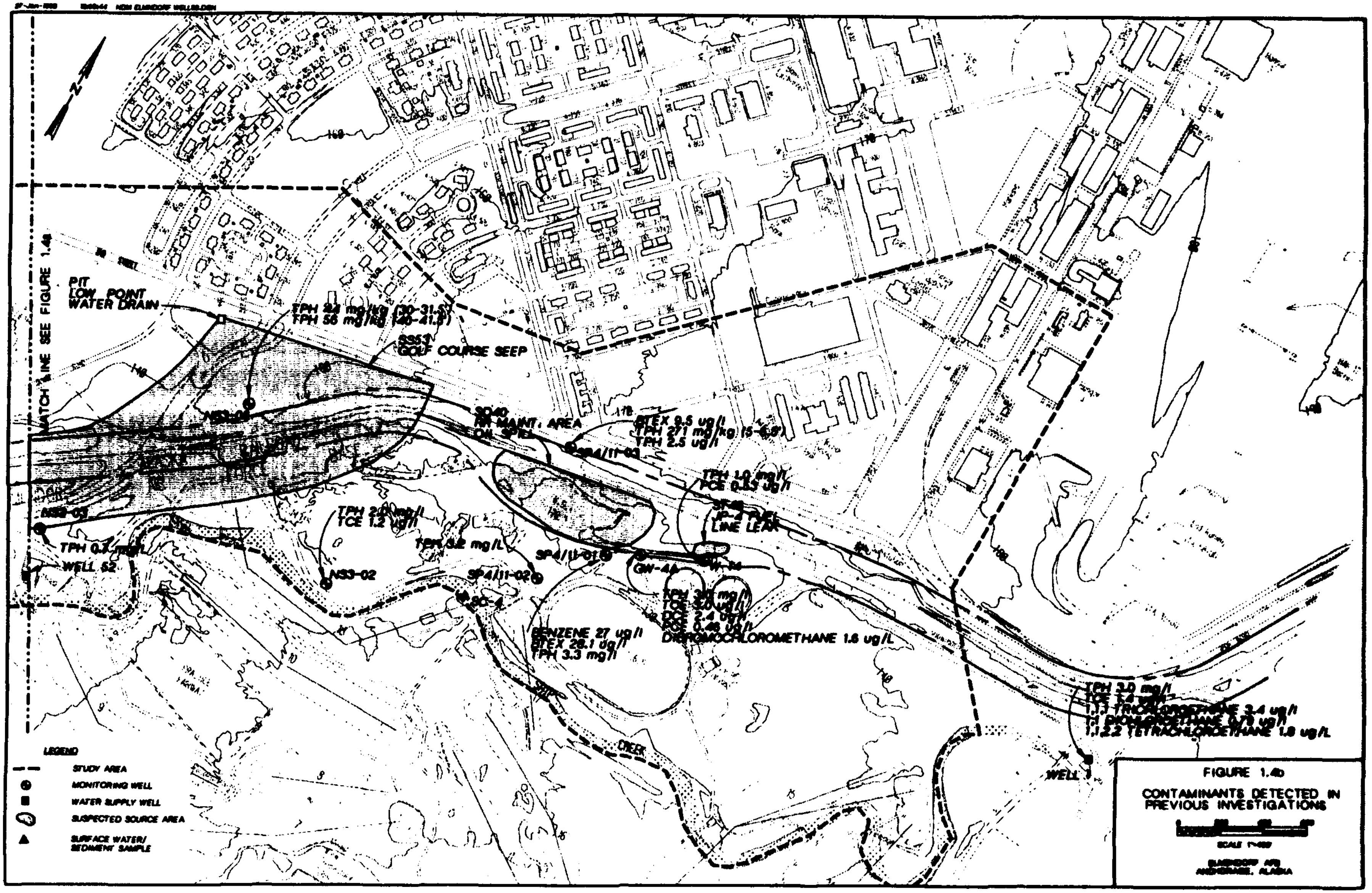

FIGURE 1.4b

CONTAMINANTS DETECTED IN PREVIOUS INVESTIGATIONS

1.2.2 Source Area Histories

1.2.2.1 Source ST37—Diesel Fuel Line Leak

Source ST37 is a diesel fuel line leak that occurred from 1956 to 1958 just south of the U.S. Army Corps of Engineers (COE) Building. The exact location of the leak was not identified in earlier reports. Diesel fuel reportedly seeped out of the ground near the railroad tracks, and thousands of gallons of diesel fuel were recovered at this location during the 1950s. An unknown amount of diesel may have remained below ground (Engineering-Science, 1983).

Elmendorf AFB Water Supply Well 2 is less than 500 feet east of Source ST37. This well is approximately 850 feet deep and draws from the confined lower aquifer beneath the base. No organic contamination has been detected in Well 2. One sample collected by the Elmendorf Bioenvironmental Engineering Services Group (BESG) contained lead at 13 $\mu g/L$ (refer to Section 1.2.3.2). Well 2 serves as a backup for cooling water for the power plant when the flow of Ship Creek is low and for drinking water when Fort Richardson can't supply enough water to meet total demand.[a]

A previous investigation (Black & Veatch, 1990) included 2 soil borings that were converted to Monitoring Wells SP1-01 and SP1-02, and soil gas surveys at 10 locations within Source ST37.

The Black & Veatch sampling and analysis program for ST37 included the following:

- Soil samples analyzed for
  - Total petroleum hydrocarbons,

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[a] Information on Water Supply Well 2 was obtained in a telephone conversation with John Barbour, Elmendorf AFB, Water and Wastewater Office, on October 13, 1992.

  - Soil moisture content;
- Groundwater samples analyzed for
  - Total dissolved solids (TDS),
  - Petroleum hydrocarbons,
  - Purgeable aromatics, and
  - Extractable priority pollutants.

Benzene was not detected at any of the 10 soil gas survey locations. Toluene was detected at eight locations, with concentrations ranging from trace levels to 9.98 parts per million (ppm). Xylenes were detected at eight locations, with the maximum concentration at 1.86 ppm. Concentrations of unidentified organics also were detected at eight locations.

Benzene exceeded the maximum contaminant level (MCL) in groundwater at one of the two groundwater sampling locations, monitoring well SP1-01, with a concentration of 13 μg/L. The maximum concentration of ethylbenzene detected in groundwater was 66 μg/L; toluene was 8.8 μg/L; and total xylenes were 105 μg/L. These concentrations are all below MCL standards. TPH in soil at monitoring well SP1-01 was 160 milligrams per kilogram (mg/kg) and exceeded State of Alaska cleanup standards of 100 mg/kg.

1.2.2.2 Source ST38—JP-4 Fuel Line Leak—and Source SS42—Diesel Fuel Spill

Source ST38 is just north of the Alaska Railroad Corporation (ARRC) tracks and east of Maple Street. As a result of a fuel line leak, an unknown quantity of JP-4 jet fuel seeped out of the bank southeast of Building 22-010 near the drainage ditch crossing Post Road during 1964 and 1965. No fuel was recovered at this location (Engineering-Science, 1983).

Source SS42 is next to Building 22-013. An estimated 8000-gallon, one-time spill of diesel fuel occurred on March 31, 1976. The spill occurred when the overflow valve failed during transfer of fuel from an aboveground tank to an underground tank. Most of the fuel was reportedly recovered from the frozen ground (Engineering-Science, 1983).

The exact locations of the JP-4 fuel leak at Source ST38 and the spill at Source SS42 have not been clearly identified. The leak and spill are thought to have occurred near a POL tank and a gasoline fill stand at Building 22-010 (Black & Veatch, 1990).

During an investigation in 1984 by Dames & Moore, monitoring well W-16 was installed near a culvert under Bluff Road, approximately 150 feet from Building 22-101. Groundwater samples collected during this investigative stage were analyzed for total organic compounds (TOC), oil and grease, specific conductance, and pH; soil was analyzed for oil and grease and moisture content. Oil and grease in soils were 28 mg/kg at 35 feet and were below the detection limit of 8 mg/kg at 40 feet. Oil and grease, and specific conductance, in the groundwater sample were only slightly elevated (Dames & Moore, 1986).

A second groundwater monitoring well, GW-6A, was installed at ST38 during the Dames & Moore 1986-1987 field effort. Monitoring Well GW-6A was installed near the top edge of the bluff south of Building 22-010 and approximately 100 feet from well W-16. Groundwater was encountered at approximately 30 feet. Water quality sampling in both wells revealed TPH concentrations of 0.8 mg/L from well W-16 and 61 mg/L from well GW-6A (Dames & Moore, 1988).

In September 1987, Harding Lawson Associates' field reconnaissance of Source SS42 identified significant quantities of floating oils and greases on stagnant waters in Ship Creek immediately opposite the diesel fuel storage site (Harding Lawson Associates, 1988b). The extent of contamination identified in the marshy area of Ship Creek extended approximately 150 yards east of the building at the fuel storage area. The nature of the observed material was undetermined (Harding Lawson Associates, 1988b).

A soil gas survey was conducted at Source ST38/SS42 during the 1988 investigation by Black & Veatch. Benzene was detected, with concentrations ranging from trace amounts to 0.88 ppm. Toluene and xylenes ranged from not detected to 2.55 ppm for toluene and 8.91 ppm for xylenes. Additionally, concentrations of unidentified organics up to a maximum of 0.80 ppm were detected at 22 of 28 locations (Black & Veatch, 1990).

Ten soil borings were also drilled at Sources ST38/SS42 during the 1988 RI/FS. Five of these borings were converted to monitoring wells (SP2/6-01 through SP2/6-05). Evidence of contamination, indicated by portable photoionization analyzer (HNu) readings, odor, and visual inspection of samples, was recorded during drilling. The sampling and analysis program for the Black & Veatch RI/FS included the following:

- Soil samples analyzed for
    - Total petroleum hydrocarbons,
    - Volatile organic compounds,
    - Semivolatile organic compounds,
    - Soil moisture content; and
- Groundwater samples analyzed for
    - Petroleum hydrocarbons,
    - Purgeable aromatics, and
    - Extractable priority pollutants.

Locations and analytical results of the samples are indicated on Figure 1-4. TPH values in groundwater were detected in four of seven locations and ranged from 1.0 μg/L to 64 μg/L. Ethylbenzene was detected in one location at 30 μg/L. M-xylene was detected in one location at 19 μg/L, and o,p-xylenes were detected in one location at 5.8 μg/L. Contaminants detected in soil included 2-methylnaphthalene in one location at 17 mg/kg, and TPH in two locations ranging from 1763 to 9843 mg/kg (Black & Veatch, 1990).

1.2.2.3 Source SD40—Railroad Maintenance Area Oil Seepage—and Source ST46—JP-4 Fuel Line Leak

Source SD40 is located near the railroad tracks approximately 600 ft. north of Ship Creek. A records search in 1983 documented that during the late 1960s quantities of brownish oil were observed seeping out of the bank near a "railroad maintenance" facility into the marsh area south of the facility and flowing into Ship Creek (Engineering-Science, 1983). The source of the oil is unknown. Also, the existence of a railroad maintenance facility has never been confirmed by Elmendorf AFB or the ARRC. Base maps show an abandoned railroad spur in the area, but interviews did not identify the purpose of the spur.

Source ST46 is a leak discovered in 1978 along the banks of a small stream north of the two 840,000-gallon JP-4 fuel storage tanks. The leak was a result of a crack in an underground pipe. After the pipe was repaired, fuel continued to seep from the bank into a beaver pond and Ship Creek.

Field investigations for Source ST46 conducted in 1984 and 1986-1987 included sampling from soil borings and groundwater monitoring wells (Dames & Moore, 1986; 1988). Figure 1-4 shows sampling locations and analytical results. In 1984, petroleum hydrocarbons were detected at concentrations of 1.7 mg/L in well W-14. In 1984, 19 mg/L of TPH was detected in well GW-4A. The water samples had petroleum odors. Groundwater sampling conducted in 1986-1987 revealed trace levels of the following compounds in well GW-4A: tetrachloroethene (PCE) at 0.46 μg/L; TCE at 3.0 μg/L; dibromochloromethane at 1.6 μg/L; trichlorofluoromethane at 0.49 μg/L; and trans-1,2-dichloroethene (DCE) at 2.4 μg/L. PCE was also detected at 0.53 μg/L in W-14 (Dames &

Moore, 1988). These solvents were not detected when GW-4A was resampled by Black & Veatch in 1988 (Black & Veatch, 1990).

As part of the Black & Veatch investigation, a soil gas survey was conducted at 35 locations. BTEX compounds were detected south of the railroad tracks. Benzene was observed at 6 of the 35 soil gas locations, with concentrations ranging from trace amounts to 6.15 ppm. Toluene was detected at all 35 soil gas survey locations, with concentrations ranging from trace amounts to 1613 ppm. Xylene was detected at 23 of the 35 locations in concentrations ranging from trace amounts to 15.97 ppm. Unidentified organics were detected in 19 of the 35 soil gas survey locations at concentrations ranging from trace amounts to 0.94 ppm (Black & Veatch, 1990).

The soil and groundwater sampling and analysis program for the RI/FS conducted by Black & Veatch at Sources SD40/ST46 included the following (Black & Veatch, 1990):

- Soil samples analyzed for
    - Total petroleum hydrocarbons,
    - Volatile organic compounds,
    - Semivolatile organic compounds,
    - Inductively coupled plasma (ICP) screen (25 metals),
    - Mercury,
    - Organochlorine pesticides and polychlorinated biphenyls (PCBs),
    - Soil moisture content; and
- Groundwater samples analyzed for
    - Petroleum hydrocarbons,

- Purgeable aromatics, and
- Extractable priority pollutants.

Locations and analytical results of the sampling program are indicated on Figure 1-4. Benzene was detected in the groundwater at 27 μg/L at SP4/11-01 and at 16 μg/L at GW-4A. Ethylbenzene was detected in one of the locations at 3 μg/L, and toluene was detected in two locations at 1.1 μg/L and 6.5 μg/L. TPH detections occurred in five groundwater samples at concentrations ranging from 1.0 milligram per liter (mg/L) to 3.3 mg/L.

Metals analyses were run on soil samples from Source SD40. Results were as follows: aluminum, 10,000 to 14,000 mg/kg; barium, 28 to 59 mg/kg; beryllium, 0.2 to 0.3 mg/kg; calcium, 4,000 to 5,000 mg/kg; chromium, 18 to 30 mg/kg; cobalt, 8 to 10 mg/kg; copper, 17 to 25 mg/kg; iron, 20,000 to 26,000 mg/kg; magnesium, 7,000 to 10,000 mg/kg; manganese, 400 to 700 mg/kg; nickel, 18 to 31 mg/kg; potassium, 600 to 1,100 mg/kg; sodium, 100 to 200 mg/kg; vanadium, 34 to 52 mg/kg; and zinc, 38 to 53 mg/kg.

1.2.2.4 Source SS53—Golf Course Seep

Source SS53 is south of Post Road, north of Ship Creek, and immediately north of the golf course pro shop. A fuel seep of unknown origin was observed during spring thaw for an unspecified number of years. Fuel from the seep was observed flowing into a drainage ditch parallel to Post Road. A U.S. Army multiproduct pipeline traverses the area and a USAF JP-4 fuel pipeline is located immediately north of the source area.

The slope where this source is located is less than 500 feet north of Ship Creek. In addition, Elmendorf AFB Supply Well BW-52 is located less than 500 feet from the source area. This well is 166 feet deep and draws from the confined lower aquifer beneath the Bootlegger Cove Formation (Engineering-Science, 1983). There is no known contamination in well BW-52.

Harding Lawson Associates performed a field reconnaissance in 1987. Fuel was observed in shallow holes and stained soil was observed in the drainage ditch along Post Road (Harding Lawson Associates, 1988b).

During the RI/FS investigation conducted by Black & Veatch (1990), a soil gas survey was performed at 26 locations. The soil gas survey showed 6340 ppm benzene at one location, with other benzene readings ranging from nondetectable to 15.85 ppm. Toluene was detected at 23 out of 26 soil gas survey locations, and readings ranged from trace levels to 7.53 ppm. Xylene was detected in 22 out of 26 soil gas survey locations, with 11 readings at trace levels and one reading at 6.26 ppm (Black & Veatch, 1990).

During the RI/FS, Black & Veatch (1990) drilled six soil borings in the source area; three were converted to monitoring wells. Twelve soil samples and three groundwater samples were collected. The sampling and analysis program included the following:

- Soil samples analyzed for
    - TPH,
    - Volatile organic compounds (VOC),
    - Soil moisture content; and
- Groundwater samples analyzed for
    - TPH,
    - Purgeable halocarbons,
    - Purgeable aromatics, and
    - Extractable priority pollutants.

Soil and groundwater sampling locations and analytical results are shown on Figure 1-4. TPH was detected in 2 of 12 soil samples: 44 mg/kg at 30 ft. and 56 mg/kg at 40 ft. in boring NS3-06. TPH was detected in two of the three water samples: 2.0 mg/L in NS3-02 and 0.7 mg/L in NS3-03. These concentrations do not exceed State of Alaska Drinking Water Standards because no sheen or odor was detected during sampling. TCE was detected in a groundwater sample from well NS3-02 at 1.2 μg/L; this concentration is below the MCL of 5.0 μg/L.

1.2.3 Other Investigations at OU 5

1.2.3.1 Fly Ash Disposal

During previous investigations by Black & Veatch (1990) and Dames & Moore (1988), fly ash deposits were observed in several borings along the bluff of western OU 5. The boring logs for Monitoring Well SP1-02 (near Source ST37) and wells SP2/6-03 and SP2/6-04 (near Source ST38/SS42) indicate fly ash deposits from 2 feet below ground surface to depths of 23, 30, and 17 feet, respectively. Soil with interbedded fly ash was observed below the water table at greater depths in these borings, and also in borings GW-6A and SP2/6-05. The areal extent of the fly ash deposits on the bluff was not determined by these investigations and no metal analyses were performed.

1.2.3.2 Ship Creek

Surface water and sediment sampling were performed at three locations in Ship Creek during the Black & Veatch field investigations. Sampling sites SC-4, SC-5, and SC-6 were located near the base golf course and Post Road gate and were adjacent to Sources ST38/SS42, SD40/ST46, and SS53 (Black & Veatch, 1990). Approximate locations are shown on Figure 1-4.

The sampling program for the RI/FS conducted by Black & Veatch included the following:

- Sediment samples analyzed for
  - TPH,
  - ICP screen (25 metals),
  - Mercury,
  - VOC,
  - Semivolatile organic compounds,
  - Cyanide, and
  - Soil moisture content; and
- Surface water samples analyzed for
  - Common anions,
  - Petroleum hydrocarbons,
  - ICP screen (total and dissolved),
  - Arsenic (total and dissolved),
  - Lead (total and dissolved),
  - Mercury (total and dissolved),
  - Selenium (total and dissolved),
  - Purgeable halocarbons,
  - Purgeable aromatics, and
  - Extractable priority pollutants.

No volatile or semivolatile organics were detected in the surface water or sediment samples. TPH was detected at a concentration of 111 mg/kg in a sediment sample from sampling site SC-6, but was not detected in surface water or other sediment samples.

Metals such as aluminum (14,300 to 17,500 mg/kg), iron (24,700 to 30,700 mg/kg), manganese (390 to 1,300 mg/kg), and magnesium (7,300 to 9,200 mg/kg) were detected in sediment samples. The highest concentrations of these metals were detected downstream at SC-6, and generally decreased upstream to SC-4. In water samples from Ship Creek, total iron, manganese, and magnesium were detected at concentrations as high as 0.21, 0.15, and 3.5 mg/L, respectively. No dissolved iron was detected. Maximum dissolved manganese and magnesium concentrations were 0.2 and 4.5 mg/L, respectively.

Small amounts (less than 120 mg/kg) of elements such as barium, chromium, cobalt, copper, nickel, vanadium, and zinc were detected in sediment samples from all locations. Water samples from all locations contained dissolved barium at concentrations less than 0.02 mg/L. No total barium was reported.

1.2.3.3 Review of Bioenvironmental Engineering Services Group Data

As part of the site reconnaissance for the OU 5 field effort and as a major task for the *Basewide Background Sampling Report* (CH2M HILL, 1992a), the USAF BESG data were reviewed to augment the background information for OU 5. The BESG at Elmendorf AFB routinely collects the following samples for chemical analyses:

- Groundwater from Elmendorf AFB supply wells in compliance with federal and state drinking water regulations; and
- Surface water samples from the major streams on Elmendorf AFB to monitor quality of water entering and leaving the base.

The samples are sent to the USAF Human Systems Division (formerly Occupational and Environmental Health Directorate), Brooks AFB, Texas, where they are analyzed or sent to contract laboratories for analysis. Since 1987, the water samples generally have been tested for total metals, volatiles, semivolatiles, total trihalomethanes, oil and grease, total organic carbons, total hydrocarbons, and other secondary standard water-quality tests.

The BESG data are presented in summary tables in Attachment C to Appendix A of the *Basewide Background Sampling Report* (CH2M HILL, 1992a). Quality control data were not available for the sample data in the local BESG files. BESG personnel indicated that the laboratory quality control data (method blanks, duplicates, surrogates, and spikes) are not routinely transmitted to Elmendorf AFB from Brooks AFB. Review of the data on file at BESG also did not identify data for trip blanks or rinsates, and only one field duplicate was identified. Trip blanks, rinsates, and method blanks are useful in identifying false positives in field data caused by contamination unrelated to the field samples. Duplicates, spikes, and surrogates are used to assess data precision and accuracy.

Without the quality control data, the BESG sample data are probably not suitable for CERCLA uses, such as quantitative risk assessment, which requires EPA Level III or equivalent data. However, the data can be used as a historical reference for observed contaminants.

The following paragraphs summarize the significant findings of the review of the BESG data. Occasionally compounds that are common laboratory contaminants (acetone, methylene chloride, chloroform, and phthalates) were detected at low levels; however, they are not discussed in the following paragraphs. Also, secondary water quality tests were eliminated from the review.

Four Elmendorf AFB supply wells are upgradient within 0.5 mile of the OU 5 study area and are monitored for water quality. Building location, aquifer, and collection period for the samples evaluated are indicated in parentheses. The wells are listed by location, progressing from west to east. In the following paragraphs, the statement "no unusual organic compounds detected" means that no organic compounds other than occasional hits of the common laboratory contaminants listed above were detected in the samples. The statement "no unusual inorganic compounds detected" means that no metals other than common elements such as iron, sodium, and potassium were detected.

- **Base Well 16** (Building 32-189, lower aquifer, July 1987 to December 1989): no unusual inorganic or organic compounds detected;
- **Base Well 40** (Building 5-800, lower aquifer, July 1987 to March 1991): one of five samples contained lead at 103 μg/L; no unusual organic compounds detected;
- **Base Well 42** (Building 11-200, lower aquifer, August 1987 to December 1989): one of two samples contained lead at 8 μg/L; no unusual organic compounds detected; and
- **Base Well 1** (Building 23-990, upper aquifer, May 1987 to July 1990): no unusual metals detected; 3 of 11 samples contained trichlorofluoromethane (2.1 to 10 μg/L); 9 of 11 samples contained TCE (1.0 to 3.2 μg/L); 8 of 11 samples contained 1,1,1-trichloroethane (TCA) (2.4 to 8.4 μg/L); 4 of 11 samples contained 1,1,2,2-tetrachloroethane (3.2 to 7 μg/L); 4 of 11 samples contained 1,1-dichloroethane (0.9 to 2.2 μg/L); 3 of 11 samples contained dichlorodifluoromethane (0.7 to 2.8 μg/L); 1 of 11 samples contained carbon tetrachloride (1.36 μg/L).

The 1,1,1-TCA in Base Well 1 increased consistently over four data points from May 1989 to July 1990, from 2.4 to 8.4 μg/L. As a result of the contamination found in base well 1, the water is no longer used as a part of the base drinking water supply.

Two Elmendorf AFB supply wells are within OU 5:

- **Base Well 2** (Building 22-001, lower aquifer, July 1987 to March 1991): 1 of 2 samples contained lead at 13 μg/L; no organics detected in 11 samples; and
- **Base Well 52** (Building 23-100, lower aquifer, June 1986 to March 1992): no unusual metals or organics detected.

In addition to the potable water wells, BESG collected surface water from the following locations of interest to the OU 5 study:

- **Ship Creek I** (Fort Richardson/Elmendorf AFB Boundary, upstream of OU 5, March 1987 to October 1991): no unusual metals detected; 2 of 15 samples detected total recoverable oil and grease (0.4 mg/L each); 6 of 10 samples contained total organic carbon (1 to 3 mg/L);
- **Ship Creek II** (Reeve Boulevard overpass near the fish hatchery, where creek exits military boundary, March 1987 to December 1991): no unusual metals detected; 6 of 12 samples contained total organic carbon (1 to 3 mg/L); and
- **Post Road gate runoff** (north of railroad track along drainage ditch, near snow disposal area in OU 5, April 1988 to October 1991): no unusual metals detected; 1 of 12 samples contained phenol (630 μg/L); 5 of 6 samples contained total organic carbon (2 to 5 mg/L); 2 of 6 samples contained 1,1,1-TCA (1.53 and 5.93 μg/L).

1.2.3.4 Base Wells 1, 2, and 52

In addition to BESG data on Base Wells 1, 2, and 52; Black & Veatch (1990) sampled the three wells as part of their 1988 investigation. The water samples were analyzed for the following parameters:

- Common anions;
- Petroleum hydrocarbons;
- ICP screen (total and dissolved);
- Arsenic (total and dissolved);
- Lead (total and dissolved);
- Mercury (total and dissolved);
- Selenium (total and dissolved);
- Purgeable halocarbons;

- Purgeable aromatics; and
- Extractable priority pollutants.

The sample from Base Well 1 contained 1,1,1-TCA at 3.4 μg/l, 1,1-DCA at 0.79 μg/l, TCE at 1.4 μg/l, 1,1,2,2-tetrachloroethane at 0.83 μg/l, and total petroleum hydrocarbons at 3.0 mg/l. Trace metals were also detected including total barium (0.007 mg/l), magnesium (5.4 mg/l), manganese (0.060 mg/l), and zinc (0.01 mg/l).

The sample from Base Well 2 contained no organics. Total metals from Base Well 2 were arsenic (0.005 mg/l), barium (0.013 mg/l), copper (0.009 mg/l), magnesium (5.7 mg/l), and manganese (0.019 mg/l).

Two duplicate samples were collected from Base Well 52. Total petroleum hydrocarbons were found at 2.0 mg/l and 0.5 mg/l and total magnesium at 6.7 mg/l.

1.2.3.5 Records of POL Line Inspections and Repairs

Three underground pipelines carry fuel that supports the operations of Elmendorf AFB and Fort Richardson (Figure 1-5). One 8-inch multiproduct pipeline originates at the Port of Whittier, approximately 40 miles south of Anchorage, and terminates at the Defense Fuels Supply Center (DFSC), near the Port of Anchorage. The multiproduct line enters Elmendorf AFB on the southeast boundary at Muldoon Road, runs along the south side of Oil Well Road to the Federal Aviation Administration (FAA) facility, and then runs due west through the FAA facility and the Elmendorf AFB golf course. At Sources ST38/SS42 in OU 5, the multiproduct pipeline bends and runs parallel to Bluff Road, a 4-inch diesel pipeline, and a 6-inch JP-4 pipeline.

The diesel and JP-4 pipelines originate at the DFSC. The diesel line terminates at the facility near Tank 105 at Sources ST38/SS42. A connecting pipeline also allows diesel to be routed, if necessary, from the facility at Sources ST38/SS42 to the power plant

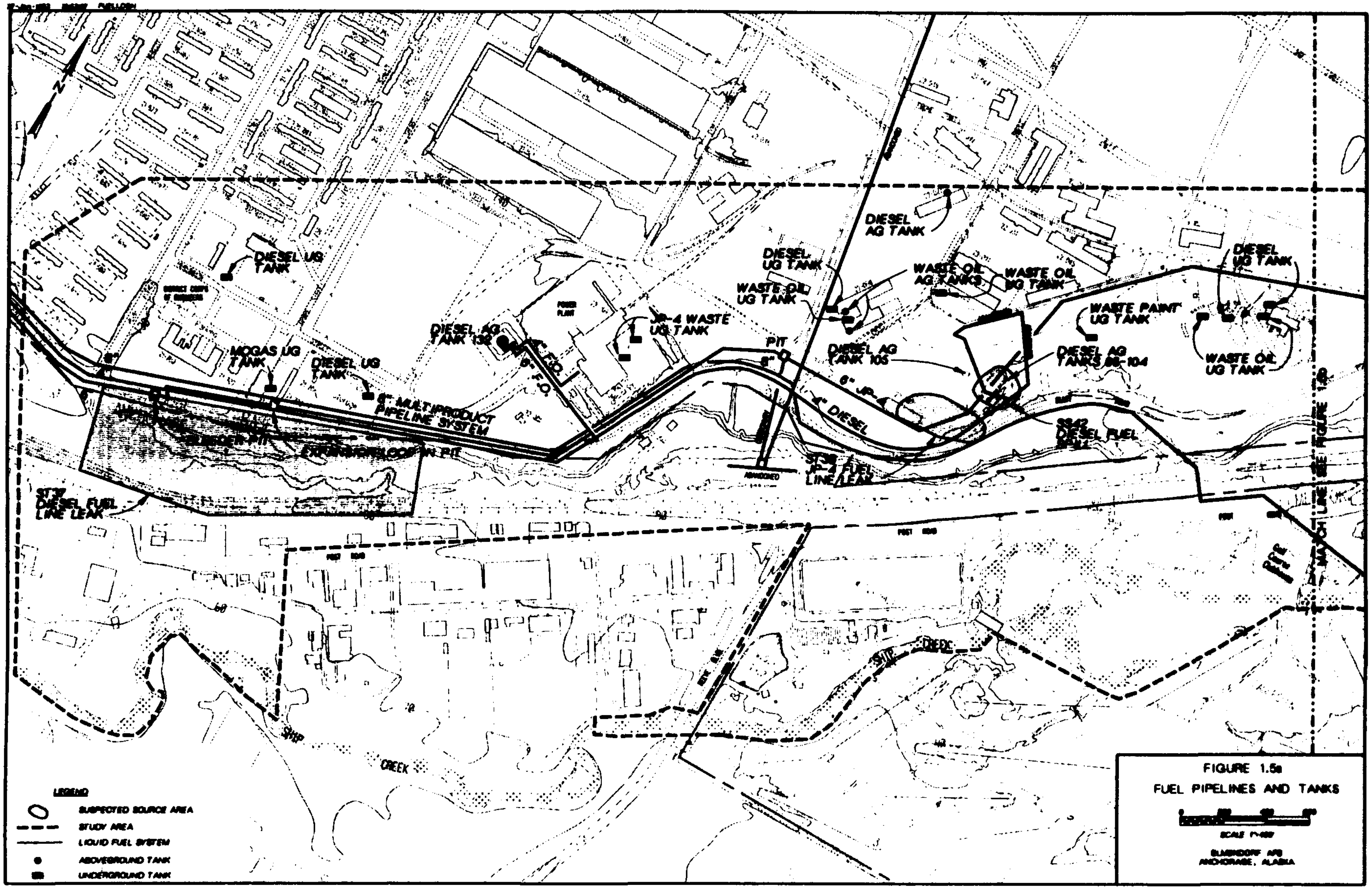

FIGURE 1.5a
FUEL PIPELINES AND TANKS

ELMENDORF AFB
ANCHORAGE, ALASKA

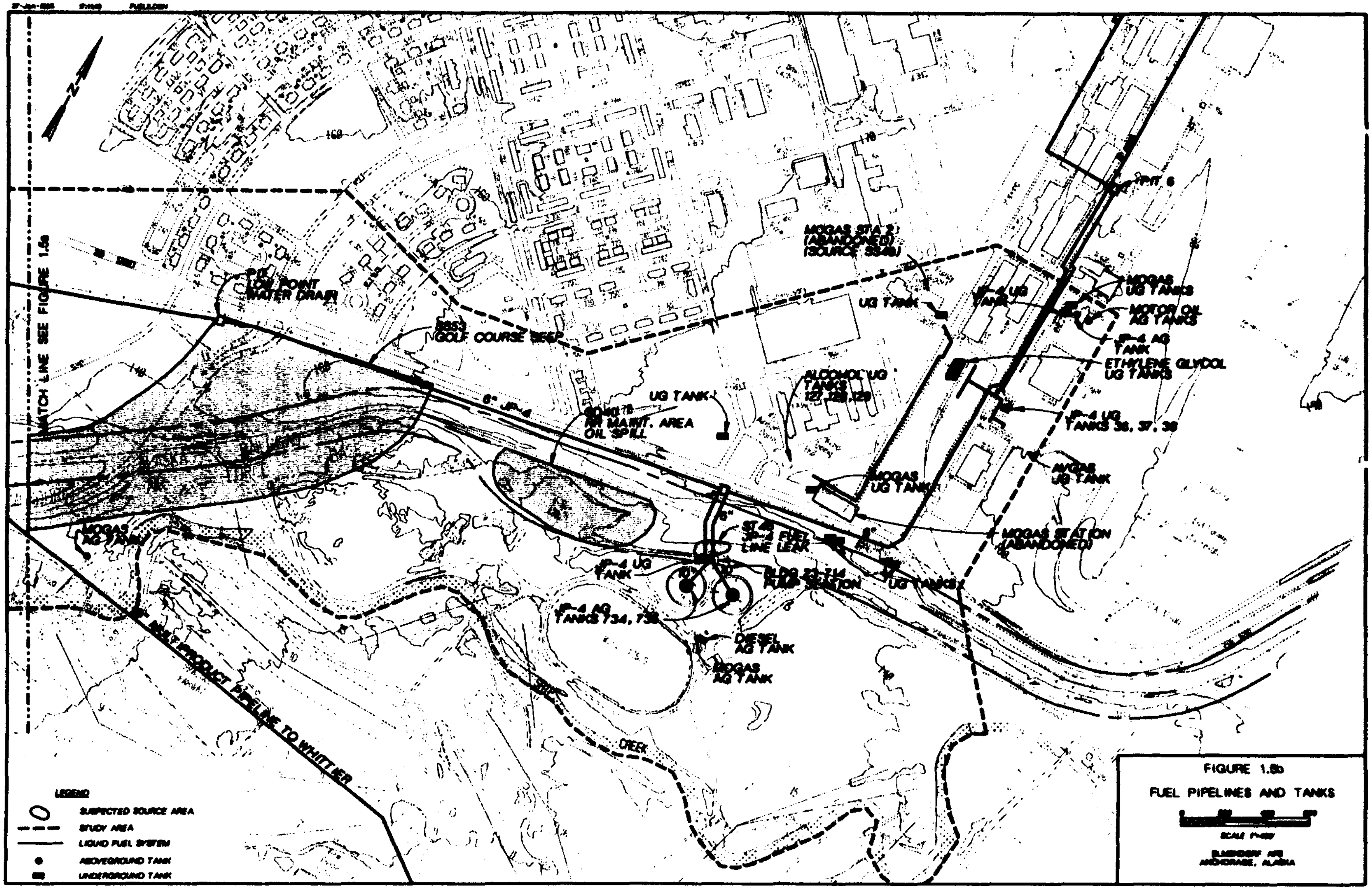

FIGURE 1.5b

FUEL PIPELINES AND TANKS

storage tank at Building 22-017. The JP-4 pipeline continues east to O Street, where it bends to the north to supply facilities near the runway.

Several underground feeder lines intersect the diesel and JP-4 pipelines. Some of these feeder lines have been abandoned; others run to storage tanks to supply fuel necessary for the operation of the USAF facilities. Table 1-1 describes the tanks that are found in or near OU 5. Information on the tanks was compiled from base maps, tank inventories supplied by the USAF, and from a USAF contractor, USKH (1992). Underground fuel storage tanks on Elmendorf AFB are currently being evaluated for repair, replacement, or removal.

Figure 1-5 shows the 4-inch diesel pipeline extending to abandoned off-loading headers near the ARRC railroad tracks. The abandoned pipeline allowed railroad cars to off-load diesel directly into the line. This section of the pipeline has not been used for several years. USAF records reviewed did not confirm whether the abandoned pipeline has been drained or still contains fuel.

Elmendorf AFB is emptying the diesel storage at the DFSC tank farm and will phase out use of the 4-inch diesel pipeline. A tank truck will deliver diesel fuel to the base.

A 12-inch pipeline carries jet fuel from the north side of the base to the south jetway. A 6-inch pipeline, which had been used to carry JP-4 fuel from the DFSC to the south jetway, has not been used since June 1992 due to an in-line pump problem. The 6-inch pipeline remains full of fuel and is available to transport JP-4. From 1975 to 1979, this pipeline transported aviation gasoline (avgas) for base operations. It is not known what products were transported through the pipeline before 1975. Base personnel responsible for maintaining the POL pipelines have noted a purplish sheen, indicative of aged avgas, in ponds along the railroad tracks in the southern portion of OU 5, near the 6-inch and 12-inch pipelines.

Table 1-1

Storage Tanks Within OU 5

Tank No.[a]	STMP ID No.[b]	Closest OU 5 Source[c]	Type[d]	Capacity (gal.)	Status[e]	Contents[f]	Tank Location[g]	Use	Date Installed	Date of Tightness Test[h]	Result of Tightness Test[h]
—	328	ST37	UG	1,000	Closed	Diesel	Building 21-700, COE, N300	Heating	1977	—	—
—	327	ST37	UG	2,000	Active	Unleaded mogas	Building 21-710, COE, E30	Vehicles	1983	12/90	Pass
—	326	ST37	UG	500	Closed	Diesel	Building 21-705, COE, S30	—	—	12/91	Pass
132	269	ST38/SS42	AG	420,000	Active	Diesel	Building 22-004, Power Plant, S200	Power	1968	—	—
—	270-271	ST38/SS42	UG	each 4,200	Active	JP-4 waste	Building 22-004, Power Plant, N30	—	1988	—	—
—	342	ST38/SS42	UG	2,000	Closed	Diesel	Building 22-007, W8	Heating	1944	—	—
—	346	ST38/SS42	AG	4,000	Active	Waste oil	Building 22-009, inside	—	1992	—	—
—	347	ST38/SS42	UG	3,000	Closed	Diesel	Building 22-009, S6	Heating	1944	—	—
—	348	ST38/SS42	UG	500	Active	Waste oil	Building 22-009, oil-water separator, W10 from SE wing	—	1990	—	—
—	349	ST38/SS42	AG	4,000	Active	Used oil	Building 22-009, E13 from SW wing	Energy recovery	1992	—	—
105	102	ST38/SS42	AG	105,000	Active	Diesel	Building 22-013, tank car unloading, NW150	Base support	—	—	—
96-104	218-226	ST38/SS42	UG	each 12,000 to 50,000	Active	Diesel	Building 22-013, Pump House, W15	Base support	1946	5/91	—
—	—	ST38/SS42	UG	1,000	Inactive	Waste paint, solvents	Building 22-044, SE225	Paint storage	—	Undergo-ing RCRA closure	—
—	343	ST38/SS42	UG	500	Active	Waste oil	Building 22-021. Pest Management. S10	—	1990	—	—

Table 1-1

(Continued)

Tank No.[a]	STMP ID No.[b]	Closest OU 5 Source[c]	Type[d]	Capacity (gal.)	Status[e]	Contents[f]	Tank Location[g]	Use	Date Installed	Date of Tightness Test[h]	Result of Tightness Test[h]
—	344	ST38/SS42	AG	500	Closed	Diesel	Building 22-023, NW50	—	—	—	—
—	339	SS53	UG	5,000	Inactive	Diesel	Building 9-154, Vehicle Service Rack, SE25	Heating	—	—	—
—	341	SS53	UG	1,000	Active	Waste oil	Building 9-154, SW150	—	1990	—	—
—	319	SS53	UG	300	Active	Waste oil	Building 8-140, W10	—	1977	12/90	Pass
—	351	SS53	UG	10,000	Active	Diesel	Building 8-140, SE	Power	1987	—	—
—	350	SS53	AG	250	Active	Unleaded mogas	Building 23-100, Golf Course Clubhouse, NE250	Vehicle mainte-nance	—	—	—
734-735	155-156	ST40/ST46	AG	each 840,000	Active	JP-4	Building 23-714, Jet Fuel Pump Station, S50	Aircraft support	1954	—	—
—	354	ST40/ST46	UG	500	Active	JP-4	Building 23-714, W8	Priming pump tank	1976	—	—
—	352	ST40/ST46	AG	600	Active	Unleaded mogas	Building 23-700, N45	Equipment fueling	—	—	—
—	353	ST40/ST46	AG	300	Active	Diesel	Building 23-700, N45	Equipment fueling	1991	—	—
—	322	ST40/ST46	UG	1,000	Inactive	—	Building 1-832, SW not located	—	—	—	—
—	379-380	ST40/ST46	UG	each 50,000	Inactive	—	Substation, W300	—	—	—	—
—	383-384	ST40/ST46	UG	each 12,000	Inactive	—	Substation, E100	Vehicles	1953	—	—
127-129	168-170	ST40/ST46	UG	each 25,000	Active	Isopropyl alcohol (diesel and mogas in past)	Building 1-832, Base Support, Old Quarter Masters Gas Station, SE700	Deicer	1956	5/91	Pass
—	374	ST40/ST46	UG	12,000	Closed	Mogas	Building 1-840, SE50	—	—	—	—

Table 1-1

(Continued)

Tank No.[a]	STMP ID No.[b]	Closest OU 5 Source[c]	Type[d]	Capacity (gal.)	Status[e]	Contents[f]	Tank Location[g]	Use	Date Installed	Date of Tightness Test[h]	Result of Tightness Test[h]
—	373	ST40/ST46	UG	12,000	Closed	—	Building 1-890, E150, abandoned	Vehicles	1960	—	—
—	177, 207-211	ST40/ST46	UG	each 25,000	Active	Ethylene glycol	Building 11-031, W500; Building 11-110, E100	Deicer	1956	5/91	Pass
—	377	ST40/ST46	UG	1,500	Inactive	JP-4	Building 11-160, W100	Unknown	1965	2/91	Pass
—	378	ST40/ST46	UG	2,500	Inactive	Mogas	Building 11-160, W100	Vehicles	1965	2/91	Pass
—	310	ST40/ST46	AG	5,000	Closed	JP-4	Building 11-160, W5	Abandoned	—	—	—
—	312	ST40/ST46	AG	500	Inactive	Motor oil	Building 11-160, E5	Purge aircraft engines	1945	—	—
36, 37, 38	100, 101, 103	ST40/ST46	UG	each 50,000	Active	JP-4	Building 11-031, N10	Direct aircraft support	1946	12/90	Pass
—	381, 382	ST40/ST46	UG	each 5,000	Inactive	Avgas	Building 11-120, NE200	Light plane refueling	1966	—	—

[a] Tank numbers are USAF numbers listed on tanks or maps and past inventories.

[b] STMP ID No. = Storage Tank Management Plan Identification Number. ENSR produced a computer data file and maps in 1992 for the USAF. The STMP identifies and locates the tanks by a specific ID number. This number is required for retrieval of information on specific tanks.

[c] Tanks in the table are presented in order based on location, starting at the western end of OU 5 and proceeding east. Approximate locations of the tanks are shown on Figure 1-5.

[d] UG = underground; AG = aboveground.

[e] A permanently closed tank may have been removed or abandoned in place, according to the regulations at the time of closure.

[f] Contents reflect current contents if tank is listed as active. Historic contents are listed if tank is shown as permanently closed or inactive. Data were not available to determine if inactive tanks were empty or still contained product.

[g] Nearest major building, direction, and distance in feet from building.

[h] Tightness testing is not required for all types of tanks.

— = information unknown

Source: Computer printout obtained from Larry Opperman, USAF Environmental Office, October 1992.

Elmendorf AFB conducts a 2-hour hydrostatic pressure test on the JP-4 and diesel lines each year and a 4-hour test every 5 years. The Liquid Fuels Office of Elmendorf AFB is required to maintain records on these POL line inspections only for the last 5 years. A review of the records in July 1992 showed files from 1986 to 1992.

In July 1991, a 4-hour hydrostatic test was conducted on the 6-inch JP-4 pipeline. This test indicated the pipeline was structurally sound. No leaks or anomalies other than routine maintenance improvements were noted.

Interviews with personnel in the Liquid Fuels Office indicated a leak was detected in June 1982 in the JP-4 line at the low-point water drain pit west of Post Road, between Bluff Road and Second Street. The pit is labeled on Figure 1-5. The records show that a follow-up acoustic pipeline inspection was conducted by Advanced Technology International in November 1986, and that a broken "bleed line" was discovered to be plugged with dirt and ice. According to the Liquid Fuels Office, the line was repaired. No records were on file to indicate when the break was repaired.

An additional unknown quantity of avgas was lost from the 6-inch pipeline in the mid-1970s (approximately 1976) at Source ST46. Base personnel discovered a leak in the pipeline near Building 23-714, adjacent to POL aboveground tanks 734 and 735, where the pipeline crossed under a creek. This section of the pipeline was replaced with an aboveground section over the creek. In 1991, a line leading to Building 23-714 was also found to be leaking. The fuel was recovered and the line repaired.[b]

The 8-inch multiproduct pipeline was emptied in April 1990 as a result of a corrosion test on the line that indicated anomalies in the pipeline wall thickness. No leaks or spills were reported in connection with the test. The DFSC had contractors working on a

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[b] Information on the 4-inch diesel pipeline and the 6-inch JP-4 pipeline was obtained in telephone conversations with Joe Pullyard, USAF Liquid Fuels Office, and Clarence Jackson, USAF Fuels Management, in February 1992.

section of the pipeline near Whittier during 1992. A small section of the pipeline in the middle of the driving range of the golf course on Elmendorf AFB also contained anomalies in pipe wall thickness and was repaired in early spring 1992. At that time, a hydrostatic pressure test was conducted on the pipeline. Fuel transport operations resumed in April 1992. While the multiproduct pipeline was being worked on, JP-4 fuel was supplied to Elmendorf AFB from local in-state refineries.[c]

According to personnel at the DFSC, there has never been a confirmed leak in the 8-inch multiproduct line. However, on May 28 and 29, 1986, the DFSC was called out to investigate fuel floating on puddles found in natural low spots in the marshy area north of the golf course clubhouse (Building 23-100). This area is represented by Source SS53. The 8-inch line was plugged and passed a 24-hour pressure test. Samples of the fuel were taken and determined to be old fuel and not the product in the line. DFSC concluded that it came from an old leak in a USAF line upgradient, and USAF took over the investigation.[d] The USAF Fuel Response Team contained the fuel with absorbent booms, an earth berm, and a trench established to focus fuel runoff by lowering the water table with vacuum pumps. After the DFSC multiproduct pipeline passed the pressure test, the USAF tested the USAF fuel line three-eighths of a mile north of the contaminated area. That line was also shown to be intact. Initially, 650 gallons of fuel and water mixture were vacuumed off the area.

An attempt was made to establish the boundaries of the golf course contamination by using a tractor-mounted posthole digger capable of digging 4-foot-deep holes. A grid was established. Holes on the south side of the parking area near Building 23-100 and in a grass island in the center of the parking lot were free of fuel. Twenty-six holes were put in a marshy area north of the clubhouse parking lot where the contamination was discovered. Depth to water varied from 6 inches below the surface to greater than 4 feet.

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[c] Information on the 8-inch multiproduct pipeline was obtained in telephone conversations with Jack Appelloni, U.S. Government contracting officer for DFSC; Paul Bestry, Tecom, Inc., contractor for DFSC; and Jack Walty, DFSC facility engineer in February 1992 and October 1992.

[d] Information on the golf course seep was obtained in telephone conversations with Jack Walty, facility manager, and A. J. Sterling, region engineer, of DFSC on October 15, 1992.

Four holes in the immediate area of the original contamination had fuel on top of the water table.

A trench was established in the center of the four "positive" holes. A small amount of fuel was skimmed from the surface of the standing water. A culvert with slits cut in it was placed in the trench to act as an accumulation point and a focus for continued skimming. On May 29, 1986, approximately 1000 gallons of fuel/water mixture were removed from the trenches. Reports do not indicate that any soil was removed during the cleanup effort. The "negative" holes were filled in. The positive holes were treated with absorbent pads.

Both the Army and the USAF ran laboratory analyses on the sampled fuel. The USAF results showed a mixture of JP-4 and diesel. The Army laboratory identified the substance as "either very old JP-4 or a JP-4/diesel mix." The USAF concluded that the contamination was likely the result of residual fuel from historic spills surfacing on the rising water table. The water table had risen in the days preceding the discovery as a result of snowmelt at higher elevations and light rain.[e]

1.3 Report Organization

The organization and content of this report are described below.

- **Section 1.0, Introduction,** summarizes the scope and objectives of the RI. Included are a history of OU 5 sources, a summary of results from previous investigations, and other relevant background information.
- **Section 2.0, Investigation and Analysis Procedures,** describes the RI activities, including field investigations, laboratory analyses, data validation, and data management. Field investigations involved site reconnaissance; a soil gas and groundwater screening survey; a water

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[e] Information on the USAF containment and investigation of the golf course seep was obtained from Master Sgt. Brian Seward, USAF, 3CES/DEVC, as an undated "memorandum for the record" titled "Fuel Spill (Underground Leak) at Golf Course, 28-29 May 1986."

use survey; aquatic and terrestrial ecological surveys; civil surveying; and soils, groundwater, surface water, and sediment sampling activities.

- **Section 3.0, Physical and Ecological Characteristics,** describes the physical and ecological features of OU 5, including climate, geology, soils, hydrology (groundwater and surface water), land use, water use, and aquatic and terrestrial ecology. It is based on data obtained from the RI and information contained in previous reports.

- **Section 4.0, Nature and Extent of Contamination,** presents the results of the RI environmental sampling and analysis program. Included are data gathered during the field investigation on the nature and extent of contamination in soil gas, soils, groundwater, seeps, surface water, sediment, aquatic biota, and terrestrial plants and animals.

- **Section 5.0, Conceptual Model,** presents an overall conceptual model of OU 5, identifying the sources of contamination when possible, contaminant characteristics and release mechanisms, and environmental fate and transport pathways. The conceptual model is based on data obtained from the RI, previous reports, and relevant technical literature.

- **Section 6.0, Baseline Risk Assessment,** presents an evaluation of the threat to human health and the environment as a result of the contamination identified at OU 5. The evaluation is based on data obtained from the RI and is consistent with the conceptual model presented in Section 5.0 and current EPA guidance on baseline risk assessments.

- **Section 7.0, Remedial Investigation Summary and Recommendations,** summarizes the findings of Sections 2.0 through 6.0 including the nature and extent of contamination, contaminant fate and transport, and the risk assessment. Results of additional investigation work, i.e., stream gaging study and snowmelt pond studies, are also presented. Contaminants of concern are identified and recommendations for each area of OU 5 are presented.

- **Section 8.0, Remedial Action Objectives,** outlines the general and specific objectives for OU 5 remediation. Applicable general response actions to implement these objectives are presented. The FS begins with this section.

- **Section 9.0, Identification and Screening of Technologies,** identifies and screens potential remedial technologies and process options that can implement the general response action identified in Section 8.0.

- **Section 10.0, Development and Screening of Media-Specific Alternatives,** assembles applicable process options into alternatives that can potentially address all media of concern. Each alternative is then evaluated applying the basic CERCLA criteria of effectiveness, implementability and cost.

- **Section 11.0, Detailed Analysis of Remedial Action Alternatives** presents a more comprehensive analysis of alternatives that passed the screening, applying the nine CERCLA criteria. A sensitivity analysis is presented, which indicates how changes in assumptions would effect the overall analysis. Finally, the alternatives are compared using several evaluation criteria.

- **Section 12.0, References,** lists all references cited in the RI/FS report.

- **Appendices** include all supporting data for the RI/FS report. Included are analytical data summary sheets, soil boring logs, monitoring well boring and construction logs, slug test data, soil gas and groundwater screening survey data, civil surveying data, aquatic survey data, terrestrial survey data, risk assessment calculations, potential ARARs identification, remedial technology descriptions, and cost estimates.

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2.0 INVESTIGATION AND ANALYSIS PROCEDURES

2.1 Field Investigations

2.1.1 Site Reconnaissance

Site reconnaissance of OU 5 was performed during May and June 1992 to meet the following objectives:

- Locate and evaluate the condition of existing monitoring wells in the OU 5 source areas;
- Look for seeps along the banks and bluffs below the OU 5 source areas;
- Map areas of perennial surface water and locate drainage and runoff locations;
- Prepare for mobilization by checking proposed locations for trailers, parking, staging areas, and equipment decontamination, and assess whether proposed locations for soil gas surveying, drilling, and surface water sampling are accessible and appropriate; and
- Review Elmendorf AFB BESG analytical data for surface and groundwater sampling stations near OU 5.

The reconnaissance activities are discussed in the following sections.

2.1.1.1 Well Inspection

Seventeen groundwater monitoring wells existed in the OU 5 study area prior to the RI investigation. These wells are shown on Figure 1-4. An inspection of all existing groundwater monitoring wells at Elmendorf AFB, including the OU 5 wells, was performed by CH2M HILL between June 3 and 10, 1992, as part of the basewide background sampling program. The complete scope and findings of this inspection are discussed in the *Basewide*

Background Sampling Report (CH2M HILL, 1992a), and findings pertaining to OU 5 wells are summarized in this subsection.

Observations and measurements made during the well inspection included the following:

- Evidence of frost heave around the well;
- Condition of well cap;
- Height of the well casing top;
- Integrity of the surface seal/concrete pad;
- Water level;
- Presence of floating light non-aqueous phase liquid (LNAPL);
- Silt content in well (soft versus hard bottom);
- Sounded well depth versus well completion log depth;
- Evidence of tampering or physical damage;
- Presence and condition of well lock; and
- Whether well number matches existing well identification information.

Table 2-1 summarizes the information collected during the well inspection. Copies of the well evaluation forms can be found in Appendix E of the *Basewide Background Sampling Report* (CH2M HILL, 1992a).

All existing OU 5 wells are constructed of 2-inch-diameter Schedule 40 PVC screen and riser casing with a 6-inch-diameter square- or round-steel protective casing (except well NS3-06, which is a flush mount). Wells in shallow groundwater table areas near Ship Creek (SP4/11-01, SP4/11-02, GW-4A, and W-14) generally had the following deficiencies: cracked concrete surface closures indicative of frost heaving; soft bottoms from

Table 2-1

Summary of Inspection Results for Wells Installed in Previous Investigations

Well	Inspection Date	Well ID Correct	Lock In Place	Integrity of Surface Seal	Protective Casing			Riser Casing			Water depth (feet)	Floating Product Thickness (feet)	Well Depth (feet)	Well Bottom Condition
					Material	Outside Diameter (inches)	Stick up Height (feet)	Material	Outside Diameter (inches)	Stick up Height (feet)				
SP4-01	3 Jun 92	Y	N	Soft, crumbling	Steel	6	2.95	PVC	2	2.70	5.14	0	24.35	Soft
SP4-02	3 Jun 92	Y	Y	Poor condition	Steel	6	3.08	PVC	2	2.77	5.38	0	27.27	Soft
SP4-03	3 Jun 92	Y	N	Poor condition	Steel	6.6	3.15	PVC	2	2.58	39.15	0	57.50	Soft
GW-4A	3 Jun 92	Y	Y	Poor condition	Steel	6.6	4.10	PVC	2	4.15	6.08	0	13.40	Soft
W-14	3 Jun 92	Y	Y	Poor condition	Steel	6.6	1.40	PVC	2	1.48	2.87	0	23.92	Mod. firm
SP1-01	4 Jun 92	Y	Y	None	Steel	6	3.17	PVC	2	2.87	8.08	0	23.15	Firm
SP1-02	4 Jun 92	Y	Y	Good	Steel	6	3.36	PVC	2	3.03	33.95	0	50.45	–
SP2/6-01	3 Jun 92	Y	Y	Good	Steel	6.6	2.73	PVC	2	2.43	49.67	0	53.00	Firm
SP2/6-02	4 Jun 92	Y	Y	Good	Steel	6	3.08	PVC	2	2.93	31.45	0	47.85	Mod. firm
SP2/6-03	4 Jun 92	Y	Y	Good	Steel	6	2.77	PVC	2	2.57	37.13	0	52.36	Mod. firm
SP2/6-04	4 Jun 92	Y	Y	Good	Steel	6	2.58	PVC	2	2.52	Dry	0	36.98	Mod. firm
SP2/6-05	3 Jun 92	Y	Y	Good	Steel	6.6	2.93	PVC	2	2.72	32.00	0	49.10	Mod. firm
GW-6A	4 Jun 92	Y	Y	Poor condition	Steel	6.6	2.18	PVC	2	2.18	30.91	0	39.50	–
W-16	4 Jun 92	Y	Y	Poor condition	Steel	6.6	1.50	PVC	2	1.20	31.30	0	56.00	Mod. firm
NS3-02	3 Jun 92	Y	Y	Good	Steel	6	3.08	PVC	2	2.63	4.20	0	37.05	Soft
NS3-03	3 Jun 92	Y	Y	Good	Steel	6	3.88	PVC	2	3.86	3.14	0	17.01	Soft
NS3-06	25 Sep 92[a]	Y	N	Good	Steel	9.8	Flush-mount	PVC	2	-0.40	27.87	0	47.77	Mod. firm

[a] Well NS3-06, a flush-mount well, was not found during the initial well inspection in June 1992 and, therefore, was inspected at a later date.

silt collecting in the wells; and in the case of wells W-14 and GW-4A, PVC riser casing higher than the top of the protective steel casing caused by frost-jacking of the wells. Three wells in the worst condition, SP4/11-01, GW-4A, and W-14, were repaired prior to sampling (protective casing reset, PVC riser pipe trimmed if frost-jacked, and concrete pads replaced).

No obstructions that would interfere with sampling or taking water level measurements were found in any of the wells. Water levels were measured in all wells except SP2/6-04, which was dry. No floating LNAPL product was detected in any of the wells. Locks were missing on two of the wells at the time of the inspection. All locks were replaced with keyed-alike locks.

It is noted that four monitoring wells—W-14, GW-4A, NS3-03, and OU5MW10—were observed to be frozen during January 1993.

2.1.1.2 Groundwater Seeps

The topography at OU 5 is dominated by a bluff that rises approximately 30 feet above the beaver ponds at the eastern end to 60 feet above the railroad tracks at the western end. Numerous groundwater seeps exposed along the bluff flow into ponds, wetlands, drainage ditches, and eventually into Ship Creek. A site reconnaissance was performed on May 14 and 15, 1992, to map seeps along the bluff areas downgradient of the POL pipelines and to map surface water and drainage pathways. General observations of water quality, as identified by odors, sheens, or discoloration, also were noted during the reconnaissance. No sampling was performed at this time; however, shallow groundwater at the seep locations was analyzed as part of the soil gas and groundwater screening survey (Section 2.1.2). Results of the seep area sampling are discussed in Section 4.1.

The reconnaissance began at the western end of OU 5 along an access road on the north side of the ARRC railroad tracks. South of the intersection of Plum Avenue and Bluff Road, the reconnaissance continued through the woods on the bluff hillside until a pond was reached near Building 22-002, the pump station for the power plant's cooling water. The reconnaissance continued along the railroad track right-of-way, which parallels the base of the bluff to the west of Post Road and Second Street, and then follows the top of the bluff above the beaver ponds and JP-4 storage tanks at the eastern end of OU 5. Seeps and surface water locations with questionable water quality were marked in the field by a piece of pink surveyor's flagging tape labeled with a surface location identification number (for example, SL01). Additional surface locations were marked during the ecological surveys to identify areas with apparent plant stress. Approximate locations of the marked surface locations are shown on Figure 2-1 and are described below.

Several seeps had discernable petroleum odors and a sheen indicative of either petroleum contamination or biological growth. A red precipitate or biological growth was also observed in many of the seeps and drainage pathways, sometimes as a fluffy growth beneath the surface of the water, and other times as a stain or precipitate on the sediments and grasses. Because the exact nature of this material is currently unknown, it is referred to as a red discoloration in the following descriptions of the seep areas. Mapping of drainage pathways was followed by additional site reconnaissance and dye-tracer studies and is described in Section 2.1.1.3, Surface Water and Drainage Pathway Mapping.

Areas Near Source ST37

South of the intersection of Plum Avenue and Bluff Road, a dirt road leads down the bluff to an access road on the north side of the railroad tracks. The reconnaissance was started approximately 225 feet west of the base of the dirt road at an aboveground sewer manhole structure. The bluff is approximately 60 feet high and is graded at approximately a 1:1 slope. Numerous small seeps observed along the toe of the bluff were flowing into a drainage ditch on the north side of the access road and the railroad tracks.

SL01. This seep is located approximately 30 feet from the base of the bluff is approximately 100 feet east of a manhole structure on the north side of the ARRC access

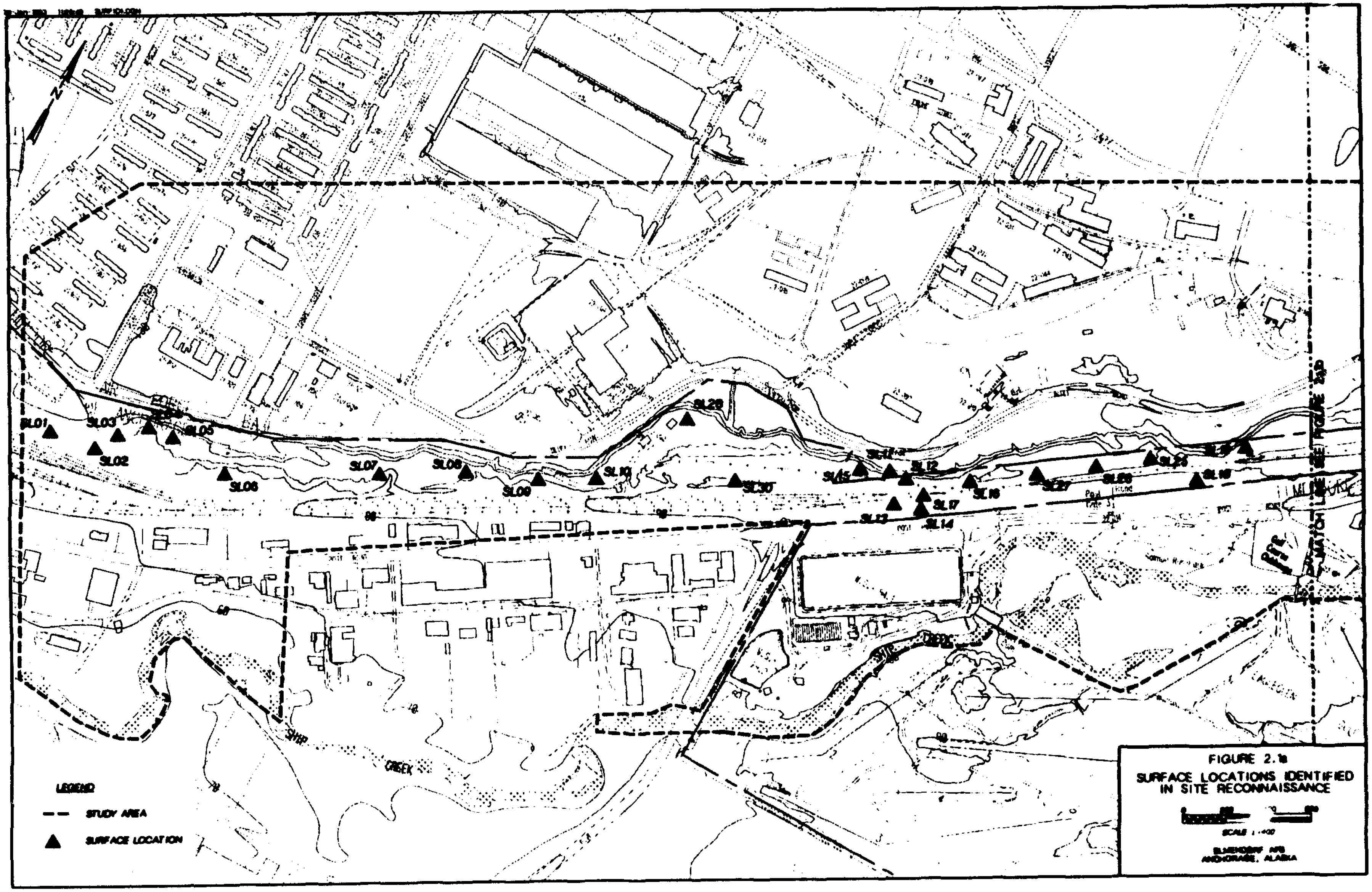

FIGURE 2.1a

SURFACE LOCATIONS IDENTIFIED IN SITE RECONNAISSANCE

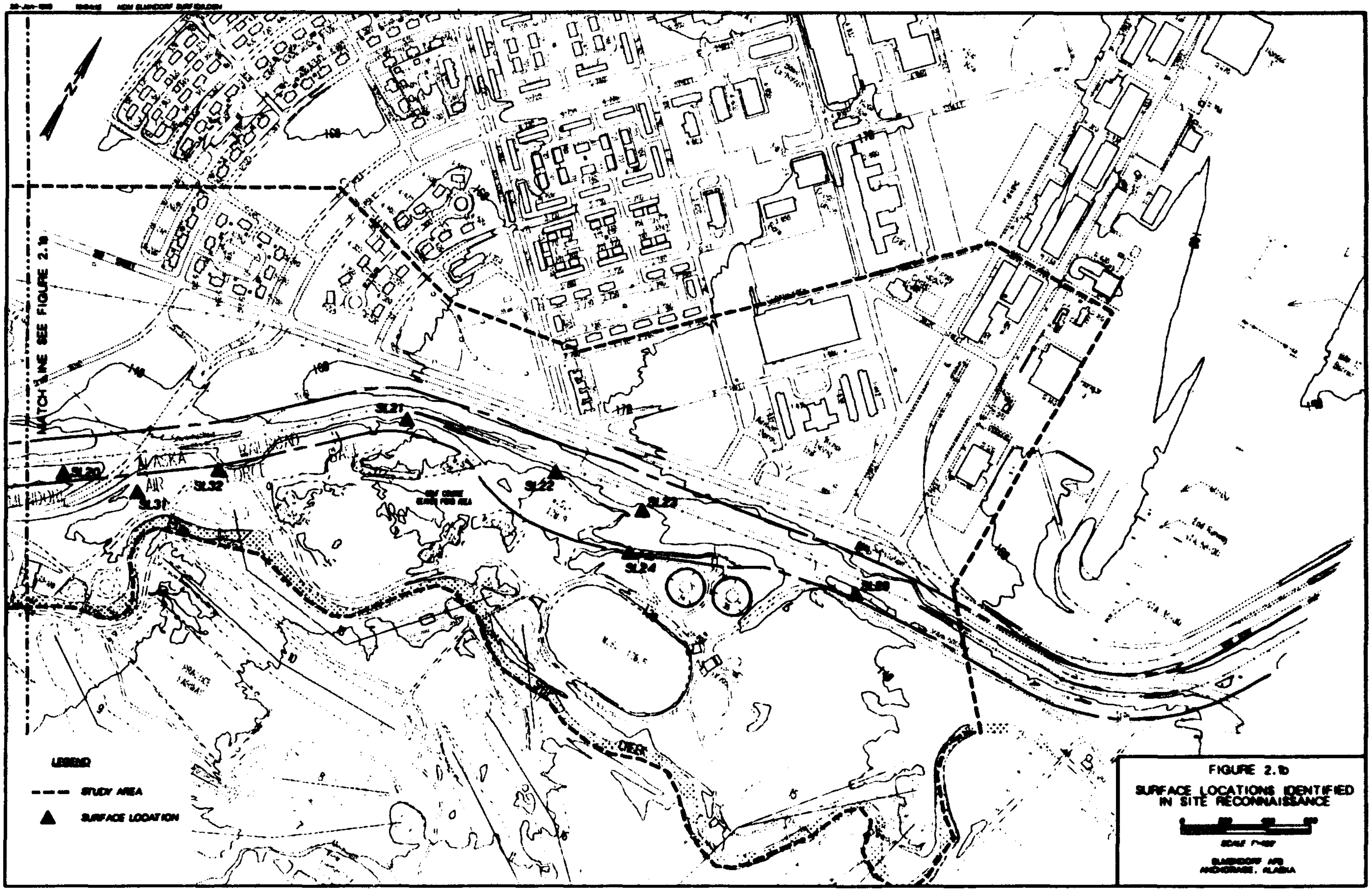

FIGURE 2.1b

SURFACE LOCATIONS IDENTIFIED IN SITE RECONNAISSANCE

ELMENDORF AFB
ANCHORAGE, ALASKA

road. The water looked clear. A green slime growth was observed about halfway up the seep, and a faint petroleum odor was noted. Approximately 30 feet east of this seep, a small seep with a sheen and red discoloration was observed at the base of the bluff. Approximately 75 feet east of SL01, a seep area approximately 36 feet wide was observed. The water looked clear and no odors were detected.

On the bluff directly across from the COE Building (Building 21-700), four prominent seeps (SL02-SL05) drain into a ditch along the northern side of the railroad tracks. Water in the ditch flows in a westerly direction to a pipe that diverts the flow south under the railroad tracks.

SL02. This seep is located in the northwest corner of the intersection of the dirt road leading down the bluff and the ARRC access road. The seep is approximately 25 feet in diameter and has areas with a sheen and red discoloration.

SL03. This seep is located approximately 20 feet east of the dirt road, adjacent to an abandoned yellow car on the dirt road. The seep is approximately 20 feet wide and had a sheen, red discoloration, and a moderate petroleum odor.

SL04. Actually a group of seeps, this seep area lies approximately 100 feet east of the dirt road, approximately 150 feet north of the railroad tracks. A sheen, petroleum odor, and red discoloration were observed.

SL05. A seep and an approximately 40-foot-diameter pond are located next to monitoring well SP1-01. Strong petroleum odors, sheens, and red discoloration were observed. Two ducks were seen at this pond.

SL06. Approximately 100 feet southeast of SL05, this seep lies at the northern edge of a marshy area that is connected to the drainage ditch along the railroad access road. A sheen and red discoloration were observed over an area approximately 10 feet wide.

SL07. This seep is located on the bluff below monitoring well SP1-02. The seep is approximately 30 feet wide. Miscellaneous trash has been discarded around the seep. A sheen, petroleum odor, and red discoloration were observed. Approximately 60 feet east of this seep, a smaller seep was observed with fewer areas of red discoloration and sheens.

Areas Near the Elmendorf AFB Power Plant

Three seeps were observed on the bluff south of the power plant (Building 22-004).

SL08. This seep is approximately 5 feet wide and lies near the base of the bluff, below the intersection of Persimmon and Bluff Roads. The water appeared clear, without odor, sheens, or discoloration.

SL09. A seep identified approximately 200 feet east of SL08, SL09 lies 60 feet north of the railroad tracks and below the intersection of Bluff Road and the dirt access road leading to the pump station (Building 22-002). The seep area is approximately 80 feet wide. A strong petroleum odor, sheens, and red discoloration were observed. Three rusted 55-gallon drums, visible from the dirt access road, are in the woods approximately 200 feet east of SL09.

SL10. This seep is located on the north side of the bend in the dirt access road to Building 22-002. The water appeared clear, although a slight petroleum odor was noted. The seep drained from a culvert under the access road to the drainage ditch on the north side of the railroad tracks.

Several ducks and geese were observed on a large area of standing water between the base of the bluff and the railroad tracks near Building 22-002. The bluff at this location is a snow disposal area.

Areas Near Sources ST38/SS42

Three seeps were observed near the drainage ditch north of the railroad tracks and south of monitoring well SP2/6-05. Flow in this ditch is toward the west.

SL11. This seep is located along the drainage ditch on the north side of the tracks, approximately 125 feet southwest of SP2/6-05. An area of this seep along the drainage ditch was covered with a black substance approximately 3 feet by 15 feet in size. The drainage ditch also had a red discoloration and a petroleum odor.

SL12. Located directly below well SP2/6-05 at the eastern end of the drainage ditch, this seep is approximately 3 feet wide and has a red discoloration. A culvert passes under the railroad tracks near this location, diverting flow to a drainage ditch on the north side of Post Road.

SL13. This seep area is a ditch between a culvert and the Post Road ditch, approximately 125 feet east of the Reeve Boulevard sign on the north side of Post Road. A sheen, petroleum odor, and a red discoloration were observed in the seep area. The drainage ditch along Post Road flows toward the west and also has a red discoloration.

SL14. This seep, approximately 100 feet east of SL13, marks the location at which the red discoloration first appears to be seeping into the drainage ditch.

SL15. This seep is located approximately 200 feet southwest of SP2/6-05, along a northern spur of the railroad tracks. The seep is approximately 40 feet wide and has red discoloration, a sheen, and a petroleum odor.

Approximately 100 feet east of SL12 on the north side of the tracks, another drainage ditch begins, with flow toward the east.

SL16. This seep area is the western edge of this eastward-flowing drainage ditch and has a red discoloration and petroleum odor. This ditch flows into a swampy area that is approximately 100 feet long by 40 feet wide on the north side of the tracks. The swampy area drains into a north-south culvert that passes under the railroad tracks and under Post Road to Ship Creek. The water in this drainage ditch appeared to be clear.

Another drainage ditch, approximately 100 feet long, is south of the tracks and flows in an easterly direction to the north-south ditch.

SL17. This seep area is the western end of the ditch and is directly below a switch on the south side of the railroad tracks. This ditch had red discoloration up to the point where it joins the north-south ditch; after this point, the water appears clear.

Areas Near Source SS53

The area west of Post Road and Second Street includes wetlands on the north side of the railroad tracks and a grassy/marshy strip between Post Road and south side of the railroad tracks.

SL18. This seep is on the southern side of the railroad tracks where the multi-product pipeline crosses. The seep is approximately 40 feet wide and drains into the marshy area between the tracks and Post Road. Red discoloration, a strong petroleum odor, and a visible sheen were noticed.

On the north side of the tracks is a marshy/wetland area that extends east to where the railroad tracks cross Post Road.

SL19. This surface location marks the western end of the marshy area where an odor and red discoloration were observed. The location is next to a culvert that conveys flow from the marshy area under the tracks and Post Road to Ship Creek.

SL20. This surface location lies on the eastern end of the wet, grassy area between the railroad tracks and Post Road. The water looked clear, and no odor or sheen was observed. A red discoloration stain was observed on the grass on the south bank of the railroad tracks.

Areas Near Sources SD40/ST46. The area south of the railroad tracks and north of a dirt access road along Ship Creek is a wetland/beaver pond area.

SL21. This seep lies at the edge of the wetland area along the south bank of the railroad track and is approximately 40 feet east of the beginning of the curve in the railroad tracks. The seep has red discoloration and a sheen approximately 20 feet wide. No odors were observed.

SL22. This seep is located at the edge of the wetland area along the southern bank of the railroad tracks and is approximately 500 feet east of SL21. The seep is approximately 10 feet wide and was observed to have red discoloration, a sheen, and a slight petroleum odor.

SL23. This seep is located at the northeast corner of the beaver pond, approximately 50 feet south of the railroad tracks and 350 feet east of SL22. The seep has red discoloration, a sheen, and a petroleum odor. The northern edge of the beaver pond between SL22 and SL23 has numerous seeps with red discoloration that were not individually cataloged.

Observations at Additional Surface Locations

During OU 5 field studies, surface locations and seep areas were identified where observations were being documented. Most of those observations were related to the occurrence of apparent plant stress (described in Sections 2.1.8.1 and 4.6.1), which occurred in a number of areas throughout OU 5.

SL24. This seep is located about halfway between the JP-4 fuel tanks and the beaver pond. During the June terrestrial ecological survey, oil droplets were seen surfacing in the small stream that flows westward from the vicinity of Source ST46 into the large beaver pond.

SL25. This location is at the eastern edge of a large wetland at the foot of the bluff north of the Post Road gate. Stressed vegetation was observed in the wetland extending westward from this location.

SL26. This location is in the same wetland as SL25. It includes the area where a grass-covered peninsula (composed of materials apparently dumped over the bluff) extends into the wetland from the north. Stressed vegetation was observed in the wetland.

SL27. This location is approximately in the center of the same large wetland as SL25 and SL26. It marks the transition area between stressed vegetation to the east and less apparent effects to the west.

SL28. Plant stress was observed in this wet area, which lies between the snow disposal site and Building 22-002. Red discoloration in the water and sediment was observed in some parts of the area.

SL29. Stressed vegetation also was observed in two beaver pond areas east of the JP-4 fuel tanks at Source ST46. The beaver pond area between the railroad tracks and a gravel road to the south was identified as SL29, but similar effects were observed in a nearby wetland south of the gravel road.

SL30. Water draining from the vicinity of SL15 flows along a small stream that enters a beaver pond south of the snow disposal area. Although this area (marked as SL30) had small trees and shrubs with yellowish or brown leaves, the effects appeared to be due to water logging (flooding) caused by beaver activity.

SL31. Stressed vegetation was observed in the open area east of Post Road, about halfway between the railroad tracks and the golf course clubhouse. This seep area is near Source SS53.

SL32. This location is near the western end of the extensive wetland complex between Post Road and Source SD40. A short distance east of SL31, stressed vegetation was observed in a wooded area within Source SS53.

2.1.1.3 Surface Water and Drainage Pathway Mapping

Surface water drainage patterns of OU 5 runoff were investigated during field reconnaissance surveys in May and September 1992. For the most part, surface water drainage from OU 5 flows from east to west. Drainage from the OU 5 bluff source areas travels through ponds, seasonal wetlands, open drainage ditches, and buried storm-water drains (culverts), until the runoff eventually reaches Ship Creek and flows west into Knik Arm. Drainage pathways identified during the field surveys are presented on Figure 2-2.

To map the flow patterns of surface water runoff within the buried storm-water culverts, drawings of the storm-water drainage system were obtained from the ARRC.[a] Additionally, a dye-tracer study (using Rotamine WT red dye) was conducted to verify suspected discharge routes of OU 5 runoff. As indicated on Figure 2-2, although OU 5 runoff is widespread and collects in numerous wetland ponds and drainage ditches at the base of the bluff, the OU 5 drainage to Ship Creek occurs as point-source discharges rather than sheet runoff.

The golf course beaver pond receives potentially contaminated groundwater discharge from one or more seeps (SL23) at its northeast perimeter, and from a drainage channel north of the JP-4 fuel storage tanks (Tanks 734 and 735), which enters the southeast corner of the beaver pond. Both water sources were observed to have a hydrocarbon odor

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[a] This information was obtained in a meeting with Robert Casey, an ARRC employee, on June 3, 1992.

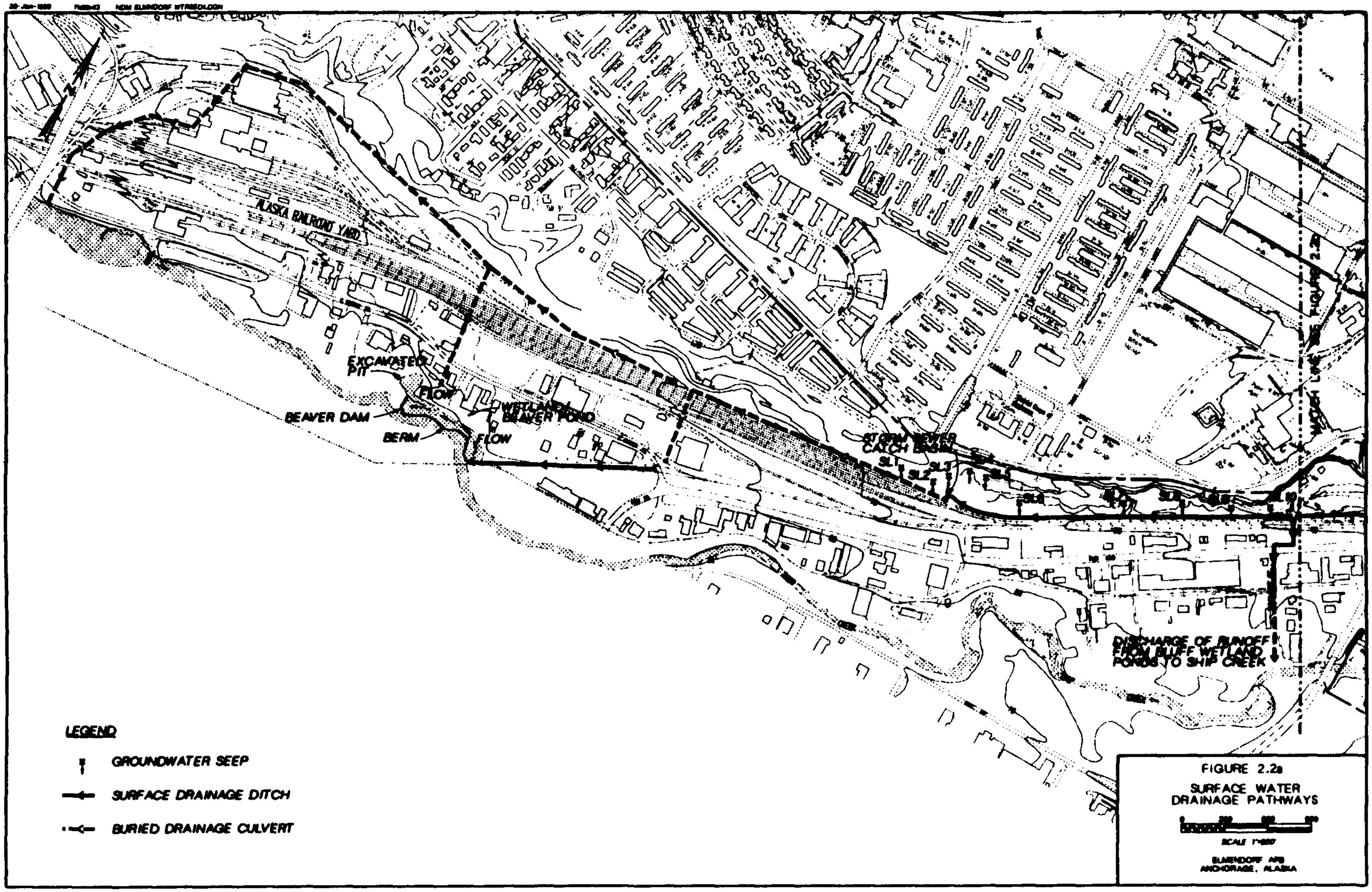

FIGURE 2.2a

SURFACE WATER DRAINAGE PATHWAYS

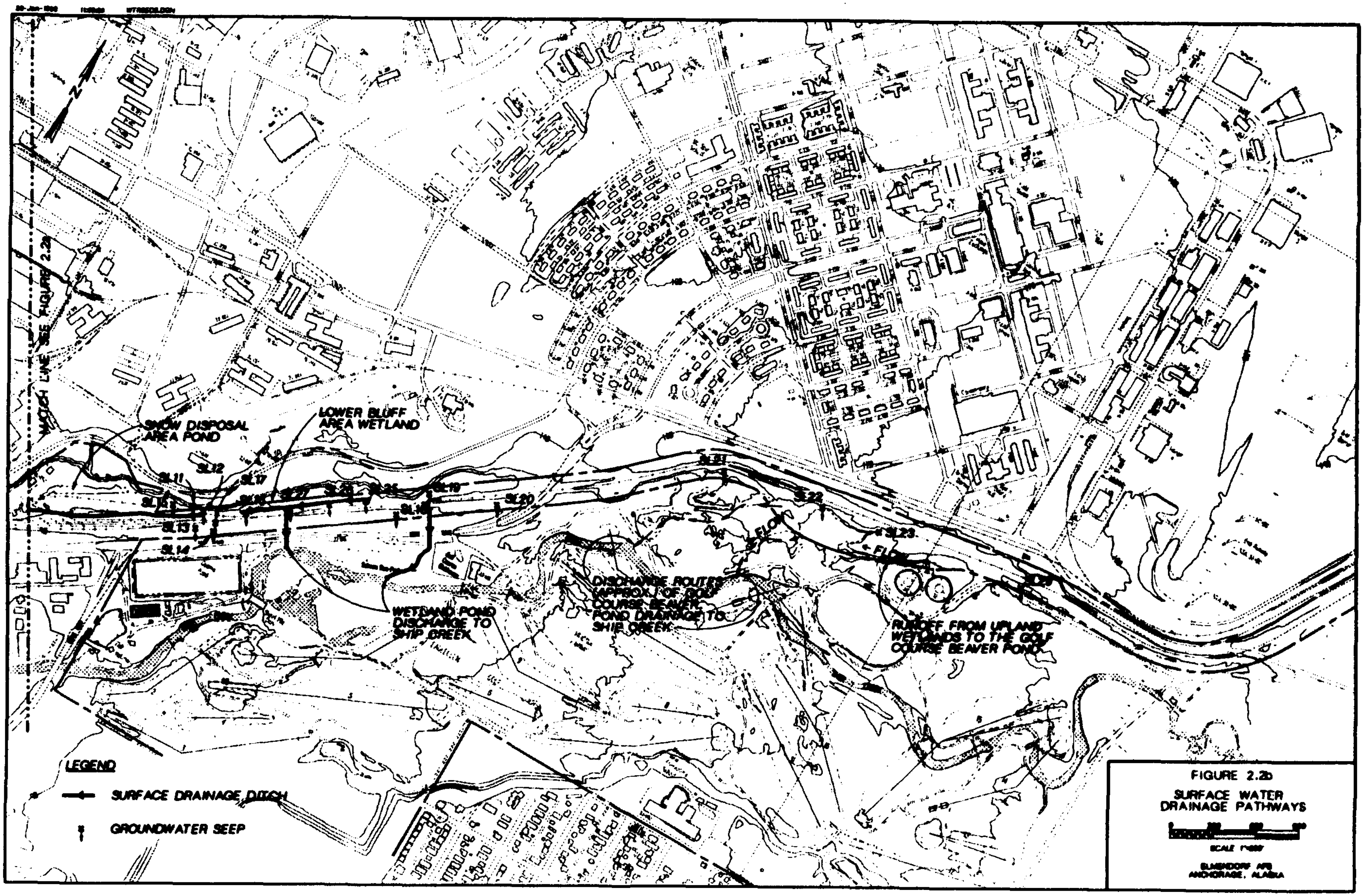

FIGURE 2.2b

SURFACE WATER DRAINAGE PATHWAYS

and sheen in May and September 1992. Discharge from the pond occurs at two areas along its south and west perimeters where the water leaks over the top of a beaver dam. The discharge travels through wetlands as it moves downgradient to where it drains into Ship Creek at two points of discharge.

As depicted on Figure 2-2, surface water runoff from the OU 5 bluff is contained within the wetland ponds and drainage ditch between the base of the bluff and the ARRC tracks. Three points of discharge that drain these areas to Ship Creek were observed:

- Between Salmon Run Park and the Elmendorf AFB fish hatchery, a culvert passes south under the ARRC tracks and Post Road to Ship Creek. This culvert drains the wetlands below Sources ST38/SS42.
- Downgradient of the Elmendorf AFB power plant and between Sources ST37 and ST38, OU 5 bluff runoff and numerous seeps collect in wetland ponds between the base of the bluff and the ARRC tracks. The dye-tracer study indicated that the runoff discharges to Ship Creek from a culvert at the end of Yakutat Street.
- At the western boundary of OU 5, a storm-water interceptor was observed collecting the runoff from the OU 5 bluff below Source ST37 and other numerous seeps. A dye-tracer study was conducted to locate the ultimate discharge point of the runoff. As indicated on Figure 2-2, the OU 5 runoff was found to flow west for 1720 feet to the eastern edge of the ARRC power plant, turn south for about 1500 feet, and surface into an open drainage ditch at the junction of Post Road and Whitney Road. From this point, the discharge flowed along the thickly vegetated open drainage ditch to the southwest, following an ARRC track spur. At the ARRC trestle at Ship Creek, the drainage ditch turns west and enters a broad wetland pond area separated from Ship Creek by a narrow berm. The wetland expands and deepens into a pond about 3 feet deep, caused by beaver dam-building activity along the west end. The pond was observed to discharge to Ship Creek at two places. One is a discharge channel between the woody debris piles of a beaver lodge; the other is a discharge channel approximately 25 feet to the southwest. During two days of the September 1992 field survey, a portion of the beaver dam was observed to have collapsed, probably from heavy overnight rains. The collapse of the dam lowered the pond by approximately 12 to 18 inches.

A narrow channel (approximately 10 feet wide) joins the beaver pond/wetland complex and another pond to the north that has no outlet other than at the beaver dams. Based on its shape and contours (greater than 8 feet deep), the pond appears to be a pit that may have been excavated as a gravel borrow area. As Figure 2-2 indicates, some of the runoff from the ARRC property is picked up in the storm-water drainage system to the west of the ARRC power plant (separate from OU 5) and conveyed to this receiving-water pit. The balance of the ARRC property drainage appears to discharge below the Ship Creek dam through an oil/water separator.

The wetland and beaver pond depicted on Figure 2-2 is the farthest downstream terminus or sink for OU 5 runoff before it discharges to Ship Creek. Based on the September 1992 observations of drainage pathways from OU 5 to Ship Creek, it appears that the wetland/beaver pond system receives nearly all its water from bluff runoff entering the storm-water interceptor/drainage system between sample station SW/SE09 and the ARRC power plant, 1720 feet to the west. Based on observations of the ground contours of the berm separating the creek from the wetland, it appears that, during spring and early summer, high runoff flows in Ship Creek overflow the low areas of the berm and replenish the wetland/beaver pond system.

2.1.1.4 Inspection of Support Area and Sampling Locations

Locations for field support facilities, such as a field office trailer, equipment storage area, decontamination pad, and contractor parking area, were coordinated with USAF and Jacobs Engineering Group, Inc., another contractor working on Elmendorf AFB CERCLA sites. It was decided that the support facilities would be located in an open field east of Building 22-035. Potable water for decontamination activities was available from a fire hydrant at this site. The fire hydrant water was sampled for metals, volatiles, and semivolatile organics in August 1992 by Jacobs Engineering; no contaminants were detected. The results of this sampling are presented in Appendix A. Wastewater from decontamination and well development and sampling activities was passed through a granular activated carbon unit and discharged to a sanitary sewer manhole.

Proposed drilling, monitoring well installation, soil gas sampling, and surface water and sediment sampling areas were evaluated during the site reconnaissance activities to determine the appropriateness and accessibility of selected locations. Final locations for wells and borings were determined during a meeting with EPA, ADEC, and USAF on July 31, 1992, and in follow-up discussions.

2.1.2 Soil Gas and Groundwater Screening

The soil gas and groundwater screening survey was used to collect screening-level data on the extent of organic contamination in soil and groundwater, and to guide the placement of soil borings and monitoring wells for the RI field investigation. Soil gas samples were collected in areas where the depth to groundwater exceeded the maximum penetration depth of the soil gas probes (generally 6 feet), including all sample locations above the bluff and isolated locations below the bluff. Seep samples were collected along the lower bluff from areas where active groundwater seeps were identified. Groundwater samples were collected in areas where groundwater was within approximately 6 feet of the ground surface.

Sample locations were selected to expand the areas covered in previous investigations around known source areas, evaluate the pipeline corridor between the known source areas, evaluate groundwater seeps along the lower bluff, and evaluate shallow groundwater along Post Road, Ship Creek, and the golf course beaver pond areas. Figure 2-3 shows the sample locations used for the survey.

Following completion of the sampling, 23 of the groundwater probes were left in the ground as temporary piezometers to provide additional groundwater elevation data. Water levels were measured in the probes at the same time as monitoring well water level

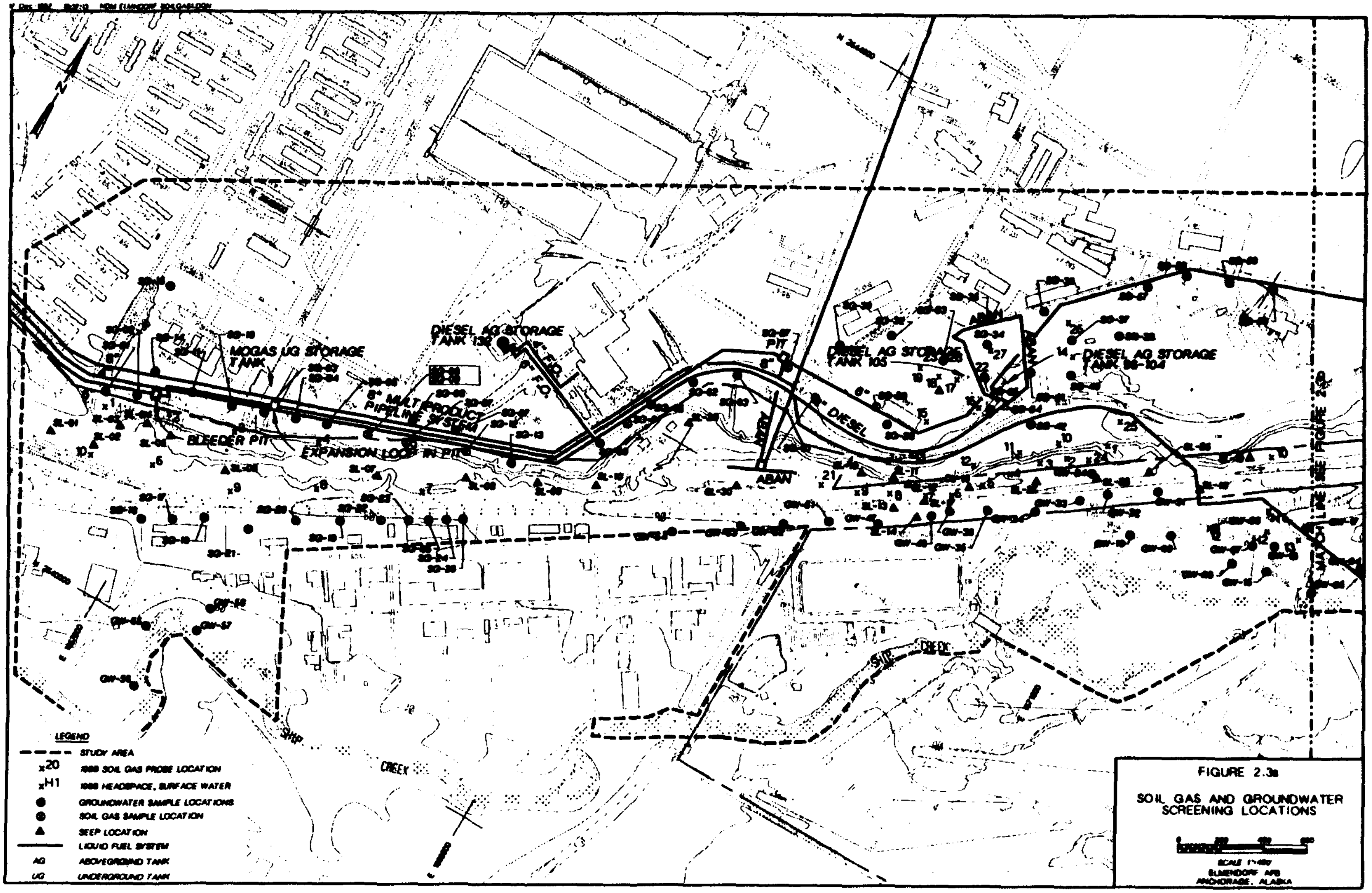

FIGURE 2.3a

SOIL GAS AND GROUNDWATER SCREENING LOCATIONS

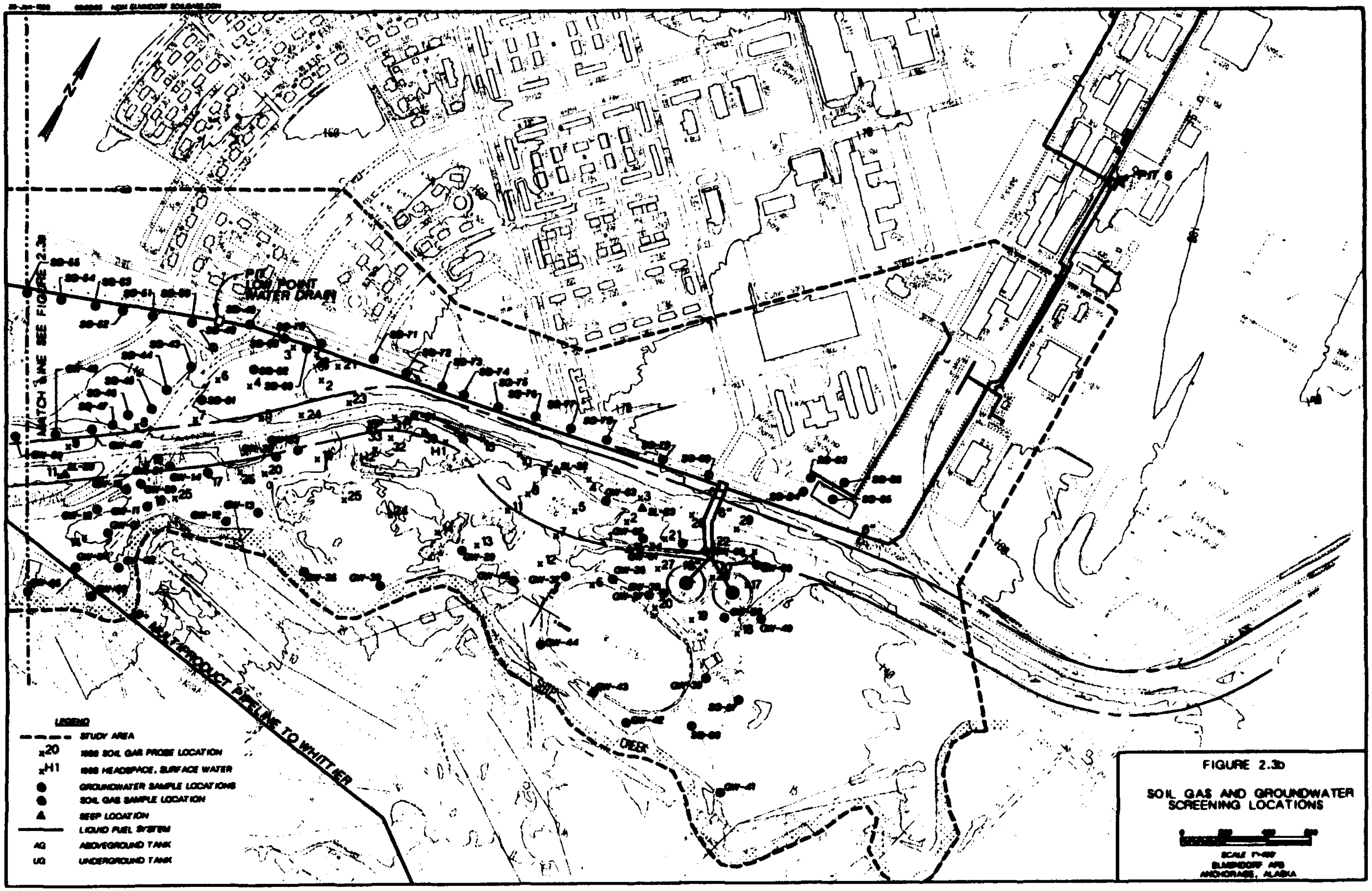
FIGURE 2.3b

SOIL GAS AND GROUNDWATER SCREENING LOCATIONS measurements were taken, and the data were incorporated into the groundwater contour maps of the site.

2.1.2.1 Soil Gas Sampling Procedures

Soil gas sampling probes consisted of 7- and 14-foot lengths of three-quarter-in-diameter hollow steel pipe. The probes were fitted with detachable drive tips and hydraulically pushed or pounded to depths of 4 to 13 feet below grade. The majority of the samples were collected at 6 feet below grade. No sample was collected at SG39 or SG79 because of refusal encountered during the three attempts.

The aboveground end of each probe was fitted with an aluminum reducer (manifold) and a length of polyethylene tubing leading to a vacuum pump. Soil gas was pulled by the vacuum pump into the probe. Samples were collected in a glass syringe by inserting a syringe needle through a silicone rubber segment in the evacuation line and down into the steel probe. The vacuum was monitored by a vacuum gage in order to maintain an adequate gas flow from the vadose zone. The volume of air within the probe was purged by evacuating 2 to 5 probe volumes of gas.

2.1.2.2 Groundwater and Seep Sampling Procedures

Sampling probes consisted of 7-foot lengths of 3/4-inch-diameter hollow steel pipe. Groundwater samples were collected at depths of approximately 2 to 6 feet below grade.

The hollow probes with detachable drive points were advanced below the water table. Once at the desired depth, the probes were withdrawn several inches to permit water to flow into the resulting hole. The aboveground end of the sampling probe was fitted with a vacuum adaptor (metal reducer) and a length of polyethylene tubing leading to a vacuum pump. A vacuum of up to 20 in mercury (Hg) was applied to the interior of the probe for 5 to 30 minutes or until water was drawn up the probe. The water accumulated in the hole was removed by vacuum through a 0.25-inch polyethylene tube inserted into the probe to the bottom of the hole. The tubing was used only once and was discarded to avoid cross contamination.

Groundwater samples were collected in 40 mL volatile organic analysis (VOA) vials that were filled with approximately 20 mL of sample. The vials were shaken vigorously and a sample of the headspace from the container was injected into the gas chromatograph (GC).

Headspace analysis was used, rather than direct injection of the water sample into the GC, to reduce the chance of semivolatile and nonvolatile organics contaminating the system. Depending on the partitioning coefficient of a given compound, the GC may be more sensitive to headspace analysis than to direct injection analysis.

2.1.2.3 Analytical Parameters

Soil gas and groundwater samples were analyzed by using screening techniques (EPA Level II) for the following compounds:

- trans-1,2-Dichloroethene;
- cis-1,2-Dichloroethene;
- 1,1,1-Trichloroethane;
- Trichloroethene;
- Tetrachloroethene;
- BTEX compounds; and
- Total volatile hydrocarbons (TVHCs) C_{4-9} and TVHC C_{10-X}.

Samples were analyzed generally within 15 minutes of collection using a GC installed in the subcontractor's van. The GC was calibrated daily by using a single-point calibration for each of the measured constituents. Twenty milliliters of a known standard was placed in a 40-mL vial, and the vial was resealed and shaken vigorously for 30 seconds. An analysis of the headspace in the vial determined the response factor (RF), which was then used to estimate the concentrations in groundwater samples. An independent gaseous standard was not analyzed to calibrate soil gas samples. Therefore, the soil gas sample concentrations cannot be quantitated because the standard headspace concentration was unknown.

Based on a raw data review, a reporting limit of 0.5 μg/L was selected as appropriate for chlorinated solvents in groundwater samples, below which the results are suspected to be false positives resulting from instrument noise or laboratory contamination. For BTEX compounds in groundwater, a reporting limit of 10 μg/L was selected because flame ionization detectors such as the one used for this project to quantify results are relatively insensitive to concentrations below 10 μg/L. The TVHCs C_{4-9} were quantified by integrating the peaks for compounds containing four carbon atoms through o-xylene. The TVHCs C_{10-x} quantification began after o-xylene, and the endpoints varied with the sample run times. The TVHC results should be considered estimates of fuel contamination because quantitations were based on estimates of both retention times and response factors for fuel hydrocarbons. For soil gas analyses, independent gaseous standards to quantify the headspace concentrations were not analyzed by the subcontractor; therefore, the soil gas results are designated as "unitless."

2.1.3 Water Use Survey

To determine the potential off-base receptors of groundwater contaminants, active water-supply wells off base and downgradient of OU 5 were identified by two methods: a water use survey of current property tenants and computer searches of databases maintained by the U.S. Geological Survey (USGS), Water Resource Division, 1209 Orca

Street, Anchorage, Alaska; and by the Alaska State Division of Water and Hydrologic Surveys, Department of Natural Resources (DNR), Eagle River, Alaska.

The off-base property south of OU 5 and north of Ship Creek along Post Road and the railroad is owned by the ARRC, which acquired the property from the U.S. Department of Transportation in 1986. Currently, several businesses lease the land from the ARRC. A list of tenants and addresses was obtained from the ARRC. The tenants were mailed the water use survey presented in Attachment A5 of the Field Sampling Plan (FSP) of the OU 5 *Management Plan*. If a tenant did not respond to the mail survey, a follow-up phone call or visit was attempted.

The water use survey requested the following information:

- Well construction details, such as installation date, depth, screened interval, pump type, and casing type;
- Water usage;
- Physical problems or damage to the well;
- Water quality; and
- Treatment systems.

The following questions were included in the survey to support the human health risk assessment:

- How many people work/reside at the survey location?
- Are there any children under 10 or adults over 70 at the survey location? If so, how many in each category?

The survey focused on those wells used as potable water sources that are most likely to be affected by off-base migration of OU 5-related contaminants. One on-base and two off-base wells identified as potable water sources were sampled in August 1992 for drinking-water priority pollutants.

2.1.4 Soils Investigation

This section describes the sampling program and procedures used to collect and analyze soil samples during the RI field investigation. Sampling locations are shown on Figure 2-4. The sampling program included the collection of soil samples from the surface, the unsaturated zone, and the saturated zone. Chemical analyses of samples were conducted by CH2M HILL's environmental laboratory in Redding, California, and the close support (48 hours turnaround time) laboratory (CSL) in Corvallis, Oregon.

Detailed descriptions of the proposed RI field activities and data analysis were included in the OU 5 *Management Plan*, the FSP, and the *Quality Assurance Project Plan* (QAPP) (CH2M HILL, 1992). The *Management Plan* and the procedures described in the FSP and QAPP were developed with the intent of augmenting previous work performed at the site. The FSP sampling approach was designed to provide data to assess the general extent and possible source areas of the contamination.

Soil sampling was conducted within OU 5 to define the extent of soil contamination around source areas and to characterize soil types. Soil sampling activities were focused on areas where soil and/or groundwater contamination was known or suspected to be present based on the results of the soil gas investigation (see Section 2.1.2). Areas upgradient of OU 5 source areas were sampled in addition to areas suspected of being contaminated. Samples were analyzed for BTEX, halogenated volatile organics, gasoline hydrocarbons, diesel/JP-4 hydrocarbons, metals, and semivolatile organics. In addition, selected soil samples were analyzed for physical parameters, including grain-size distribution, liquid plastic limits, and total organic carbon.

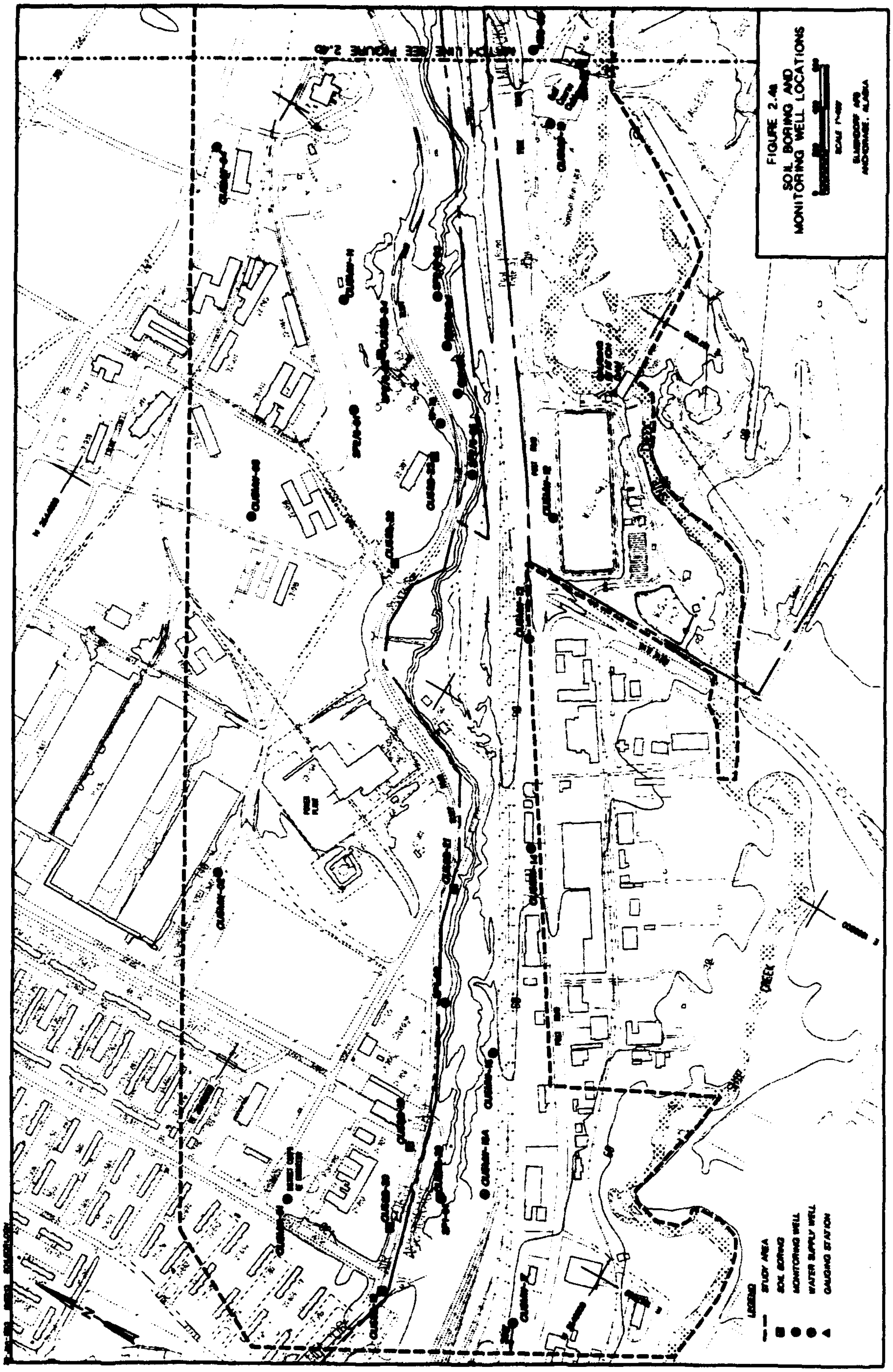

FIGURE 2.4A
SOIL BORING AND
MONITORING WELL LOCATIONS

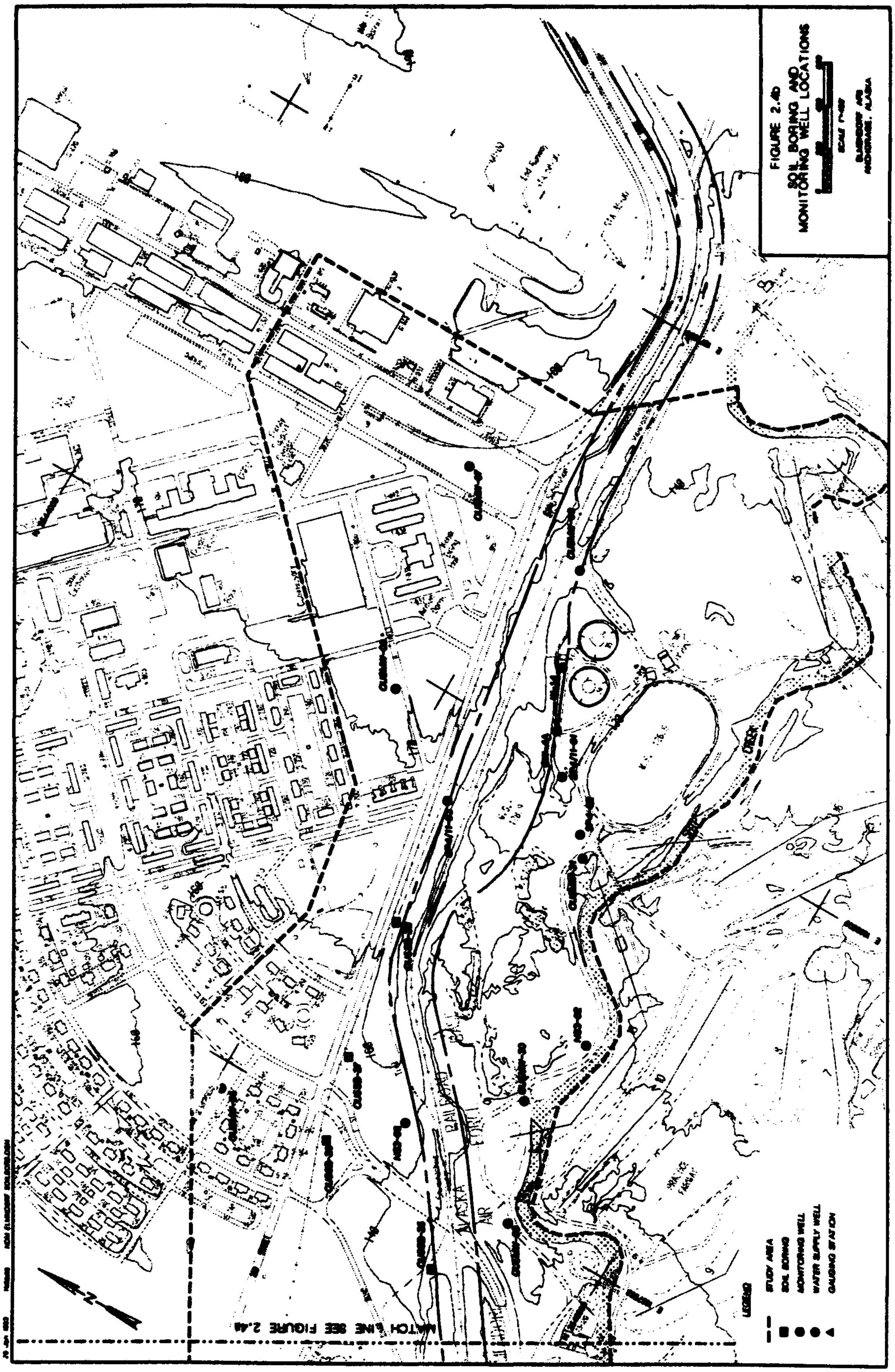

FIGURE 2.4D
SOIL BORING AND MONITORING WELL LOCATIONS

During the soil boring investigation, the following measures were taken to minimize the possibility of drilling into buried utility lines or underground pipes:

- Excavation or drilling permits were obtained from all appropriate utility services, including telephone, electric, natural gas, water, sewer, steam, communications, and military petroleum fuel lines;
- All proposed boring locations were either checked against an as-built map by representatives of each utility service or were field-located before drilling began;
- Underground utilities off base were located by appropriate civilian utility representatives; and
- The ARRC was contacted before drilling began on its property.

2.1.4.1 Borehole Drilling

Boreholes were drilled to depths ranging from 7.5 to 79.5 feet using truck-mounted and track-mounted hollow-stem auger drilling rigs equipped with 4.25-inch-inner-diameter (ID) augers. No oil, grease, or other thread compounds were used on augers or tools entering the borehole.

During drilling, standard penetration tests and split-barrel sampling were performed following procedures described in American Society for Testing Materials (ASTM) D1586-84. A total of four deep borings were advanced to the Bootlegger Cove Formation, with continuous split-barrel sampling to log the soil stratigraphy and verify the depth of the Bootlegger Cove Formation. Other borings were sampled at 5-foot intervals and advanced only to the top of the water table, unless the boring was designated to be completed as a monitoring well.

Soil samples were collected from 31 soil boring locations. Samples were collected with either a standard 2-inch-outside-diameter (OD) split-barrel sampler driven by a 140-pound hammer, or a 3-inch-OD sampler driven by a 300-pound hammer. Each soil sample was classified by the field geologist following the "Standard Procedures for Logging of Soil Borings" (CH2M HILL, 1991). Samples for chemical analysis were collected at regular, predetermined intervals in the boring (10-, 20-, and 30-foot depths) and at the groundwater/unsaturated zone interface. To analyze for sinking contaminants, an additional soil sample was collected from the bottom of each boring that extended into the Bootlegger Cove Formation. Samples for chemical analysis were collected using decontaminated split-barrel samplers. Decontamination procedures for sampling equipment are listed in Section 2.1.4.2.

Samples for volatiles analysis were collected from split-barrel samplers in a manner minimizing aeration and the subsequent loss of volatiles. For health and safety reasons a photoionization detector (PID) was used to check volatile concentrations at both ends of the split-barrel sampler before it was opened. The split-barrel sampler was opened and the contents quickly split into the two barrel halves. Samples for volatile analysis were immediately collected by taking small, representative amounts of sample material from the middle of the soil column along the entire length of the barrel, minus any slough or unrepresentative material at the top of the sampler. A decontaminated stainless steel spoon was used to transfer the sample to a sterilized jar. The jars were filled to allow as little headspace as possible. Small representative amounts of sample material were collected in a plastic bag and sealed for headspace analysis. The remaining sample material (minus any slough or unrepresentative material) was placed in a decontaminated stainless steel bowl and mixed until homogeneous using a decontaminated stainless steel spoon. Sample jars were then filled with the homogeneous sample material. Sampling equipment was decontaminated between samples following the decontamination procedures given in Section 2.1.4.2.

2.1.4.2 Decontamination Procedures

All non-disposable, multiple-use sampling equipment was decontaminated following the procedures listed below:

- Wash with alconox or liquinox detergent;

- Rinse with potable water;
- Rinse with deionized water;
- Let air dry; and
- Wrap in clean aluminum foil (shiny side out).

Soil samples collected for field classification or other non-chemical analyses were collected with either decontaminated split-barrel samplers or samplers rinsed only with potable water.

2.1.4.3 Classification of Soils

Soil samples collected at each interval were classified by the field geologist following the "Standard Procedures for Logging of Soil Borings" (CH2M HILL, 1991). Field classification data were recorded directly into a CH2M HILL soil boring log or recorded in a bound, weatherproof logbook and transferred to a soil boring log at a later time. The boring log contains the following technical information, when applicable, for each soil boring:

- Sample numbers and types;
- Sample depths;
- Blow counts;
- Sample recovery/sample interval;
- Soil density or cohesiveness;
- Soil color;
- United Soils Classification System (USCS) material description and symbol;

- Field geologist's name and dated signature; and
- Project number.

Each soil boring log included depths of changes in lithology, sample moisture observations, depth to water, PID readings, drilling methods, total depth of each borehole, and any other pertinent observations. Soil boring logs for boreholes completed as part of this project are presented in Appendix B.

Samples were screened by the field geologist for volatile organic compounds using a PID. Headspace analysis was performed on soil samples sealed in plastic bags. After at least 15 minutes had passed from the time the sample was collected, the probe end of a PID was inserted through the sealed plastic bag. The stabilized concentration of volatiles then was read directly from the PID. Stabilized PID readings were recorded on soil boring logs at the specific sample interval from which the samples were collected. The results of the headspace analysis are intended to be used only to evaluate relative differences in volatile contaminants between depth in a particular borehole or between boreholes. Headspace results are not intended to replace laboratory analysis for volatiles and are not directly comparable with laboratory results.

Laboratory analyses for soil classification were performed on several randomly selected samples of observed soil types to confirm the field classification of soils. Classification of soils (ASTM D2487-85) is a standardized interpretation of results from the liquid and plastic limits and grain-size distribution tests. Total organic carbon analysis was also performed on these selected samples.

2.1.4.4 Completion of Borings

Borings were completed by either backfilling the borehole from the end of the boring to the surface using a cement-bentonite grout or by installing a groundwater monitoring well. Well installation is discussed in Section 2.1.5.2, Monitoring Well Installation. For backfilling boreholes, grout was mixed as follows:

- Potable water was added to a 100-gallon galvanized trough;
- A hydraulic mixer was placed in the water and turned to establish a shearing action in the trough;
- One 94-pound sack of Portland Type 1-2 cement and 4.5 pounds of pure, powdered bentonite were added for every 7 gallons of water; and
- The grout was mixed until homogeneous to the satisfaction of the field geologist or hydrogeologist.

The grout mixture then was pumped through a tremie pipe to fill the boring from the bottom to ground surface. Additional grout was added to the borehole as augers were withdrawn and the column of grout dropped. Grout was allowed to cure for at least 4 hours, and additional grout was added as needed to bring the boring to ground level. A summary of soil boring data is presented in Table 2-2.

2.1.4.5 Sample Handling

All sample containers, with the exception of the headspace sample, were immediately placed in coolers containing double-bagged ice. The samples were later transferred to a shipping cooler packed with double-bagged ice, bubble wrap, and vermiculite to protect the samples during shipping. The chain-of-custody procedures described in the OU 5 *Management Plan* (CH2M HILL, 1992d) were followed throughout the handling and shipping of the samples.

2.1.4.6 Management of Investigation-Derived Wastes

Investigation-derived wastes (IDWs) generated during field activities included soil boring (drill) cuttings, equipment decontamination washwater, personal protective clothing, and monitoring well development and purge water.

Table 2-2

Soil Boring Summary

Soil Boring Number	Total Depth (feet)	Total Samples Collected	Total Samples Analyzed	Depth Interval of Samples	Date Sampled
MW01	45.0	8	5	5.0 - 7.0 10.0 - 12.0 15.0 - 17.0 25.0 - 27.0 35.0 - 37.0	13 Aug 92
MW02	45.0	8	3	10.0 - 12.0 25.0 - 27.0 32.5 - 34.5	23 Aug 92
MW03	45.0	8	3	10.0 - 12.0 25.0 - 27.0 30.0 - 32.0	17 Aug 92
MW04	45.0	8	3	10.0 - 12.0 25.0 - 27.0 30.0 - 32.0	18 Aug 92
MW05	38.0	7	2	10.0 - 12.0 25.0 - 27.0	24 Aug 92
MW06	48.0	8	3	10.0 - 12.0 25.0 - 27.0 35.0 - 37.0	27 Aug 92
MW07	50.0	8	3	10.0 - 12.0 25.0 - 27.0 35.0 - 37.0	26 Aug 92
MW08	20.0	4	2	5.0 - 7.0 14.0 - 16.0	11 Aug 92
MW09	9.0	2	1	2.5 - 4.5	10 Aug 92
MW10	9.0	2	1	5.0 - 7.0	10 Aug 92
MW11	52.0	8	3	10.0 - 12.0 25.0 - 27.0 35.0 - 37.0	21 Aug 92
MW12	10.0	4	1	7.5 - 9.5	25 Aug 92
MW13	7.5	2	1	2.5 - 4.5	14 Aug 92
MW14	12.0	3	1	7.5 - 9.5	13 Aug 92
MW15	12.0	3	1	7.5 - 9.5	7 Aug 92
MW16	20.0	5	1	10.0 - 12.0	6 Aug 92

Table 2-2

(Continued)

Soil Boring Number	Total Depth (feet)	Total Samples Collected	Total Samples Analyzed	Depth Interval of Samples	Date Sampled
MW16A	13.0	0	0	NA	26 Aug 92
MW17	15.0	4	1	9.0 - 11.0	12 Aug 92
SB18	37.0	8	3	10.0 - 12.0 25.0 - 27.0 35.0 - 37.0	12 Aug 92
SB19	52.5	20	5	0.0 - 2.0 10.0 - 12.0 25.0 - 27.0 38.0 - 40.0 52.0 - 54.0	10 Aug 92 11 Aug 92
SB20	37.0	9	3	12.0 - 14.0 25.0 - 27.0 35.0 - 37.0	6 Aug 92
SB21	50.0	20	4	10.0 - 12.0 25.0 - 27.0 35.0 - 37.0 48.0 - 50.0	12 Aug 92 13 Aug 92
SB22	37.0	7	3	10.0 - 12.0 25.0 - 27.0 30.0 - 32.0	28 Aug 92
SB23	60.0	23	5	0.0 - 2.0 10.0 - 12.0 25.0 - 27.0 40.0 - 42.0 58.0 - 60.0	18 Aug 92 21 Aug 92
SB24	32.0	7	3	10.0 - 12.0 25.0 - 27.0 30.0 - 32.0	23 Aug 92
SB25	12.0	2	2	5.0 - 7.0 10.0 - 12.0	18 Aug 92
SB26	27.0	6	2	10.0 - 12.0 25.0 - 27.0	28 Aug 92
SB27	32.0	7	3	10.0 - 12.0 25.0 - 27.0 30.0 - 32.0	27 Aug 92

Table 2-2

(Continued)

Soil Boring Number	Total Depth (feet)	Total Samples Collected	Total Samples Analyzed	Depth Interval of Samples	Date Sampled
SB28	79.5	29	5	0.0 - 2.0 10.0 - 12.0 25.0 - 27.0 38.0 - 40.0 76.0 - 78.0	24 Aug 92 25 Aug 92
SB29	22.0	6	2	4.0 - 6.0 10.0 - 12.0	7 Aug 92
MW30	10.0	3	2	0.0 - 2.0 5.0 - 7.0	11 Aug 92
MW31	9.0	3	1	2.5 - 4.5	20 Aug 92

Drill cuttings were stored in 55-gallon steel drums. The drums were clearly marked on both the lid and the side with the boring identification number, borehole depth, date, headspace analysis results, and drum contents. Cuttings from different borings were placed in separate drums.

The analytical results (EPA Method 8010, 8015, and 8020 analyses) for soil samples from each boring were reviewed to determine if analytes exceeded any of the hazardous waste criteria under 40 CFR 261(C). No Method 8010 analytes were detected in any soil sample. Some samples contained petroleum-related contaminants (Method 8015 and 8020 analytes); however, benzene concentrations (up to 20 μg/kg) were well below the levels that would constitute a hazardous waste under 40 CFR 261(C). All soil cuttings were moved to the on-site Elmendorf AFB landfill. Soils from borings with any detectable levels of petroleum concentrations were stockpiled in a bermed and lined area within the landfill. The USAF plans to treat these soils using bioremediation at a later date. Soils from borings with no detectable levels of contaminants were placed at an unlined location within the landfill.

Wastewater from equipment decontamination and monitoring well development and purging was containerized in properly labeled 55-gallon drums and was staged at the end of each day next to the decontamination pad. The wastewater was then pumped through an activated carbon unit and, with the permission of Elmendorf AFB and the Municipality of Anchorage (MOA)[b], was discharged to a sanitary sewer manhole. Effluent from the activated carbon unit was sampled approximately halfway and near the end of the field investigation program, and was analyzed for Method 8010, 8015, and 8020 analytes. No organics were detected in the effluent, indicating that breakthrough of the activated carbon unit did not occur.

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[b] Permission documented in letters from Colonel Everett L. Mabry, base civil engineer, dated May 15, 1992, and from Mark Spano, Industrial Pretreatment Program coordinator, Anchorage Water and Wastewater Utility, dated May 5, 1992, concerning wastewater discharge from the equipment decontamination facility.

Personal protective clothing (gloves, overboots, and tyvec suits) were considered nonhazardous because hazardous contamination was not found in the soil cuttings. The clothing was disposed of in dumpsters at Elmendorf AFB.

2.1.5 Groundwater Investigation

2.1.5.1 Monitoring Well Site Selection Rationale

Nineteen groundwater monitoring wells were installed as part of this investigation. Monitoring well locations were selected to confirm contamination identified by the soil gas survey, to provide groundwater data source in areas of known or suspected leaks, and to sample groundwater directly upgradient and downgradient of OU 5. The well placements were intended to augment the existing well network; wherever possible, existing monitoring wells were sampled to provide the required data. When placing wells, consideration was also given to the need to construct reliable water table maps for the OU 5 area. All the monitoring wells were completed above the Bootlegger Cove Formation.

Six of the monitoring wells, MW01 through MW06, were installed north of OU 5 source areas. These locations were selected to provide information on the quality of the groundwater migrating from upgradient areas located north to northeast of OU 5. Monitoring wells MW07 and MW08 were installed northeast to east of OU 5 source areas to intercept upgradient groundwater flowing from areas east of OU 5. Well MW08 is also located south of the JP-4 pipeline and several fuel storage tanks; depending on the groundwater flow direction, this well may also detect fuel products that may have leaked from the pipeline or the storage tanks. Well MW11 was placed next to a waste paint tank located upgradient of Sources ST38/SS42.

All other wells were intended to provide data from areas near or downgradient from suspected OU 5 source areas. Wells MW09, MW10, MW30 and MW31 were installed near Ship Creek south of Post Road to intercept suspected hydrocarbon plumes from Sources

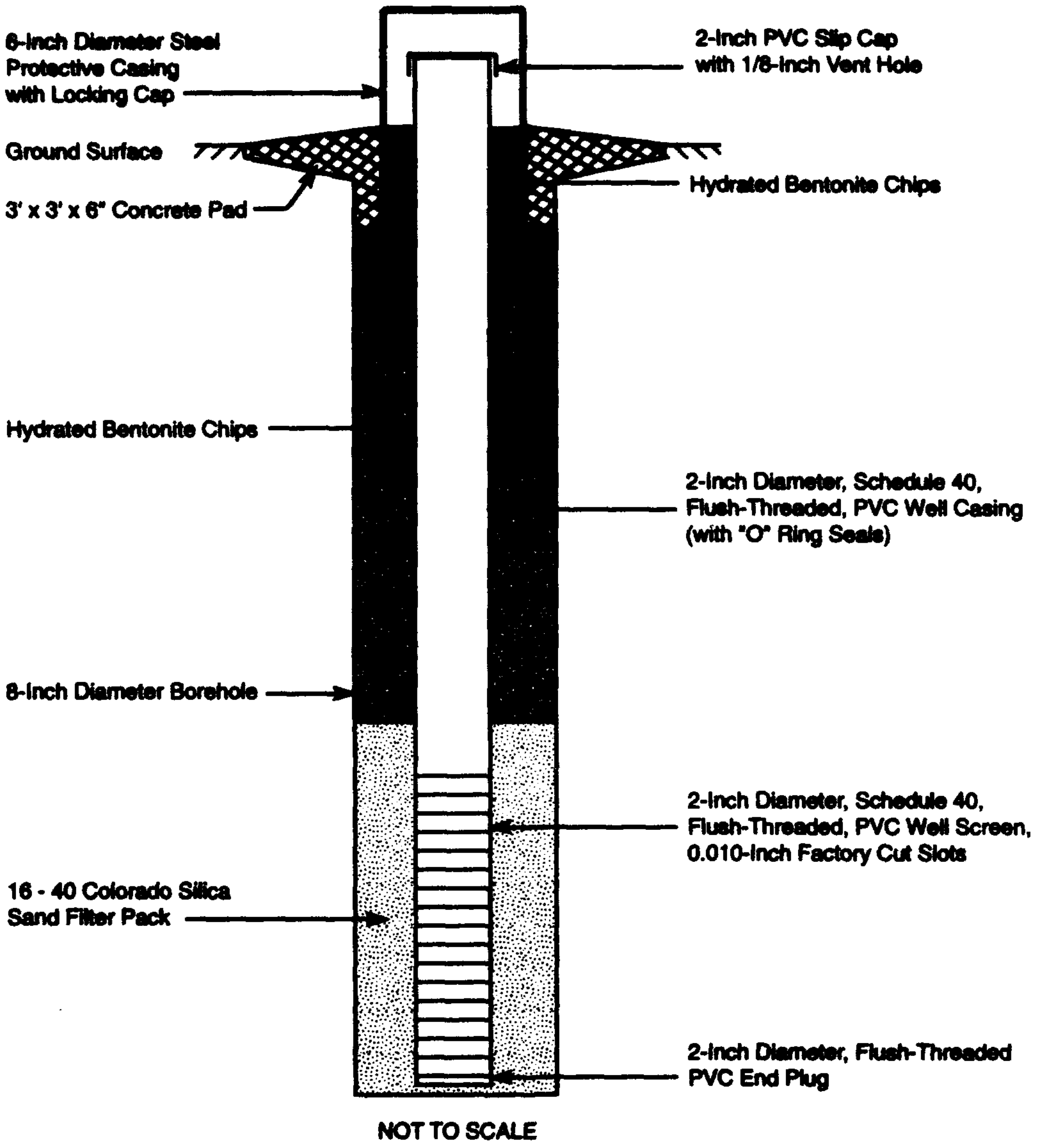
SD40, ST46, and SS53. Wells MW11 through MW17 were spaced at approximately equal distances along Post Road to intercept plumes that may be migrating toward Ship Creek from Sources ST37, ST38 or SS42. To the extent possible, these wells were located upgradient from areas outside the scope of the OU 5 investigation, such as the railroad yard and the industrial area along Post Road.

2.1.5.2 Monitoring Well Installation

Monitoring well construction diagrams for shallow and deep wells are shown on Figures 2-5 and 2-6. Monitoring well casings and screens were constructed of 2-inch-ID, Schedule 40, flush-threaded PVC. The field hydrogeologist determined the length of the well screen based on the observed thickness of the water table, depth to the water table, and depth to the Bootlegger Cove Formation. Well screens for completed wells were between 5 and 15 feet long. Whenever possible, wells were constructed with the well screen extending into both the water-saturated formation and the overlying unsaturated soil. This design allows the sampling of LNAPL contaminants, such as petroleum products and solvents, that tend to float on the groundwater surface and may not be captured if only the saturated formation were screened.

Shallow wells MW09 and MW13 were screened below the top of the water table because the groundwater depth was too shallow to screen above and below the water table and to install a sufficient surface seal on the well (see Figure 2-5). Screen slot size and corresponding sand-filter pack gradation were selected based on field observations of soil types. A well screen slot size of 10-slot (0.010 inch) and sand filter pack gradation of 16-40 Colorado Silica Sand Inc. (CSSI) were used for all monitoring wells to gain consistency in the hydraulic responses of the monitoring wells.

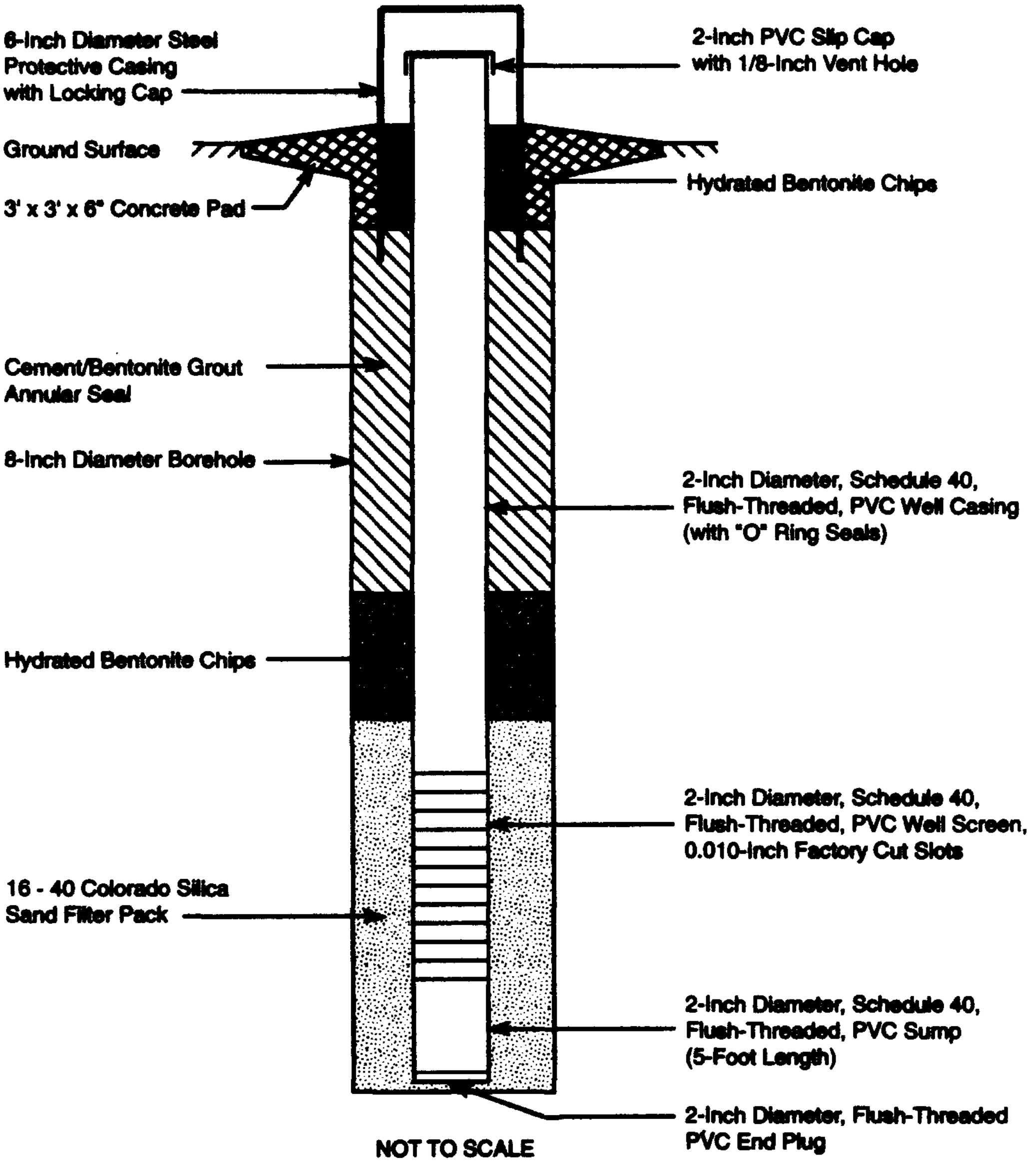
Stainless steel centralizers were installed on only one well, MW01. The use of centralizers caused problems with the sand pack installation and measurement during the construction of this well. A field change request was written recommending that the use of



NOTE: General construction used for wells
MW09, MW10, MW12, MW13, MW14, MW15, MW16A, MW30, & MW31

Figure 2.5. Generalized Shallow Monitoring Well Cross Section, Elmendorf AFB, Anchorage, Alaska

ELMF25.FH3 - VMG 8/11/93 SAC



NOTE: General construction used for wells MW01 through MW08, MW11, & MW17

Figure 2.6. Generalized Deeper Monitoring Well Cross Section, Elmendorf AFB, Anchorage, Alaska

ELMF38.FH3 - VMG 8/11/93 SAC

the centralizers be discontinued. In subsequent well installations, the 4.25-inch-ID augers acted as a guide to hold the 2-inch-ID PVC well assembly in place during construction. The PVC well assembly was suspended from above to help keep the well plumb within the borehole until the sand filter pack and grout seal could be installed.

The sand filter pack was installed by slowly pouring 16-40 CSSI in the annular space between the auger and the PVC well screen. Measurements to monitor the filter pack placement were taken, at a minimum, after each 5-gallon bucket of sand was added. After the sand filter pack was in place, 3/8-inch bentonite chips were added to the space between the auger and the well screen to a thickness of approximately 2 feet. Potable water was added slowly to hydrate the bentonite chips, which were allowed to swell for at least 20 minutes. The cement/bentonite grout seal was pumped through a tremie pipe into the area between the auger and the PVC well screen, using a pump mounted on the drill rig. The tremie pipe was lowered to approximately 5 feet above the top of the bentonite seal before pumping began, and was withdrawn as the borehole was filled with grout from the bottom. Cement/bentonite grout was added to the borehole as the auger was withdrawn. When the auger was removed from the borehole, the grout was brought up to approximately 2 feet below ground surface. Hydrated bentonite chips were added to the remaining 2 feet, providing a watertight seal between the protective steel casing and upper PVC well casing the seal will not adhere to the PVC when the overlying concrete pad is displaced by frost heave. A 6-in-diameter steel protective casing with a locking cap was placed over the PVC well assembly and driven into the hydrated bentonite chips. A 3-foot-by-3-foot-by-0.5-foot concrete pad was then installed around the protective steel casing to hold it in place and protect the surface seal. Protective steel bollards set in concrete were installed around monitoring wells located near roadways or parking areas.

Well construction details were recorded by the field hydrogeologist in a bound field logbook and on CH2M HILL well construction forms. As-built diagrams of all wells are presented in Appendix C. A summary of monitoring well data is presented in Table 2-3.

Table 2-3

Monitoring Well Summary

Monitoring Well Number	Total Well Depth (feet)	Screened[a] Interval (feet)	Sand Filter Pack[b] Interval (feet)	Depth to Water (feet)/Date Installed
MW01	45.0	30.0 - 45.0	27.0 - 45.0	35.0/13 Aug 92
MW02	45.0	25.0 - 40.0	23.0 - 45.0	31.23 Aug 92
MW03	45.0	25.0 - 40.0	23.0 - 45.0	31.5/17 Aug 92
MW04	43.0	23.0 - 38.0	21.0 - 45.0	30.6/18 Aug 92
MW05	38.0	18.0 - 33.0	16.0 - 38.0	24.0/24 Aug 92
MW06	48.0	28.0 - 43.0	26.0 - 48.0	34.7/27 Aug 92
MW07	50.0	30.0 - 45.0	26.0 - 50.0	35.5/26 Aug 92
MW08	20.0	10.0 - 20.0	9.0 - 20.0	14.3/11 Aug 92
MW09	8.0	3.0 - 8.0	2.0 - 9.0	1.7/10 Aug 92
MW10	8.0	3.0 - 8.0	2.0 - 9.0	2.1/10 Aug 92
MW11	50.0	30.0 - 45.0	28.0 - 52.0	36.5/21 Aug 92
MW12	10.0	5.0 - 10.0	3.0 - 10.0	7.5/25 Aug 92
MW13	7.5	2.5 - 7.5	2.0 - 7.5	1.4/14 Aug 92
MW14	12.0	7.0 - 12.0	5.0 - 12.0	8.7/13 Aug 92
MW15	12.0	7.0 - 12.0	5.0 - 12.0	9.5/7 Aug 92
MW16A[c]	12.5	7.5 - 12.5	5.5 - 13.0	10.0/25 Aug 92
MW17	13.0	8.0 - 13.0	7.0 - 15.0	9.5/12 Aug 92
MW30	7.5	2.5 - 7.5	2.4 - 10.0	4.5/11 Aug 92
MW31	7.5	2.5 - 7.5	2.0 - 9.0	3.5/20 Aug 92

[a] All wells were constructed using 2-inch-ID, Schedule 40, flush-threaded PVC casing and screen (10-slot).

[b] Sand filter pack is 16-40 CSSI.

[c] Alternate well installed after poor yield caused Well MW16 to be abandoned.

One well, MW16, did not yield sufficient groundwater for development and sampling. Well MW16 was abandoned by removing the well screen and casing and backfilling the boring with cement/bentonite grout. An alternate well, MW16A, was installed near MW16 and yielded enough groundwater to be properly developed and sampled.

2.1.5.3 Monitoring Well Development

New monitoring wells were "developed" (purged repeatedly) before sampling, using a combination of surging and bailing or pumping to remove fines from the borehole, enhance well yield, and provide turbidity-free samples. The first step in developing these wells was to measure the static water level and total depth of the well. The water volume required for purging a well volume then was calculated from these data. The wells were surged over the screened interval by manually raising and lowering a surge block in the well. This step was followed by either bailing, using a decontaminated stainless steel bailer, or pumping, using a decontaminated submersible pump. The bailing and pumping were done throughout the screened interval to remove the fines pulled into the well by surging.

During monitoring well development, groundwater was monitored for pH, temperature, and specific conductance. Wells were developed until purge water was free of turbidity, to the satisfaction of the field hydrogeologist; the monitored parameters were stable to within 10 percent in consecutive well purge volumes; and at least three well volumes had been purged from the well. Several wells could not be developed to the point that the purge water was free of turbidity. Wells that were still turbid after development generally were constructed in shallow borings that extended into the top of the Bootlegger Cove Formation. Well purging and development data are presented in Appendix F.

2.1.5.4 Groundwater Level Measurements

Water levels in new and existing OU 5 wells and at temporary piezometers installed during the soil gas survey were measured four times during the field season at approximately 3-week intervals. Electronic water level indicators were used to collect groundwater measurements. An oil/water interface probe was used to check for a floating product layer. Measurements were taken relative to the top of the PVC well casing. Water levels were measured to the nearest 0.01 foot. Water level and floating product level measurements were recorded in bound field logbooks. Water level monitoring data are presented in Appendix E.

2.1.5.5 Groundwater Sampling

Groundwater samples from a total of 17 existing and 19 new monitoring wells were collected and analyzed to evaluate groundwater quality within and around the OU 5 source area. All groundwater samples were analyzed at an off-site laboratory for halogenated volatile organics, BTEX, semivolatile organics, and diesel/gasoline/JP-4-range hydrocarbons. Monitoring wells located near fly ash deposits (east of Source ST37) were additionally analyzed for total and dissolved metals. General water-quality parameters (alkalinity, hardness, and anions) were analyzed in five randomly chosen sample locations. Results of the general water-quality analysis were used to perform a geochemical comparison of water collected from the shallow and deep aquifers.

The first step in sampling the monitoring wells was to determine if a floating product layer was present in the well using an oil/water interface probe. No floating product layers were detected in the OU 5 monitoring wells. The static water-level and total depth of the well were then measured using an electronic water-level indicator to calculate a borehole volume of water for purging. Before sampling, wells were purged to remove a minimum of three borehole volumes of water. The borehole volume was calculated as the water inside of the well and in the pore spaces in the silica sand filter pack, assuming a porosity of 30 percent for the sand filter pack. Purging was performed using a low-rate WaTerra sampling pump to minimize aeration and subsequent volatilization of organics. Groundwater sampling crews were careful not to disturb sediment that may have accumulated in the bottom of the well. A WaTerra sampling pump or a decontaminated bailer were used to collect groundwater samples. All equipment that came into contact with groundwater or the inside of the wells either was provided by the manufacturer in clean, sealed, plastic packaging, or was decontaminated before use according to the decontamination procedures in Section 2.1.4.2.

Field parameters (pH, temperature, and specific conductance) were measured after each borehole volume was purged from the wells. Wells were purged until field parameter results between consecutive borehole volumes were within 10 percent (at least three borehole volumes) or until the well was purged to dryness. Disposable plastic cups were used to hold groundwater samples analyzed for field parameters. No field parameter monitoring probes were placed into sample containers to be used for laboratory analysis. Probes used for field parameter monitoring were rinsed with deionized water between each use. Field parameter monitoring instruments were field calibrated or checked against standards daily according to the manufacturer's specifications.

2.1.5.6 Sampling of Water Supply Wells

In addition to OU 5 area monitoring wells, on-site and off-site water supply wells potentially affected by OU 5 were sampled. The off-site water supply wells were identified through a survey of property tenants in the industrial area located between OU 5 and Ship Creek. Samples were analyzed for volatile organics, semivolatile organics, and diesel/gasoline/JP-4-range hydrocarbons. In addition, samples from selected wells were analyzed for alkalinity and for selected cations (magnesium, calcium, iron, sodium, and potassium) and anions (sulfate, nitrate, and chloride) to allow a geochemical comparison with water from the shallow aquifer. A sampling point nearest to the wellhead was selected at each well. The sampling points were generally outdoor spigots or bathroom sink faucets.

2.1.5.7 Aquifer Slug Testing

Slug tests were completed on 11 of the new monitoring wells at OU 5. The tests were conducted to estimate hydraulic conductivity values for the aquifer materials. The slug tests were chosen because they are less expensive to conduct than pump tests. Slug tests have been used at many hazardous waste sites to provide estimates of hydraulic conductivity for the aquifer material directly adjacent to the well.

Some of the assumptions inherent in completing slug tests are that the aquifer is characterized by radial flow, that drawdown of the water table around the well is negligible, that there is instantaneous withdrawal of water from the well, that the aquifer is homogeneous and isotropic, and that the well is fully penetrating. Although all sites violate these assumptions to some extent, slug tests generally provide reliable well-specific, order-of-magnitude estimates that may be used to estimate fate and transport parameters and preliminary evaluations of design options for remedial alternatives.

The aquifer material at OU 5 is generally homogeneous and does not exhibit a high degree of stratification when compared to other slug test sites. Slug tests are generally believed to provide reliable estimates under these conditions.

The slug tests were performed on the following wells: MW01, MW03, MW05, MW08, MW10, MW12, MW13, MW14, MW15, MW16, and MW31. Wells were selected to provide as broad a geographic coverage as possible. Several wells south of the bluff were tested to provide data that may be useful later during the design of an aquifer recovery system.

Slug tests were completed by a team consisting of a field technician and a hydrogeologist. The tests were conducted using PVC slugs, which were either 1 inch or 1.5 inch in diameter and 10 feet in length. Pressure transducers wired to an electronic data recorder were used to record water level measurements during the tests. The data recorders were programmed to record data every one-fifth of a second during the earliest portion of each test, increasing the recording interval incrementally as the test progressed. The longest recording interval used for most of the tests was 1.2 seconds. This recording schedule resulted in frequent data measurements during the earliest portion of the test when the water levels were responding quickly to the slug removal, and less frequent measurements as the water levels began to equilibrate.

Equipment was decontaminated before testing each well following procedures described in Section 2.1.4.2. The tests were conducted by first placing the pressure transducer near the bottom of the well. The height of the water column above the transducer was read using the electronic data recorder. The static water level was read manually using a water level meter, and the value was recorded in the field notebook. Next, the slug was placed into the well and submerged as far as possible. Some wells contained less than 10 feet of water, so complete submergence was not always possible. Before beginning the test, the water level was allowed to return to its original level, which typically took less than 30 seconds. Equilibration was checked by periodically measuring the water level with a water level meter, or by reading the water level at the pressure transducer using the electronic data recorder.

After the water level in the well had returned to its original height, the slug was removed quickly and completely from the well. Simultaneously, the electronic data recorder was turned on. The data recorder was left on until the water level had restabilized as determined by periodic manual water level measurements. Tests typically lasted 1 minute or less. Each test was repeated at least once so that duplicate test results could be compared.

Following the completion of each test, the data were downloaded from the data recorder onto a laptop PC. The results were then analyzed using the Bouwer and Rice solution (Bouwer, 1989; Bouwer and Rice, 1976). Appendix F contains the results of this analysis.

2.1.6 Surface Water and Sediment Investigation

Surface water and sediments were sampled from Ship Creek, the golf course beaver pond, and selected surface water impoundments and drainage ditches downgradient of the OU 5 bluff, as shown on Figure 2-7, to characterize the level of contamination and assess whether the contamination is related to OU 5 source areas. The surface water and sediment sampling stations were selected during the site reconnaissance performed by project biologists identifying appropriate locations for concurrent fish and benthic macroinvertebrate sampling.

The Ship Creek substrate is composed primarily of loose or slightly embedded gravel. To characterize potential sediment contaminant concentrations of seemingly localized sediments, the sample stations were selected in the most quiescent areas possible where suitable quantities of potentially unflushed silty sediment could be collected.

A background reference station was selected for Ship Creek at the boundary between Elmendorf AFB and Fort Richardson. No reference pond station with biological and physical characteristics similar to those of the golf course beaver pond and not potentially affected by an Elmendorf AFB OU could be identified.

The Ship Creek sample stations were within aquatic habitats where the stream configuration was braided or split. The golf course beaver pond was sampled near a seep inlet (SL23), and near its point of discharge (beaver dam). Surface water impoundments on the OU 5 bluff and drainage ditches conveying flow from OU 5 source areas were sampled for surface water and/or sediments at strategic points of inlet or discharge to receiving waters, or where stressed vegetation was apparent.

The surface water and sediment sampling stations and corresponding station numbers are as follows:

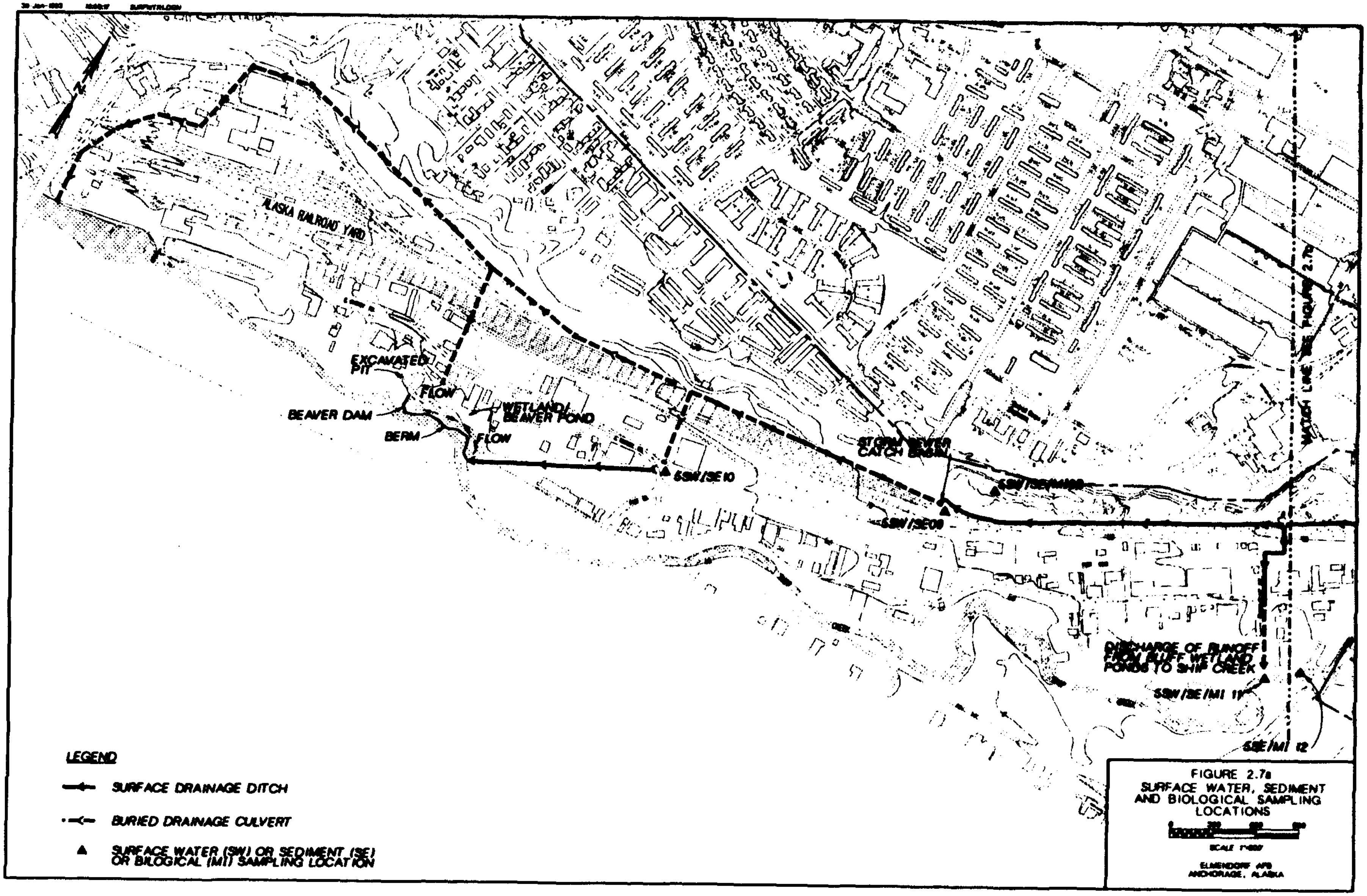


FIGURE 2.7a
SURFACE WATER, SEDIMENT AND BIOLOGICAL SAMPLING LOCATIONS

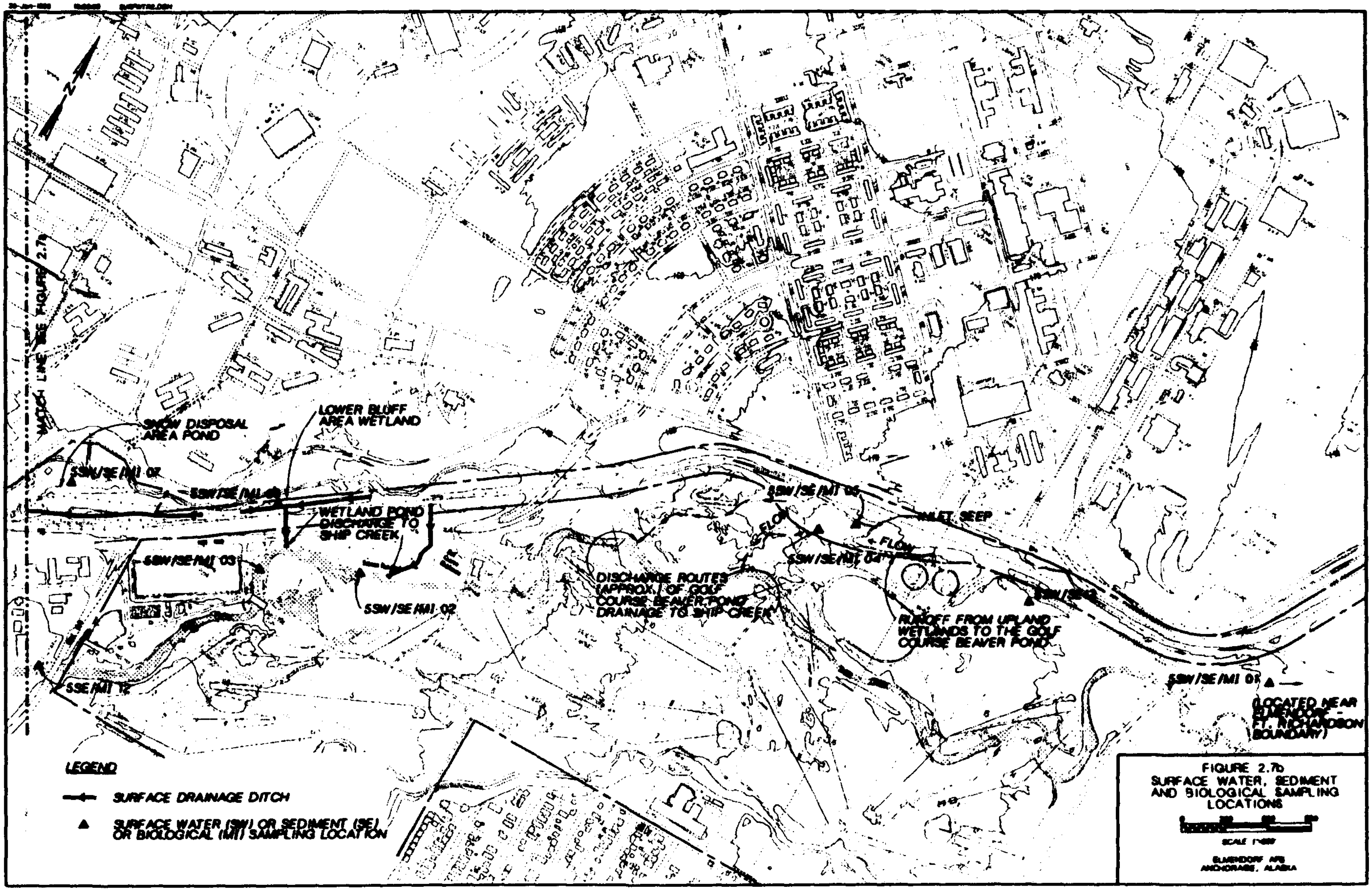


FIGURE 2.7b
SURFACE WATER, SEDIMENT AND BIOLOGICAL SAMPLING LOCATIONS

Sample Station	Location
SW/SE/MI01 (reference)	Ship Creek (Elmendorf AFB-Fort Richardson Boundary)
SW/SE/MI02	Ship Creek (Salmon Run Park)
SW/SE/MI03	Ship Creek (upstream of fish hatchery)
SW/SE/MI04	Golf course beaver pond
SW/SE/MI05	Golf course beaver pond
SW/SE/MI06	Wetland pond at base of OU 5 bluff
SW/SE/MI07	Snowmelt pond at base of OU 5 bluff
SW/SE/MI08	Bluff pond on side of bluff
SW/SE09	Drainage ditch within OU 5
SW/SE10	Drainage ditch west of OU 5
SW/SE/MI11	Yakutat Street, discharge point to Ship Creek
SE/MI12	100 feet upstream of SW11 on Ship Creek
SW/SE13	Beaver pond at seep SL29

SW represents surface water sample stations; SE represents sediment sample stations; and MI represents biological (macroinvertebrate) sample stations. When designated SW, SE, or MI, sampling of the different media occurred at the same location.

Surface water and sediment analyses were performed at off-site laboratories. Surface water samples were analyzed for volatile and semivolatile organic compounds, total and dissolved metals, diesel/gasoline/JP-4 hydrocarbons, and alkalinity. In-situ field measurements included pH, temperature, specific conductance, and dissolved oxygen. Sediment samples were analyzed for volatile and semivolatile organic compounds, diesel/gasoline/JP-4 hydrocarbons, and total metals. PCB analyses were included for sediment samples obtained near Source SD40 and lower bluff pond locations.

Surface water was collected directly into appropriate sample containers by immersing the open top container a few inches below the water surface. Dissolved metals samples were collected by immersing a sterile Nalgene filter unit, and filling the upper reservoir of the two-reservoir assembly. The water then was filtered through a 0.45-micron-mesh filter until the filtered water filled the lower reservoir. The filtered water sample then was poured directly into a 1-liter polyethylene container and preserved with nitric acid.

Sediment samples were collected using decontaminated stainless steel trowels, spoons, corers, or a Ponar grab sampler. The sediment was placed in a stainless steel bowl or polyethylene pail. After volatile organic and BTEX samples were transferred with a stainless steel spoon into sample containers, the rest of the sediment sample was homogenized by mixing and then spooned into respective sample containers.

2.1.7 Aquatic Ecological Survey

The aquatic ecological survey consisted of qualitative and quantitative sampling of benthic macroinvertebrates and fish to accomplish the following:

- Describe the biological characteristics of OU 5;
- Identify receptors and important habitats;
- Determine if there is evidence of stress on ecosystems in the area; and
- Assess toxicity of onsite water and sediments to fish and macroinvertebrates.

2.1.7.1 Field Measurements

Field measurements were conducted to document water quality, physical, and habitat conditions at each site. The data were used to characterize the site and make comparisons with other sites. The in-situ field measurements included pH, temperature, specific conductance, and dissolved oxygen. A qualitative description was made of the station, the general sampling conditions (such as weather) and the habitat (Ship Creek and, where applicable, the ponds) using the habitat assessment protocols established in the EPA Rapid Bioassessment Protocols for Use in Streams and Rivers (RBP) (Plafkin et al, 1989). Field observations of the physical and biological features at each station were recorded on field data sheets and in a field log book. This provided a qualitative habitat assessment for comparison of each site. Each element of the physical measurements and qualitative habitat descriptions is discussed below.

Physical Measurements

At each station, a description of the physical features was recorded. The physical characterization parameters included weather conditions at the time of sampling, estimations of general land use, and physical characteristics such as stream width, presence of undercut banks, high watermarks, channel morphology, and canopy cover (Appendix J, Table J.3).

Weather Conditions. This assessment included approximate cloud cover, rain or mist, and air temperature.

Predominant Surrounding Land Use. The prevalent land use type—for example, agriculture, industrial, silviculture, and forested wetlands—in the vicinity of each station was observed. Also noted were any other land uses in the area that, although not predominant, may affect water quality.

Local Watershed Erosion. The potential for erosion in the watershed at each station was estimated by observing any exposed soil that drained directly into the creek or pond.

Local Watershed Nonpoint Source Pollution. Nonpoint source estimates were made by identifying diffuse urban runoff.

Average Stream Width. The average distance from shore to shore within each stream sampling area was measured in feet with a 100-foot tape measure.

High-Water Mark. The high-water mark was determined by estimating the vertical distance from the stream bank to the peak overflow level, as indicated by debris hanging in bank or floodplain vegetation and by deposition of silt or soil in the floodplain.

Canopy Cover. The proportion of open to shaded area was estimated by visual observation of overstory and shrub canopy.

Sediment Odors, Oils, and Deposits. Bottom substrate materials were examined to measure odors by smell and oils by visual observation of surface sheen or tar deposits. A visual observation of the substrate was made to determine the type of deposition.

Inorganic and Organic Substrate Components. Estimates of the percentage and size of inorganic substrate material were made according to the scheme on the data sheets. Estimates also were made for organic compounds.

Habitat Measurements

The RBP habitat analysis procedures were used to develop a semiquantitative comparison of the habitat conditions at each stream site (Plafkin et al, 1989). Using this procedure, each parameter was evaluated in the field and rated based on protocols listed on the habitat assessment field data sheets. From this analysis a total score was obtained for each stream station. Reference and test station scores were compared and used to classify each station on the basis of similarity and the station's apparent potential to support an acceptable level of biological health.

The habitat parameters were separated into three categories: substrate and instream cover, channel morphology, and riparian bank structure. These were selected to provide a semiquantitative comparison of the habitat conditions at the test and reference stations.

Substrate and Instream Cover. Bottom substrate, available cover, and water current were evaluated. Bottom substrate refers to habitat for support of aquatic organisms. A variety of substrate materials and habitat types results in a diverse biotic community. In general, a direct relationship exists between favorable habitat suitability and the diversity of habitat types and substrate materials present. Substrate and instream cover were evaluated by visual assessment during sampling by qualitatively determining the amount of habitat available for refuge. These habitats included rocks, rubble, submerged logs, undercut banks, and other stable habitat. The qualitative assessment included ranking each site according to the categories listed on the field data sheets. Stream flow was evaluated qualitatively as the ability of a stream to provide and maintain a stable aquatic environment. Areas where the velocity is highest generally provide the least suitable habitat for fish and benthos.

Riparian Bank Structure. Riparian bank structure refers to three parameters: bank stability, bank vegetation, and streamside cover. Bank stability is rated by observing existing or potential detachment of soil from the upper and lower stream bank and the potential for movement of the soil into the stream. Steeper banks are generally more subject to erosion and failure and do not support stable vegetation. Bank soil generally is held in place by plant root systems. An estimate of the density of bank vegetation covering the bank provides an indication of bank stability and the potential for instream sedimentation. Streamside cover is evaluated in terms of stream shading and escape cover or refuge for fish.

2.1.7.2 Benthic Macroinvertebrate Sampling

Benthic macroinvertebrates (bottom-dwelling organisms) were sampled using both quantitative and qualitative methods. Quantitative surveys of benthic invertebrates were conducted using one of two methods, depending on the bottom substrate composition:

- The petite Ponar grab sampler was used to sample soft sediment in ponds.
- The Surber sampler was used to sample riffles and the erosional zone in creeks.

To supplement the quantitative sampling and provide additional information on the colonization of different benthic habitats within the stream and ponds, natural substrates were qualitatively sampled. The natural substrates sampled included soft sediments, woody debris, stumps, vegetation, leaf packs, bark, and twigs.

Quantitative Sampling

Stream Locations. Stream location sampling is described in Table 2-4. At each stream station (Figure 2-7), three quantitative Surber (1024-micron net) samples were collected from riffle locations along a stream reach. A Surber sampler collects benthos from a 1-square-foot area. Surber collection sites coincided with the surface-water quality sampling sites. Surber samples were placed inside a plastic bag enclosed in a second plastic bag, and were preserved with formalin (approximately 10 percent).

Pond Locations. At each of the pond sites, three petite Ponar grabs were collected (Table 2-4, Figure 2-7). The Ponar sampler collects benthos from a 0.25-square-foot area. Ponar collections also coincided with the water quality sampling sites. Ponar samples were sieved through a wash bucket (No. 30 mesh), placed in plastic bags, each within a second plastic bag, and preserved with formalin (approximately 10 percent).

Table 2-4

Macroinvertebrate, Fish, and Bioassay Sample Collection Locations, in Spring (May–June) and Fall (August–September) 1992

Location	Ship Creek	Golf Course Beaver Pond	Surface Discharge Area	Bluff Pond
MI01	S, QL, F			
MI02	S, QL, F, BSW, BSE			
MI03	S, QL, F, BSW, BSE			
MI04		PP, QL, F, BSW, BSE		
MI05		PP, QL, F, BSW, BSE		
MI06			PP, QL	
MI07				QL
MI08				QL
MI11	S, QL			
MI12	S, QL			
SW/SE09			BSW, BSE	

MI = Macroinvertebrate and fish collection station
SW/SE = Surface water/sediment collection station
S = Quantitative macroinvertebrate collection=Surber stream bottom sampler
PP = Quantitative macroinvertebrate collection=petite, Ponar sampler
QL = Qualitative macroinvertebrate collection=kicknet and/or hand collection
F = Fish collection=backpack electrofisher
BSW = Bioassay surface water
BSE = Bioassay sediment

Qualitative Sampling

Qualitative samples at each of the above stations consisted of invertebrates collected by kicknet and hand collection into the kicknet. The collections were made by three methods:

1. In streams only, physically disturbing the bottom substrate by kicking the material upstream of the net and allowing time for the material to be washed into the net.
2. Collecting by hand woody debris and leaf packs that were scraped into the net.
3. In ponds only, dragging the net across the surface of the sediments and scraping organic material from stumps into the net.

The qualitative collection was placed into a small bucket and was mixed thoroughly. Then a small sample aliquot was removed and placed into a plastic picking pan. A 100-organism subsample (or the number picked in 30 minutes) was removed from the pan for preliminary identification of invertebrate taxa present at each sample site. Qualitatively picked samples were washed into doubled plastic bags and preserved with formalin (approximately 10 percent).

Evaluation Metrics

Where appropriate, in stream and pond areas, the following metrics (ecological variables) were used to assist in the ecological assessment.

Taxa Richness. The health of the community can be determined by a measurement of the variety of taxa (for example, total number of order, family, genera, and/or species) present. The premise for using this metric is that the taxa richness increases with better water quality, habitat diversity, and/or habitat suitability.

EPT Index. The EPT index, which generally increases with increasing water quality, is the total number of distinct taxa within the three orders Ephemeroptera, Plecoptera, and Trichoptera. This value summarizes taxa richness within the insect orders that are generally considered to be pollution sensitive.

Ratio of EPT and Chironomidae Abundance. The Ephemeroptera, Plecoptera, Trichoptera (EPT), and Chironomidae (C) abundance ratios (EPT/C) use these indicator organisms as a measure of community balance. Good biotic conditions—generally water quality and habitat—are reflected in communities having a fairly even distribution among these four major groups, with substantial representation in the sensitive EPT groups. Skewed populations have a disproportionate number of the generally tolerant Chironomidae relative to the more sensitive insect groups; this skewing may indicate environmental stress.

Diversity Index. Species diversity is an expression of community structure. In general, a community will have a high species diversity if equally abundant species are present. On the other hand, if a community is composed of a very few species, or if only a few species are abundant, diversity is low.

Evenness. Diversity of a community depends on the number of species present and the evenness with which the individuals are apportioned among them. To describe a community's diversity in terms of its diversity index alone confounds these two factors; a community with few, evenly represented species can have the same diversity as one with many, unevenly represented species. Therefore, it is desirable to keep these two components of diversity distinct. The use of this index is based on the assumption that the better the water quality and more diverse the habitat, the more species abundance will be distributed evenly among the taxa present. This would increase the evenness index value toward one.

Functional Feeding Groups. Macroinvertebrates were classified into functional feeding groups according to the schemes proposed by Merritt and Cummins (1984) and Cummins and Klug (1979). Functional group analysis was done to assist in the assessment of potential changes in functional groups in the invertebrate community due to the contaminant of concern.

2.1.7.3 Fish

Fish were sampled during May and September 1992 at the three sampling stations within Ship Creek above the Elmendorf AFB fish hatchery (SW01 through SW03), and in June 1992 only at the two golf course beaver pond sampling stations (SW04 and SW05). Fish were sampled qualitatively using electroshocking. Minnow seining of the creek and pond was intended, but not possible due to high creek-flow velocities and pond bottom obstructions.

2.1.7.4 Toxicity Tests

Acute and chronic toxicity tests for contaminants of concern were conducted on selected surface water and sediment samples to assess the potential for stress to aquatic organisms. The results of the testing are discussed in Section 4.5.

2.1.8 Terrestrial Ecological Survey

Surveys were conducted during May and June 1992 to describe the terrestrial biological characteristics of OU 5, identify receptors and important habitats, and determine if there is evidence of stress on ecosystems in the area. In accordance with the phased approach being used at OU 5 (CH2M HILL, 1992d), the surveys were designed to obtain qualitative rather than quantitative information. More detailed studies may be conducted in the future if quantitative data are needed for assessment of ecological risks.

The earlier basewide ecological survey reports and assessments (Rothe et al., 1983, NOAA, 1990, USDI, 1990, CH2M HILL, 1992c) were reviewed for general information pertaining to OU 5. The field surveys during May and June were designed to focus on the terrestrial habitats and species identified in those earlier references and to obtain more specific inventories and assessments within OU 5. These surveys were conducted from May 19 through 25 and June 23 through 29, 1992. (In addition, after the first survey, some follow-up was done on May 27 and June 5. Cursory observations were made, and nests found during the May survey were checked.) Because evidence of plant stress was observed during the June survey, plant and soil samples were collected from selected areas in OU 5 during September 1 through 5, 1992.

Primary access routes for making observations in OU 5 included Bluff Road and the ARRC right-of-way north and west of Post Road, and the ARRC right-of-way and gravel roads north of Ship Creek in the areas east of Post Road (see to Figure 2-1). From those access routes, walking surveys were performed throughout the wooded, grassy, and wetland areas within the OU 5 portion of the base. Particular attention was given to those locations where seeps had been identified (see Section 2.1.1), source areas in or near wildlife habitats, and wetlands that could receive groundwater or surface water discharges from those areas.

2.1.8.1 Habitats and Vegetation

OU 5 was surveyed to identify the major habitats and plant communities present and their general distribution. Potentially sensitive habitats, such as wetlands, were identified and visible areas of recent or historical disturbance were noted. The terrestrial habitats were surveyed by walking transects through each OU 5 source area between the bluff and Ship Creek to identify common species present. Less intensive surveys were conducted above the bluff, and aerial photographs were examined to assist in mapping habitat types throughout OU 5. Vegetation types were identified according to the summary of types presented in the basewide ecological survey (CH2M HILL, 1992c), which was based on earlier studies by Rothe et al (1983).

Habitat types were compared to maps and descriptions from Rothe et al (1983) and to color aerial photographs taken in 1982. Evidence of plant stress was noted when there were visual signs of foliar damage. Potential reference sites were surveyed for comparison to the OU 5 habitats.

Table 2-5 provides a summary of the plant and soil samples that were collected to evaluate possible relationships between plant stress and OU 5 contaminants. The sampling locations are shown on Figure 2-1. At most of the sampled locations (excluding SL16 and SL27, where no affected plants were observed), aboveground portions of plants were collected. These included plants showing apparent stress and others of the same species, but not showing effects, that were growing nearby (usually 10 to 30 yards from the affected area). The selected species were considered representative of the affected plants at that location. The plant species included horsetail (*Equisetum arvense*), bluejoint grass (*Calamagrostis canadensis*), fireweed (*Epilobium angustifolium*), brook veronica (*Veronica serpyllifolia*), and willow (*Salix* sp.). Sections 3.6.2 and 4.6 provide descriptions of general habitat types and locations where plant stress was observed.

Along with each of those plant samples, soils were collected at depths that were expected to reflect the root zone of the sampled plant species (although the extent of the root zone for each species was not determined in the field). Soil samples also were collected at SL16 and SL27 (even though affected plants were not observed there) for comparison to soils between SL25 and SL26 (which are located in the same wetland as SL16 and SL27, but where affected plants were observed). At SL29, the soil sample was sediment from an affected area that was flooded.

Collection of paired soil samples (one sample from an area where plants showed effects), the other from a nearby area where the same types of plants were unaffected was considered superior to comparing samples from a more distant reference site where soil, water, and environmental conditions might confound comparisons. At each of the sampling

Table 2-5

Plant and Soil Sample Collections in Areas Showing Evidence of Plant Stress

Location	Plants										Soils (depth in inches)					
	Bluejoint		Grass		Fireweed		Viburnum		Willow		2-12		12-24		24-36	
	A	N	A	N	A	N	A	N	A	N	A	N	A	N	A	N
SL4, SL5	X	X									X	X				
SL19	X	X									X	X				
SL20			X	X	X	X					X	X	X	X		
SL31			X	X	X	X					X	X	X	X		
SL16												X		X		
SL27												X		X		
SL25, SL26			X	X			X	X	X	X	X	X	X	X	X	X
SL29			X	X	X	X			X	X	S	X	S	X	S	X

Notes: At each location except SL16 and SL27, paired samples of stressed plants and soils were collected along with nearby, apparently healthy plants and the soil in which they were growing.

A = Affected
N = Nonaffected
S = Sediment samples collected because the area was flooded

points, soils were collected from depths of 2 to 12 inches, 12 to 24 inches, and 24 to 36 inches deep, as appropriate for the expected root depths for plants at that station.

These representative areas (listed in Table 2-5) in which plants showed evidence of stress were sampled to determine whether chemicals in the soil may be associated with the observed effects. This sampling was conducted as an exploratory survey during the 1992 growing season—consistent with the phased approach described earlier (CH2M HILL, 1992d)—to obtain information potentially useful for preliminary identification of causative factors and planning of bioassays or experimental studies using available toxicity tests (for example, Kapustka and Reporter, 1991, SETAC, 1991). The goal of this additional work was to determine, if possible, the cleanup (no effect) levels for contaminants that are associated with plant stress within OU 5.

Plants in the affected area were examined to further characterize the signs of stress. The goal was to conduct this examination during August (before plants began seasonal die-off or winter dormancy) but it could not be conducted before the first week of September 1992. The specific signs of stress in various plants may provide insight to the causative factors; in other words, whether the signs of stress are directly related to contaminant exposure or perhaps to nutritional deficiencies or imbalances induced by contaminants.

Sampling locations included two where horsetail showed effects (between SL04 and SL05, plus SL19), two open areas where grasses and herbaceous plants were affected (SL20 and SL31), and two larger wetlands where multiple species showed effects. These wetlands included the one between SL16 and SL25, as well as the one at SL29. Within the SL29 wetland, sampling was conducted at one location where multiple species showed effects (and a paired no-effect sample). Within the SL16 to SL25 wetland, sampling was conducted along an east-west transect that included two stations at SL16 and SL27 (where vegetation appeared normal) and at one station between SL25 and SL26. Plant and soil samples were collected concurrently.

In addition to petroleum-related chemicals (BTEX and diesel/gasoline/JP-4 hydrocarbons), the constituents for analysis included other chemicals found in soil vapors or groundwater (volatile organics), pH, conductivity, nitrogen, phosphorus, soluble and extractable cations, and trace elements. Among the trace elements, the analyses of plants or soils included essential elements for nutrition (boron, cobalt, copper, iron, manganese, molybdenum, nickel, and zinc), non-essential elements that may be present (arsenic, cadmium, chromium, lead, mercury, and selenium), and those that may be antagonistic to iron (boron, cadmium, cobalt, chromium, copper, molybdenum, and zinc) because some of the signs of stress were similar to iron deficiency.

2.1.8.2 Fauna

Surveys were conducted at OU 5 to identify resident and migratory animals using the site during the spring and early summer, and to determine their distribution among the identified habitats. The surveys concentrated on small and selected medium-sized mammals (beaver [*Castor canadensis*], muskrat [*Ondatra zibethicus*], voles, and shrews), birds (especially waterfowl and shorebirds), and amphibians, because these animals range over a smaller area or nest in the vicinity and thus are at greater risk for exposure to any contaminants that may be present. Wood frogs (*Rana sylvatica*) may be among the more sensitive receptors because they lay their eggs in direct contact with potentially contaminated surface waters. Larger animals such as river otter (*Lutra canadensis*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*), bear (*Ursus americanus*), and moose (*Alces alces*) are wide-ranging and were not surveyed, although their presence was noted when they were observed.

Mammals

Surveys of mammals were completed by walking various habitat types and observing signs of presence, such as nests, dens, scat, and trails. More reclusive species (such as voles and shrews) were surveyed by trapping with live traps and snap traps. The traps were typically set as pairs, with one live trap and one snap trap at each location.

Table 2-6 provides a summary of the number of trap nights (nights on which traps were set for small mammals). The trapping was conducted in habitats near identified source areas or seeps as well as near the margins of wetlands located close to those areas. The habitats included steep, heavily wooded slopes (for example, those in Source ST37), moist and dry grassy areas, and mixed grass-shrub habitats. Small mammals that were captured were saved for possible examination and also for chemical analysis if appropriate.

Surveys of larger mammals (such as beavers and muskrats) were performed by direct observation and by observation of signs such as burrows, nests, scat, and trails. No trapping was involved.

Birds

Surveys of waterfowl and shorebirds observed at OU 5 were performed to determine which species or individuals feed or nest in ponds and wetlands on OU 5. Birds using ponds with visible surface sheens were observed more closely to detect whether oil could be seen on their plumages. Nest searches were conducted and the eggs in the nests were counted and recorded; hatching success was monitored, insofar as possible. Eggs were examined for evidence of petroleum products on the shell surface. Eggs that failed to hatch were collected and examined to determine if embryos were present and if there were gross abnormalities.

Surveys of birds other than waterfowl and shorebirds entailed walking through habitat types and recording sightings and calls for each species.

Amphibians

The presence of egg, tadpole, or adult wood frogs in ponds, waterways, and other suitable habitats of OU 5 was determined by visual observation and by dipnet.

Table 2-6

Small-Mammal Trapping Summary

Trapping	May					June				
	22	23	24	25	Total	25	26	27	28	Total
Live Traps Set	20	20	39	37	116	37	38	16	16	107
Snap Traps Set	49	49	38	36	172	37	38	16	16	107
Trap Nights	69	69	77	73	288	74	76	32	32	214

2.1.9 Civil Surveying

Coordinates and elevations for monitoring wells, soil borings, piezometers, water supply wells, and stream gauges in or near the OU 5 study area were surveyed in October 1992. Horizontal and vertical control was established to third-order accuracy and was referenced to published control points for the 1983 North American Datum (NAD83) and the 1983 National Geodetic Vertical Datum. Elevations were determined for the following points:

- **Monitoring wells**—top of PVC casing (cap removed), top of steel casing (cap removed), and ground surface next to concrete pad;
- **Piezometers**—top of steel pipe (cap removed) and ground surface next to steel pipe;
- **Water supply wells**—top of flange (well BW-40) or top of seal (wells BW-50 and BW-52) and ground surface next to wells;
- **Soil borings**—ground surface next to backfilled boring; and
- **Stream gages**—top of steel rod supporting gaging instruments.

The coordinates and elevations were used to map sampling locations and provide common reference points for water-level measurements used to evaluate site hydrology. The surveying results are summarized in Appendix G.

2.1.9.1 Horizontal Control

Four permanent monuments having NAD83 values exist within the project area. These monuments, along with several others, are also a part of the "Elmendorf Grid" system. The Elmendorf Grid is an assumed coordinate system; its significance here is that most survey projects at Elmendorf AFB are related to it.

Table 2-7 below lists four monuments within the project limits that are common to both systems.

All computations and adjustments were performed using the Elmendorf Grid values. Each traverse was independently closed and adjusted using the compass rule. Previously adjusted values were held during subsequent adjustments.

When all traverses were adjusted, the inverse distances between monument TT AN 7 and the other three monuments having NAD83 values were compared. The results of this comparison are summarized in Table 2-8.

Monuments TT AN 7 and RY-6A were held because they offered the least scale factor for transforming the survey coordinate values to NAD83 values. The NAD83 values were substituted for the two desired monuments, and all surveyed coordinates were rotated and scaled accordingly.

2.1.9.2 Vertical Control

Vertical datum for the project was specified to be the 1983 National Geodetic Vertical Datum. The survey was initiated at U.S. Coastal and Geodetic Survey (USC&GS) bench mark E-74, which has a published elevation of 76.09 feet above mean sea level. USC&GS bench mark F-74 was also used.

It was found that this datum does not agree with the Elmendorf Grid, which is approximately 2.2 feet higher. To determine which datum other OU 5 project information was related to, AeroMap of Anchorage, Alaska, was contacted for information regarding the 1987 aerial mapping that was used to generate the Elmendorf AFB site maps used in this report. Vertical control for the Elmendorf AFB site maps was based on MOA bench marks

Table 2-7

Coordinates for Survey Monuments

Monument	Coordinate	Elmendorf Grid (feet)	NAD83 (feet)
TT 7	Northing	110,000.00	2,644,656.61
	Easting	110,000.00	1,673,691.80
RY-6A	Northing	109,589.33	2,644,234.04
	Easting	105,835.94	1,669,528.78
G-3	Northing	110,480.95	2,645,074.05
	Easting	112,918.63	1,676,608.68
O-4	Northing	110,913.17	2,645,586.11
	Easting	115,664.45	1,679,352.60

Table 2-8

Comparison of Survey Results to Published Data

Traverses	Survey Inverse Distance	NAD83 Inverse Distance
TT AN 7 to RY-6A	4184.77	4184.42
TT AN 7 to G-3	2946.92	2946.59
TT AN 7 to O-4	5737.23	5736.60

CB-1A, CB-1B, CB-2A, CB-2C, and CB-6A.[a] The datum for these bench marks is NGS 1972 adjusted (mean sea level = 0.00 foot). During the 1987 survey, the elevations for bench marks E-74 and F-74 were found to be 0.60 foot lower than the USC&GS published values. The 1987 survey value used by AeroMap for bench mark E-74 was 75.49 feet. Because the 75.49-foot bench mark elevation agrees with the control used for previous Elmendorf AFB mapping, the OU 5 surveyed elevations were referenced to this datum.

2.2 Laboratory Analyses

This section summarizes the laboratory analysis program for samples collected during the field investigation. The analytical program used both 48-hour turnaround time analyses at the CH2M HILL Corvallis, Oregon, CSL and standard turnaround time analyses at the CH2M HILL Redding, California, laboratory for EPA Level III analyses. Additional contract laboratories to support add-on work included Superior Analytical, ENSECO, and the CH2M HILL Milwaukee, Wisconsin, aquatic biology laboratory. Table 2-9 summarizes the number of samples and parameters analyzed by each laboratory. These totals do not include the quality assurance and quality control (QA/QC) samples (trip blanks, field blanks, rinsate blanks, and field duplicates) collected during the sampling efforts.

2.3 Data Validation

Samples collected during the field investigation were analyzed according to EPA Level III, with documentation equivalent to Level IV. Level III and Level IV are defined as follows:

- Level III—all analyses performed in an off-site analytical laboratory. Level III analyses may or may not use contract laboratory program (CLP) procedures, but do not usually utilize the validation or docu-

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[a] From a letter dated January 15, 1987, from Thomas A. Sturgis of Tryck, Nyman & Hayes to Steve St. Peter of Air Photo Tech, Inc.

Table 2-9

Summary of Laboratory Analyses

[illegible]		CH2M HILL Corvallis (48-hour turnaround)	CH2M HILL Redding (Normal Turnaround)	Enseco (Normal Turnaround)	Superior (Normal Turnaround)
Halogenated Volatile Organics	EPA8010		10	5	
Diesel/JP-4 Range Hydrocarbons	EPA8015 mod		13	5	
BTEX, Gasoline Range Hydrocarbons	EPA8020/8015		13	5	
PCBs	EPA8080		8		
Cyanide	EPA-CLP SOW		1		
Total Metals	EPA6010, 200, 7000 ser.		18		
Semivolatile Organics	EPA8270		13	5	
Soil					
Halogenated Volatile Organics	EPA8010	78	9		27
Diesel/JP-4 Range Hydrocarbons	EPA8015 mod	78	9		27
BTEX, Gasoline Range Hydrocarbons	EPA8020/8015	79	9		27
Agricultural Analyses	ASA/9 12-3.4 & 31-3		10		
	ASTM D2216 & D421		27		
	EPA/CE18-3-155		27		
	USBR 514.8.8		16		
	USBR 514.8.15		27		
	USBR 514.8.2		27		
	USBR 514.8.3		27		
	USBR 514.8.5		27		
	EPA9080		27		
Total Organic Carbon	EPA9060		32		
Total Metals	6010, 200, 7000 ser.		38		
Semivolatile Organics	EPA8270		12		

Table 2-9

(Continued)

[illegible]		CH2M HILL-Corvallis (48-hour turnaround)	CH2M HILL Redding (Normal Turnaround)	[illegible] (Normal Turnaround)	Superior (Normal Turnaround)
Surface Water					
Halogenated Volatile Organics	EPA8010		13	4	
Diesel/JP-4 Range Hydrocarbons	EPA8015 mod		5	3	
BTEX, Gasoline Range Hydrocarbons	EPA8020/8015		5		
Total Metals	6010, 200, 7000 ser.		17		
Dissolved Metals	6010, 200, 7000 ser.		17		
Alkalinity	310.1		17		
Semivolatile Organics	EPA625M		13	3	
Hardness	SM314A		10		
	TPH-A			1	
Ground Water					
Halogenated Volatile Organics	EPA8010		24		
Diesel/JP-4 Range Hydrocarbons	EPA8015 mod		36		
BTEX, Gasoline Range Hydrocarbons	EPA8020/8015		37		
Total Metals	6010, 200, 7000 ser.		8		
Dissolved Metals	6010, 200, 7000 ser.		8		
Anions (SO_4, NO_3, Cl)	300.0		2		
Alkalinity	310.1		4		
Semivolatile Organics	EPA625M		36		
Drinking Water Supply					
Halogenated Volatile Organics	EPA8010		2		
Diesel/JP-4 Range Hydrocarbons	EPA8015 mod		2		
Cations (Ca, Mg, Fe, Na, K)	EPA8020/8015		5		
Total Metals	6010, 200, 7000 ser.		1		

Table 2-9

(Continued)

[illegible]	[illegible]	CH2M HILL Corvallis (48-hour turnaround)	CH2M HILL Redding (Normal Turnaround)	[illegible] (Normal Turnaround)	Superior (Normal Turnaround)
Anions (SO_4, NO_3, Cl)	300.0		4		
Alkalinity	310.1		4		
Semivolatile Organics	EPA625M		4		
Volatile Organics	524		4		
Plant Tissue					
Nitrogen, Phosphorus	AG EXT BULL 766		24		
Total Metals	6010, 200, 7000 ser.		24		

mentation procedures required of CLP Level IV analysis. The laboratory may or may not be a CLP laboratory.

- Level IV—CLP routine analytical services (RAS). All analyses are performed in an off-site CLP analytical laboratory following CLP protocols. Level IV is characterized by rigorous QA/QC protocols and documentation.

Laboratory reports included:

- Sample results, with copies of raw data;
- QC test results, with copies of raw data (matrix spikes, blanks, and duplicates);
- Calibrations and tunes, with raw data;
- A narrative summarizing problems or unusual circumstances that may have been encountered during sample analysis;
- Chain-of-custody forms;
- Sample preparation logs; and
- Raw data for tentatively identified compounds (TICs).

All of the data packages submitted by the CSL and off-site laboratories were reviewed for adherence to QC limits defined in the *Management Plan Operable Unit 5 Quality Assurance Project Plan* (QAPP) (CH2M HILL, 1992d). An additional 10 to 20 percent of the data was validated using raw data according to functional guidelines for evaluating organics analysis and guidelines for evaluating inorganics analysis (EPA, 1988b, 1988c).

Data validation reports are presented in two technical memoranda in Appendix F, one for the CSL and one for other off-site laboratories.

The data were evaluated according to applicable requirements for the following:

- Holding times;
- Calibrations and times;
- Blank contamination;
- Surrogate spikes (organics only);
- Matrix spikes and blank spikes; and
- Duplicates.

Generally, the data met the quality assurance objectives described in the project QAPP; minor nonconformances are described in the technical memoranda in Appendix H. Data flags and their application to the data set are presented in Table 2-10.

In addition to the data review based on EPA guidelines, field duplicate results were summarized and evaluated. Of the 197 pairs of duplicate results, 5 pairs resulted in a greater relative percent difference (RPD) than the project goal of 100. A summary of field duplicate results is presented in Appendix H with data validation memoranda.

In evaluating the data, it was observed that several common laboratory contaminants were present in method blanks and associated samples for many of the analytical procedures. For metals and volatile organic analysis, laboratory contamination was observed in both blanks and samples for each data set. However, for semivolatile analysis (EPA Method 8270), several samples were reported to have low levels (1 to 2 μg/kg) of common laboratory contaminants (phthalates and n-nitrosodiphenylamine) that were not reported in the method blank for the sample set. In these cases, it is believed that the low levels of phthalates and n-nitrosodiphenylamine are laboratory contaminants, and are not originating from samples collected at Elmendorf AFB.

Table 2-10

Data Validation Flags

Source	Flag	Description
Laboratory-assigned flag[a]	U	This flag is used with organic and inorganic results when an analyte was not detected above the method detection limit (MDL) or the contract-required detection limit (CRDL).
	B	This flag is used with organic results when an analyte is found in the associated method blank as well as in the sample, indicating possible laboratory contamination. This flag is also used with inorganic results when a reported analyte concentration is between the instrument detection limit (IDL) and the CRDL. This indicates that the analyte concentration may be estimated.
	J	This flag is used with organic analyses when the raw data indicate the presence of a compound below the stated MDL. This indicates that the analyte concentration may be estimated.
	E	This flag is used with gas chromatograph/mass spectrometer (GC/MS) data only. It indicates that the concentration of the compound is above the linear calibration range of the instrument, which means the sample should be reanalyzed at an appropriate dilution. The results of the dilution are reported on a separate form and flagged with a "D" (see below) if the dilution brings the concentration within proper calibration.
	D	This flag is used with GC/MS data only; it identifies compounds that have been diluted to bring their concentration within the linear range of the instrument.
	C	This flag is used with organic analyses when results are confirmed by a second column.
	X	This flag is used exclusively by the Superior Analytical Laboratory with JP-4 results when the sample JP-4 chromatographic fingerprint pattern does not match standard JP-4 chromatographic fingerprint patterns.
	Y	This flag is used exclusively by the Superior Analytical Laboratory with JP-4 results and indicates that the JP-4 detection limit was raised due to an integration error.
	Z	This flag is used exclusively by the Superior Analytical Laboratory with diesel results and indicates that the diesel detection limit was raised due to an integration error.

Table 2-10

(Continued)

Source	Flag	Description
Reviewer-assigned flag[b]	J	This flag is used with organic and inorganic results. It indicates that it is difficult to determine a direction of bias. This difficulty may occur when a duplicate RPD result is outside the acceptable range for precision or when holding time criteria have been exceeded.
	UJ	This flag is used with organic and inorganic results when a compound analyzed for was not detected. It indicates that the sample quantitation limit is estimated. This may occur when a duplicate RPD result is outside the acceptable range for precision or when holding time criteria have been exceeded.
	NJ	This flag is used with organic results. It indicates that the presence of a tentatively identified compound is at an estimated concentration.
	K	This flag is used with organic and inorganic results when an analyte is present but the actual value is expected to be lower; the reported value may be biased high. This may occur when the matrix spike recovery is above QC acceptance limits.
	L	This flag is used with organic and inorganic results when an analyte is present, but the actual value is expected to be higher; the reported value may be biased low. This may occur when matrix spike recovery is below QC acceptance limits.
	UL	This flag is used with organic and inorganic results when analytes were not detected. It indicates that the sample quantitation limit may be biased low and the actual quantitation limit is expected to be higher. This may occur when matrix spike recovery is below QC acceptance limits.
	R	This flag is used with organic results only and indicates that the sample results are unusable (compounds may or may not be present). This may occur when surrogate spike recovery is below 10 percent.

[a] Flags that are assigned by the laboratory are descriptions about the concentration of the analyte and usually do not indicate a problem with the data.

[b] Data that do not strictly meet QC acceptance criteria were qualified by the reviewer with flags that are single- or double-letter abbreviations that provide descriptions or indicate a problem with the data. Control or acceptance limits are delineated in the appropriate method or the CLP Statement of Work. The assignment of validation qualifiers is discussed in the Data Review section (Appendix H).

2.4 Data Management

A data management system was implemented to assist the flow of information by providing a means of tracking, cataloguing, organizing, and archiving information. This system includes:

- **The database**—data structures, hardware, and software for data handling; and
- **Data management procedures**—data tracking and preparation, data entry and verification, and data administration.

2.4.1 Database System

The Environmental Information Management (EIM) Branch of the Air Force Center for Environmental Excellence (AFCEE) maintains a database to store, analyze, and report information used for the Air Force Installation Restoration Program (IRP). The database is referred to as IRPIMS and is written in dBase®, a commercially available management system.

CH2M HILL has developed an environmental database application using Paradox® software, which is similar in design to IRPIMS. To reduce data entry time and improve reporting capabilities, the Paradox® application was modified to provide data entry and reporting functions with IRPIMS database structures.

2.4.2 Data Management System

Approximately 50 percent of the data received from the laboratories was available in both electronic and hard-copy formats; the remainder of the data was available as hard copy only, which required manual entry of the data. To ensure consistency between data sets, internal database integrity, and a verified, usable data set, the following procedures were followed for all data entered either electronically or manually into the data management system.

Electronic Data Preparation

- Check for completeness; compare data received to analyses requested.
- Log in data disks.
- Verify that files received match transmittal paperwork.
- Copy and archive files for project files.

Electronic Data Entry

- Download data into temporary database files.
- Restructure temporary files to fit the data management system structures.
- Map fields of temporary files to appropriate fields of final database.

Electronic Data Verification

- Print data file output (checkprint).
- Compare number and identity of samples to hard-copy data.
- Compare 10 percent of values to original data sheets received from laboratory.
- Proceed with manual data verification procedures for 100 percent of values if discrepancies are noted.

Manual Data Preparation

- Check for completeness; compare data received to analyses requested.
- Copy and archive field and analytical data for project files.
- Amend hard copies to include pertinent information not printed on the forms.
- Clearly mark all sample preparation information to be entered in database.

Manual Data Entry

- Enter data into temporary database files that will be loaded into final files when verification is complete.

Manual Data Verification

- Print a checkprint of data.
- Compare each record to original coded sheets; highlight correct values; mark incorrect values with revisions in red.
- Sign and date the first page of each data listing.
- Correct the database.
- Print checkprint and compare corrected data to original coded sheets; repeat until all corrections are completed.
- Bind and file coded data sheets and checkprints.
- Convert temporary files to final files.

Final database files will be converted to comma-delimited ASCII format for submittal to the USAF in IRPIMS format.

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3.0 PHYSICAL AND ECOLOGICAL CHARACTERISTICS

3.1 Climate

The principal factors affecting the climate of Elmendorf AFB include terrain, latitude, and geographic position relative to large land masses and oceans. Elmendorf AFB is situated in a transitional climatic zone between the maritime climate effects to the south and the interior, or continental, climate zone to the north (Selkregg et al, 1972). The St. Elias and Chugach mountains to the south and east act as a barrier to the maritime influences of the northern Pacific Ocean, while the Alaska Range to the north protects the area from the extreme cold air masses of the state's interior region. The proximity of the base to Cook Inlet provides additional temperate effects on the climate.

This transitional zone experiences a reasonably moderate climate, generally lacking extremes in precipitation and temperature. However, because of the northern latitudinal location of the base, reduction of annual input of solar radiation results in low mean annual temperatures.

3.1.1 Precipitation

Table 3-1 presents monthly precipitation data for Elmendorf AFB collected from 1941 to 1987.

Average annual precipitation for the Elmendorf AFB area is 15.91 inches. Most of this precipitation (9.63 inches, or 61% of the annual precipitation) falls from June through October (Leslie, 1989). The 2-year, 24-hour rainfall, a measure of rainfall intensity, is 1.5 inches in the Anchorage Bowl (Miller, 1963).

Annual net precipitation is the mean annual precipitation minus the mean annual lake evaporation. No value for mean annual lake evaporation was available from

Table 3-1

Climatic Data for Elmendorf AFB

	Temperature (degrees F)												Precipitation (inches)									
	Means			Extremes				Mean No. Days				Heating Degree Days[a]							Snow[b]			
				Record		Record		Max Temp		Min Temp						Mean No. Days Precipitation Exceeded						
Mth	Max	Min	Mth	Hi	Yr	Lo	Yr	Above 70	Below 32	Below 0	Below 32	Mth Mean	Mean Mth Tot	Max Day	Yr	0.5	0.25	0.1	Mean Mth Tot	Max Mth	Yr	Mean Days 1.0
Jan	19.3	5.1	12.3	49.0	1945	-39.0	1975	0.0	26.2	12.0	30.7	1588.4	0.94	1.15	1965	0.3	1.3	2.9	10.5	29.0	1956	31.0
Feb	23.0	9.5	17.3	58.0	1943	-43.0	1947	0.0	20.4	7.6	27.9	1320.8	0.91	1.70	1975	0.2	0.9	3.0	11.0	31.0	1956	28.0
Mar	32.1	15.9	24.0	51.0	1965	-24.0	1946	0.0	14.1	4.0	29.5	1247.9	0.75	1.32	1979	0.2	0.6	2.5	8.7	27.0	1979	29.0
Apr	43.0	27.9	35.5	65.0	1976	-20.0	1944	0.0	2.0	0.1	22.7	883.8	0.62	0.83	1963	0.1	0.6	2.3	5.3	21.0	1975	12.4
May	54.3	38.6	46.5	80.0	1947	-1.0	1945	0.6	0.1	0.0	3.2	591.4	0.59	0.57	1980	0.1	0.3	2.1	0.4	2.0	1965	0.1
Jun	61.5	47.1	54.4	86.0	1969	33.0	1943	2.9	0.0	0.0	0.0	351.7	1.12	1.31	1962	0.4	1.4	3.3	0.0	0.0		0.0
Jul	64.6	51.4	58.0	83.0	1952	34.0	1941	5.8	0.0	0.0	0.0	252.8	2.11	1.61	1969	1.0	2.6	5.5	0.0	0.0		0.0
Aug	63.1	49.1	56.1	82.0	1968	29.0	1948	3.6	0.0	0.0	0.1	308.6	2.33	1.56	1960	0.9	3.6	6.4	0.0	0.0		0.0
Sep	54.8	41.4	48.1	74.0	1957	20.0	1946	0.1	0.0	0.0	2.6	527.0	2.43	1.67	1951	1.3	2.8	6.6	0.2	1.0	1981	0.0
Oct	40.0	28.2	34.1	63.0	1966	-10.0	1969	0.0	5.4	0.3	20.6	963.8	1.64	1.17	1952	0.6	2.1	5.2	7.4	13.0	1983	6.9
Nov	27.4	15.0	21.2	57.0	1947	-20.0	1948	0.0	20.7	4.4	28.3	1277.1	1.16	1.31	1981	0.4	1.2	3.7	11.3	19.0	1956	21.1
Dec	20.1	7.0	13.6	53.0	1941	-34.0	1961	0.0	26.2	10.1	30.2	1559.0	1.31	1.27	1955	0.3	1.7	4.4	15.6	30.0	1955	28.9
Year[c]	Ave. 42.1	Ave. 28.0	Ave. 35.1	Rec. 86.0		Rec. -43.0		Tot. 13.0	Tot. 115.2	Tot. 38.5	Tot. 195.8	Tot. 10872.3	Tot. 15.92	Rec. 1.70		Tot. 6.0	Tot. 19.1	Tot. 47.8	Tot. 70.4	Rec. 31.0		Tot. 157.5

[a] Heating degree days are compiled from a base temperature of 65°F.

[b] Snow: Mean Mth Tot=mean monthly total snowfall
Max Mth=maximum snow depth on the ground
Mean Days 1.0=mean number of days with 1.0 inch of snow on the ground

[c] Annual temperature means are an average of the monthly means with no weighting factor for the variability in the number of days per month.

Record of data from 1941 to 1987.

Coordinates of station: Latitude 61°15'N, Longitude 149°48'W, Elevation 192 feet above mean sea level

Source: Leslie, L. D. February 1989. "A Compilation of Long-Term Means and Extremes at 478 Alaskan Stations." *Alaska Climate Summaries*. Alaska Technical Note No. 5, 2nd ed., Arctic Environmental Information and Data Center, University of Alaska.

literature sources or local meteorological stations. Using a mean annual temperature of 35.3°F and a mean annual precipitation of 14.27 inches, the potential and actual evapotranspiration rates for the Anchorage area are estimated to be 19.25 inches and 15.20 inches, respectively (Thornwaite, 1968). With evapotranspiration rates greater than the average annual precipitation, the net precipitation would be negative.

Snow with minor amounts of rain is prevalent October through April. Average snowfall during this period is 69.8 inches (5.8 inches of precipitation), which comprises 36% of the annual precipitation. Rainfall averages 1.49 inches during this same period. Snow usually covers the ground from mid-October through mid-April in most areas of the Anchorage Bowl. During periods of snow cover, the surface soil temperatures would be expected to be near or below freezing. The treeless south-facing bluffs of OU 5 often become free of snow by late March. Adjacent areas that are shaded by trees are not free of snow until late April. The snow dump area south of Sources ST38/SS42 feeds the adjacent ponds with melt water until mid-summer.

3.1.2 Temperature

Table 3-1 presents temperature data for the Elmendorf AFB area from 1941 to 1987.

Seasonal variations in temperature at Elmendorf AFB are exaggerated because of the reduced number of daylight hours during the winter. However, daily fluctuations in temperature are relatively slight. January exhibits the lowest monthly mean temperature at 12°F. The highest monthly mean temperature, 58°F, is in July. Daily temperature fluctuations are on the order of 15°F. The monthly mean temperature is below freezing for 5 months of the year and below 40°F for 7 months of the year. Therefore, the ponds and other stagnant areas of surface water in OU 5 can be expected to be frozen at least 5 months of the year.

3.1.3 Wind

Table 3-2 shows the wind direction by percent for Elmendorf AFB[a].

Above-surface air flow in the Elmendorf AFB area is generally toward the northeast and northwest. Surface flow, however, is more variable. During summer, surface winds blow from the west and northwest onto the base from Cook Inlet. In winter, these winds are more likely to blow south along Knik Arm. Surface wind velocities average 5.8 knots (6.7 miles per hour [mph]), although channeling of the winds near Ship Creek is common, with velocities reaching 53 knots (60 mph) (Rothe et al, 1983).

3.2 Geology and Soils

Since 1950, three USGS teams have mapped the region that encompasses Elmendorf AFB. They were R. D. Miller and Ernest Dobrovolny between 1950 and 1959; Henry Schmoll, Ernest Dobrovolny, and Clyde Wahrhaftig between 1965 and 1972; and Lynn Yehle, Henry Schmoll, and Ernest Dobrovolny between 1987 and 1991. All maps were scaled at 1:24,000 (1 inch=2000 feet). The discussion in this subsection is based on these USGS reports, as well as onsite investigations by CH2M HILL, Black & Veatch, Harding Lawson Associates, and James Montgomery Consulting Engineers.

3.2.1 Regional Physiographic and Geologic Setting

Elmendorf AFB lies in the Cook Inlet-Susitna Lowland physiographic province, within an informal subdivision termed the Anchorage Lowland. The highest point in the Anchorage Lowland is about 380 feet in altitude, east of the Knik Arm along the Elmendorf Moraine. About 9 miles east of Elmendorf AFB is a boundary between the Cook Inlet-Susitna Lowland and the Kenai-Chugach Mountains physiographic provinces; here the

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[a] Original source (Selkregg et al, 1972) does not list dates for the data in Table 3-2. James L. Wise, retired Alaska state climatologist, estimated that the data were summarized for the period from the mid-1950s to the early 1970s. Phone conversation on January 14, 1993.

Table 3-2

Wind Direction by Percent for Elmendorf AFB

Direction	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Mean
North	44.4	47.7	49.8	40.7	29.2	21.8	23.6	29.8	38.1	45.7	46.9	43.8	38.5
East	20.3	14.9	9.8	6.9	6.7	5.9	5.7	7.6	9.2	13.5	17.0	20.7	11.5
South	7.5	11.6	11.7	15.1	21.6	25.7	22.6	18.9	15.0	12.7	9.9	8.2	15.0
West	2.3	3.0	6.3	16.5	26.5	30.3	27.6	17.8	8.6	3.5	2.5	2.2	12.3
Calm	25.5	22.8	22.4	20.8	16.0	16.3	20.5	25.9	29.1	24.6	23.7	25.1	22.7

North = northwest, north-northwest, north, north-northeast, northeast
South = southeast, south-southeast, south, south-southwest, southwest
East = east-northeast, east, east-southeast
West = west-southwest, west, west-northwest

Source: Selkregg et al. 1972. Data from the mid-1950s to the early 1970s.

rugged Chugach Mountains rise abruptly above the Anchorage Lowland along the Chugach Mountain front.

Bedrock in the Anchorage area consists of consolidated and partly consolidated deposits. The oldest rocks in the Elmendorf AFB are consolidated rocks that form the Chugach Mountains. These rocks are a complex mixture of deformed and metamorphosed sedimentary and igneous rocks deposited during the Paleozoic and Mesozoic eras, about 65 to 650 million years ago. During the Tertiary Period (2 million to 65 million years ago), as much as 20,000 feet of gravel, sand, and organic material—present-day conglomerate, sandstone, mudstone, and coal—filled a gradually sinking trough in the Cook Inlet-Susitna Lowland. These moderately consolidated rocks occur extensively throughout the lowland; they are covered by about 1000 feet of unconsolidated, surficial material deposited during the Quaternary Period in the last 2 million years.

3.2.2 Regional Surficial Deposits and Geomorphology

The entire regional land area is covered by surficial deposits of Quaternary age; these deposits are mapped and divided mainly on the basis of landform boundaries. Surficial deposits within the region consist mainly of Pleistocene-age glacial drift that includes extensive areas of moraine deposits, as well as related glacioalluvial and glacioestuarine deposits. Although covering less area than other deposits, nonglacial deposits are widely distributed. They include intertidal, colluvial, alluvial, bog, and anthropogenic (man-made fill) deposits.

3.2.2.1 Glacial Deposits

Most geologic landforms and surficial deposits in the region consist of products of several glacial advances and retreats, most notably the Wisconsin Epoch glaciation. During this epoch, the Matanuska-Knik lobe of the Naptowne Glacier advanced out of the northeast toward the southwest to approximately the position marked by the Elmendorf

Moraine. The retreat of this glacier resulted in three topographic subdivisions: ground moraines and a terminal moraine that comprise the Elmendorf Moraine, and an outwash plain extending beyond the Elmendorf Moraine toward the south and west.

The ground moraines slope gently upward toward the west, ending at the terminal, or end, moraine. Features found within the ground moraine include drumlins, eskers, kames, kame terraces, and lakes.

The end moraine and southern boundary of the Elmendorf Moraine is visible as a rising bluff line on the north side of the east-west Elmendorf AFB runway. The topography of this end moraine is rough and hilly, with elevations ranging from 200 feet in altitude at the bluff edge of Knik Arm to about 380 feet at the eastern boundary. Relief is not uniform; it reflects the hilly nature typical of a terminal moraine.

The relatively smooth outwash plain extends south of the moraine, encompassing the region south and west of Knik Arm, as well as a sizable portion of the Kenai Peninsula. Relief is generally flat, with elevations ranging from 25 feet along Knik Arm bluffs to 225 feet at the flank of the Elmendorf Moraine. The outwash plain also has been incised by stream channels, displaying the braided and meandering nature of fast-flowing streams in glacial material. Ship Creek, which parallels the Elmendorf Moraine, is an example of an incised, glacial-fed stream.

The main deposit types found in these landforms include the following:

- Morainal;
- Glacioalluvial; and
- Glacioestuarine.

Morainal deposits consist of material deposited directly by glacier ice that occurs in end and ground moraines. Morainal deposits consist of till that is composed mainly of diamicton—a poorly sorted mixture of clay, silt, sand, and gravel with poorly sorted silty and sandy gravel.

Glacioalluvial deposits are composed of material deposited by running water within, around, and draining away from the glacial ice. These deposits generally consist of gravel and sand, although some diamicton and finer-grained material is commonly present in kames.

Glacioestuarine deposits are composed of material deposited in estuaries, partly by glacier ice. These deposits, principally the Bootlegger Cove Formation, typically consist of clays and silts, with some interbedded and scattered coarser material, including medium to coarse sand and gravel.

3.2.2.2 Nonglacial Deposits

Most nonglacial deposits are recent, having been deposited within the last 10,000 years. These deposits included the following:

- Intertidal;
- Colluvial;
- Alluvial;
- Bog; and
- Anthropogenic.

Modern intertidal deposits in the region are limited to those on the modern beach bordering the sea bluffs along Knik Arm, as well as a small area of tidal-flat deposits within Goose Bay. The beach deposits consist of mostly sand and gravel overlying boulders and cobbles.

Colluvial deposits, or colluvium, are deposits that have accumulated on or at the base of slopes with the aid of gravity and running water. Examples are found in the bluffs that border Knik Arm and locally on the walls of a few channels within glacial deposits, especially along the outwash plain. Colluvium occurs as a downslope-thickening wedge of silt, sand, and gravel that has been cut or eroded by streams or waves.

Other surficial deposits include alluvial deposits, or alluvium, as well as bog and fill. Alluvium that is not directly related to glacial activity is restricted to stream alluvium found in active creek beds and fan alluvium found in a few gullies on slopes of the Elmendorf Moraine. Alluvial deposits typically consist mostly of fine sand and silt, but sand and gravel are dominant in some of the region's alluvium. Bog deposits are scattered throughout the irregular terrain of the Elmendorf Moraine and consist mostly of peat, with varying amounts of silt and sand, as well as local lenses of tephra. Anthropogenic, or man-made, deposits include areas that have been emplaced or reworked. Fill deposits are found throughout the Anchorage Bowl, and for the most part, south of the Elmendorf AFB runways. The fill typically consists of silty or sandy gravel and sand; in one case, it also contains fly ash material, a possible byproduct of the Elmendorf AFB power plants.

3.2.3 Site Investigation Results

Information on soil was obtained primarily by field observations during drilling, and also from physical laboratory test results of select soil samples collected during drilling. Soil boring logs are provided in Appendixes B and C. Results of laboratory tests of physical properties are discussed below.

The soil profile of OU 5 is shown in several figures that depict the area in cross sections. Figures 3-1 and 3-8 show the locations of the soil cross sections; Table 3-3 is an expanded legend for the cross sections presented on Figures 3-2 through 3-7 and 3-9.

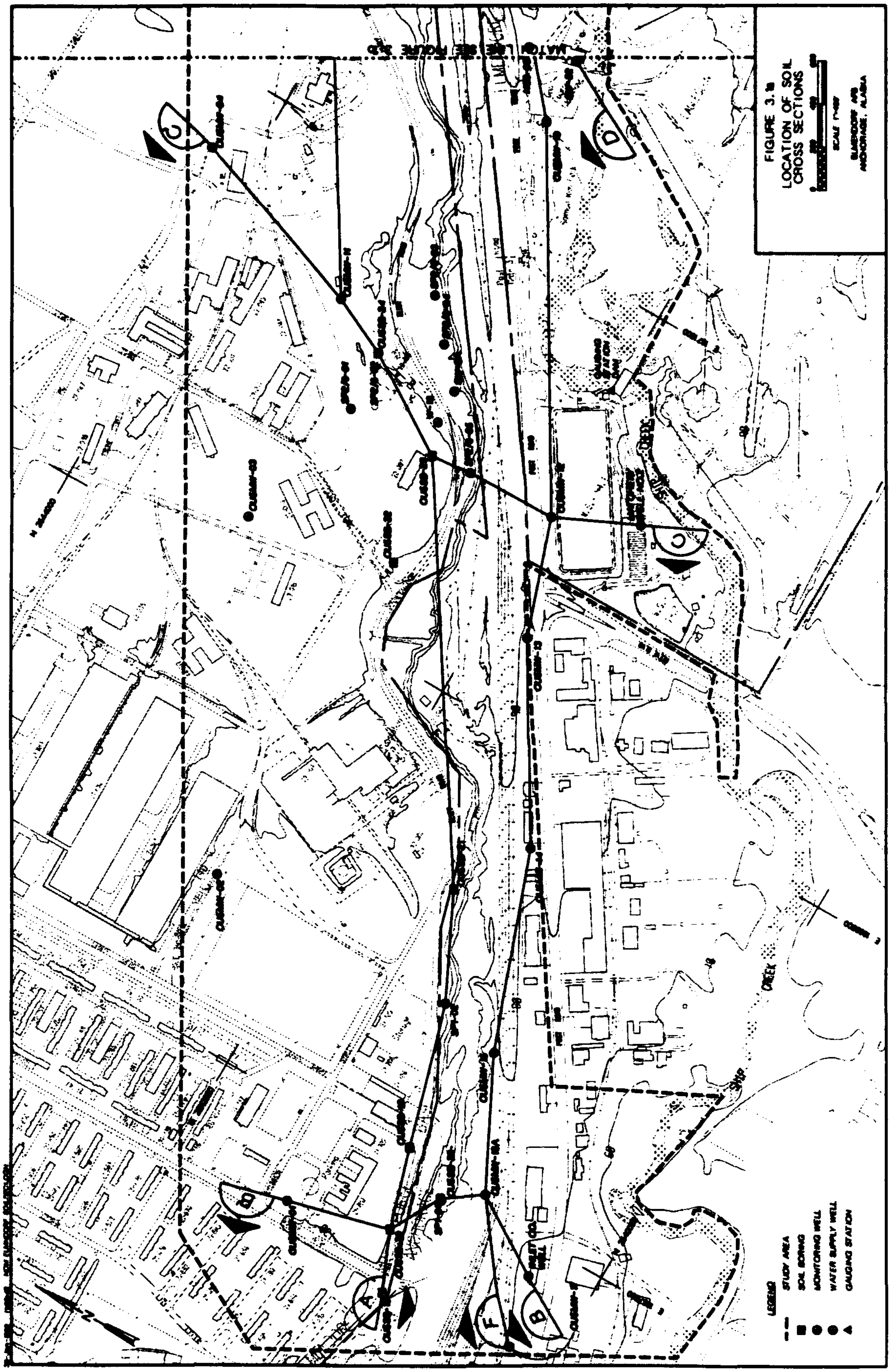


FIGURE 3.1b
LOCATION OF SOIL
CROSS SECTIONS

ELMENDORF AFB
ANCHORAGE, ALASKA

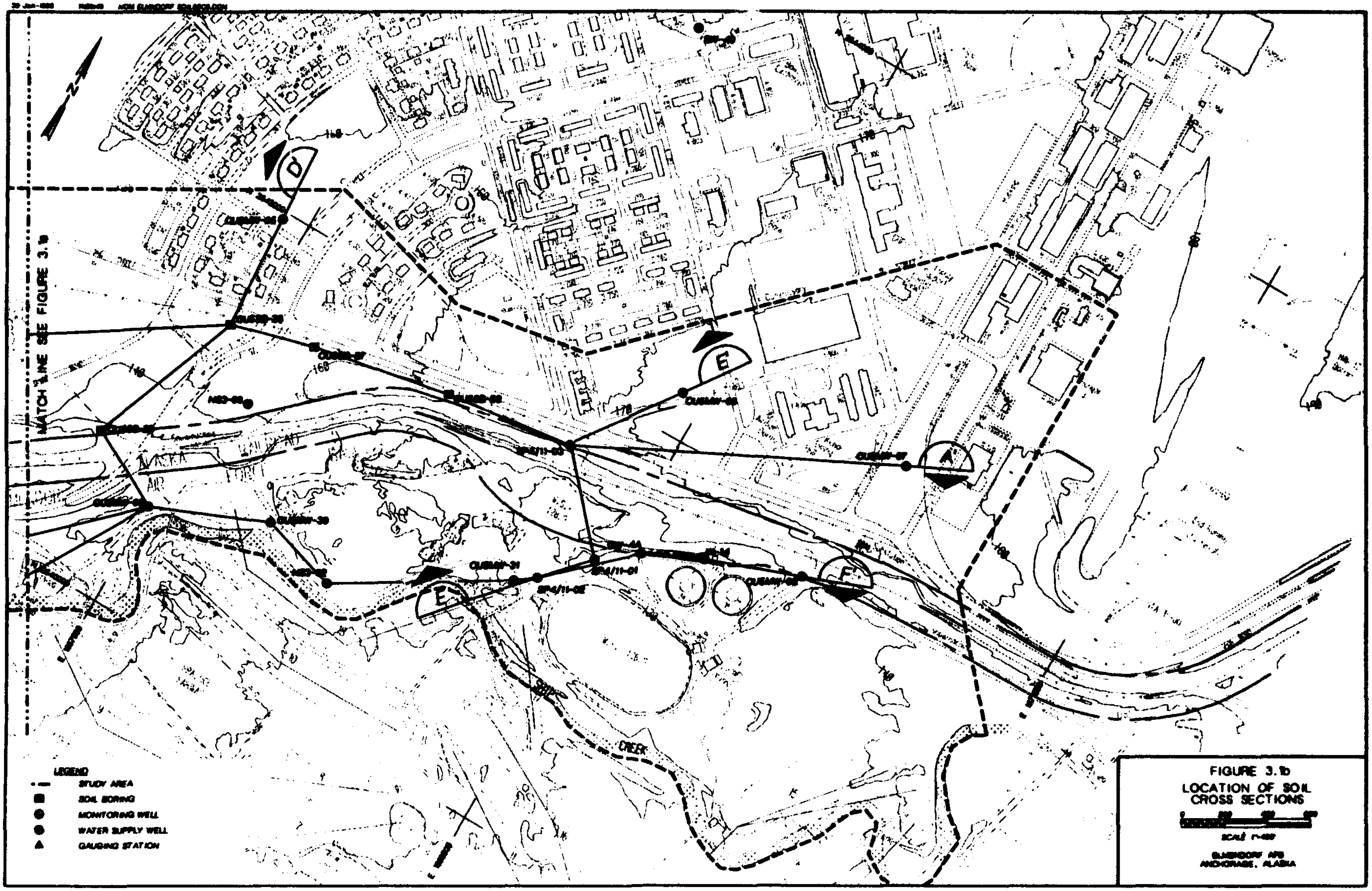
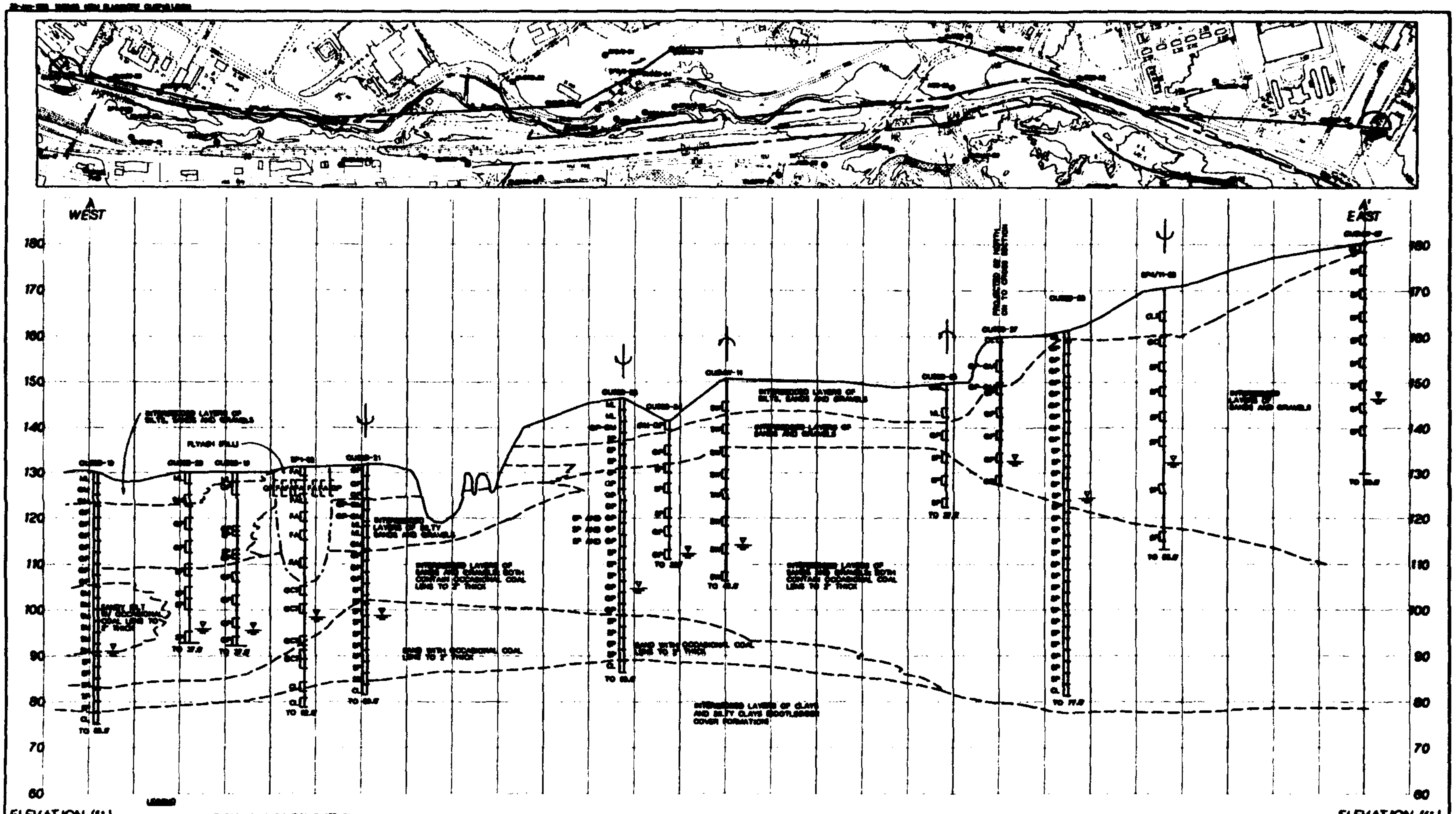


FIGURE 3.1b
LOCATION OF SOIL
CROSS SECTIONS



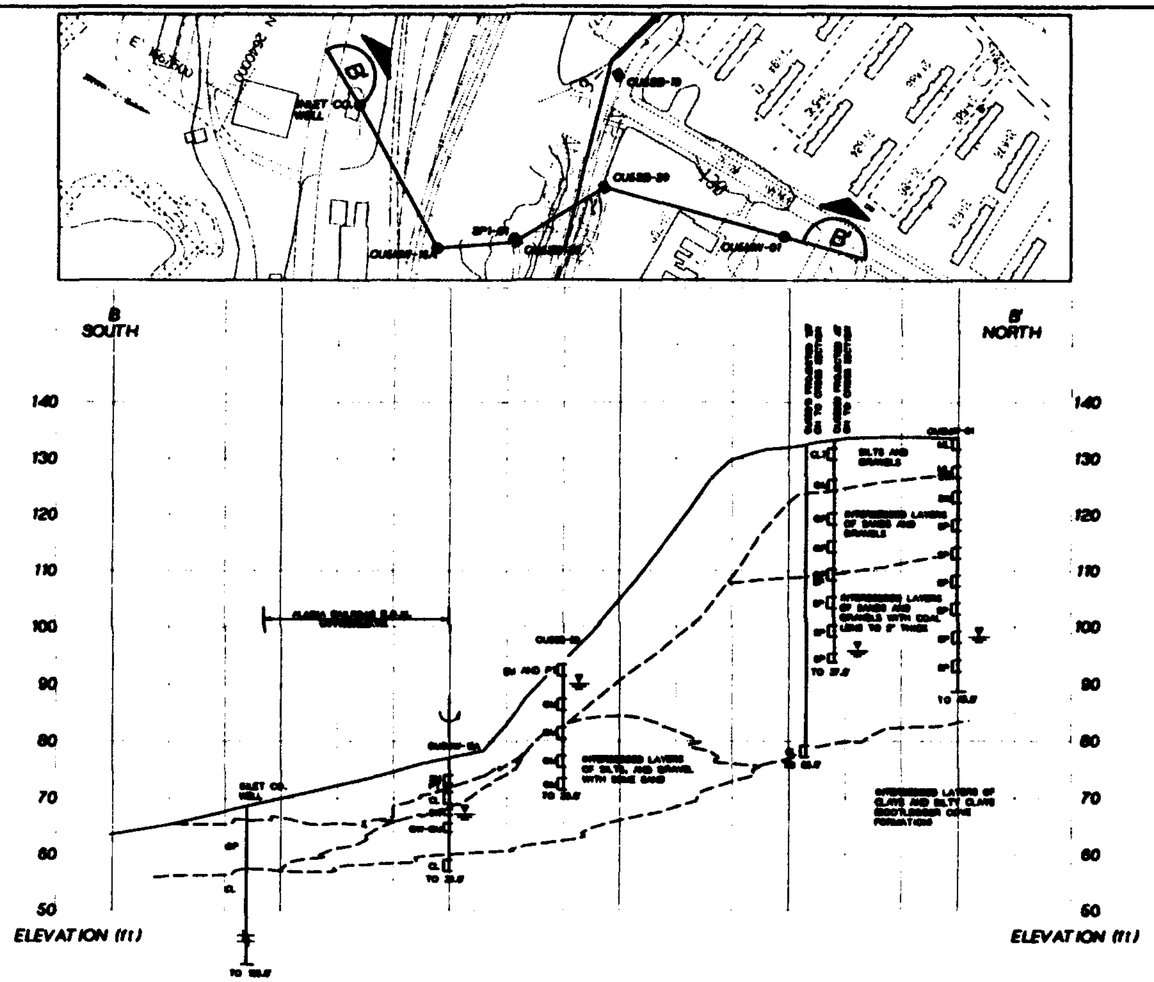
NOTES:

1. THIS CROSS SECTION IS BASED ON BORINGS LOGGED BY CH2M HILL AND OTHERS. THE BORING LOGS RELATE INFORMATION DEPICTING SUBSURFACE CONDITIONS ENCOUNTERED AT SPECIFIC TIMES AND DATES. SUBSURFACE CONDITIONS MAY VARY BETWEEN BORINGS, AND SUBSURFACE CONDITIONS (ESPECIALLY WATER LEVELS) MAY CHANGE WITH THE PASSAGE OF TIME.
2. ELEVATIONS (ABOVE MEAN SEA LEVEL) BASED ON SURVEY BY SOIL ENGINEERING AND AEROMAP.
3. TH1, TH2, TH3, TH5, TH7, TH8, TH9 AND TH10 PROJECTED [illegible] ON TO CROSS SECTION.

FIGURE 3.2
CROSS SECTION A-A'
ALONG BLUFF AREA

SCALE [illegible]

ELMENDORF AFB
ANCHORAGE, ALASKA



LEGEND

- ● LABORATORY CLASSIFICATION BASED ON GRAIN SIZE ANALYSIS; ALL OTHERS ARE FIELD CLASSIFICATIONS
- – · – · ESTIMATED BOUNDARY BETWEEN FILL AND NATIVE SOIL
- — — — APPROXIMATE CONTACT BETWEEN MATERIAL TYPES
- SAMPLE INTERVAL
- WATER LEVEL MEASURED IN BOREHOLE DURING OR IMMEDIATELY AFTER DRILLING
- CROSS SECTIONAL CHANGE IN DIRECTION

SCALE

HORIZONTAL EXAGGERATION = x10

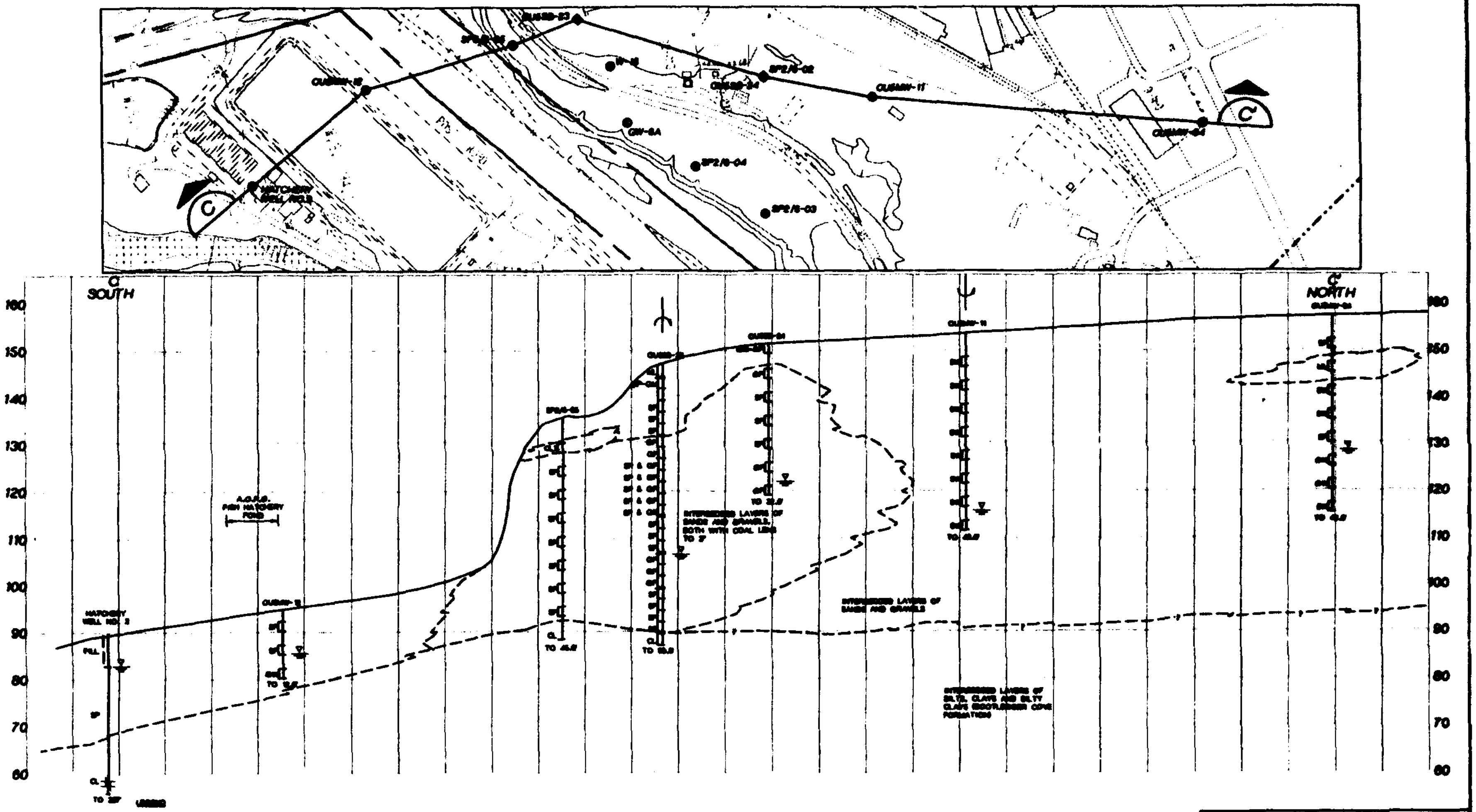
NOTES:

1. THIS CROSS SECTION IS BASED ON BORINGS LOGGED BY CH2M HILL AND OTHERS. THE BORING LOGS RELATE INFORMATION REGARDING SUBSURFACE CONDITIONS ENCOUNTERED AT SPECIFIC TIMES AND DATES. SUBSURFACE CONDITIONS MAY VARY BETWEEN BORINGS, AND SUBSURFACE COND[illegible] (ESPECIALLY WATER LEVELS) MAY CHANGE WITH THE PASSAGE OF TIME.
2. ELEVATIONS (ABOVE MEAN SEA LEVEL) BASED ON SURVEY BY [illegible] ENGINEERING AND AEROMAP.

FIGURE 3.3
CROSS SECTION B-B'
ACROSS BLUFF AREA

SCALE [illegible]

ELMENDORF AFB
ANCHORAGE, ALASKA



LEGEND

- LABORATORY CLASSIFICATION BASED ON GRAIN SIZE ANALYSIS; ALL OTHERS ARE FIELD CLASSIFICATIONS
- · — · ESTIMATED BOUNDARY BETWEEN FILL AND NATIVE SOIL
— — APPROXIMATE CONTACT BETWEEN MATERIAL TYPES
SAMPLE INTERVAL
WATER LEVEL MEASURED IN BOREHOLE DURING OR IMMEDIATELY AFTER DRILLING
CROSS SECTIONAL CHANGE IN DIRECTION

10
100
SCALE
HORIZONTAL EXAGGERATION = x10

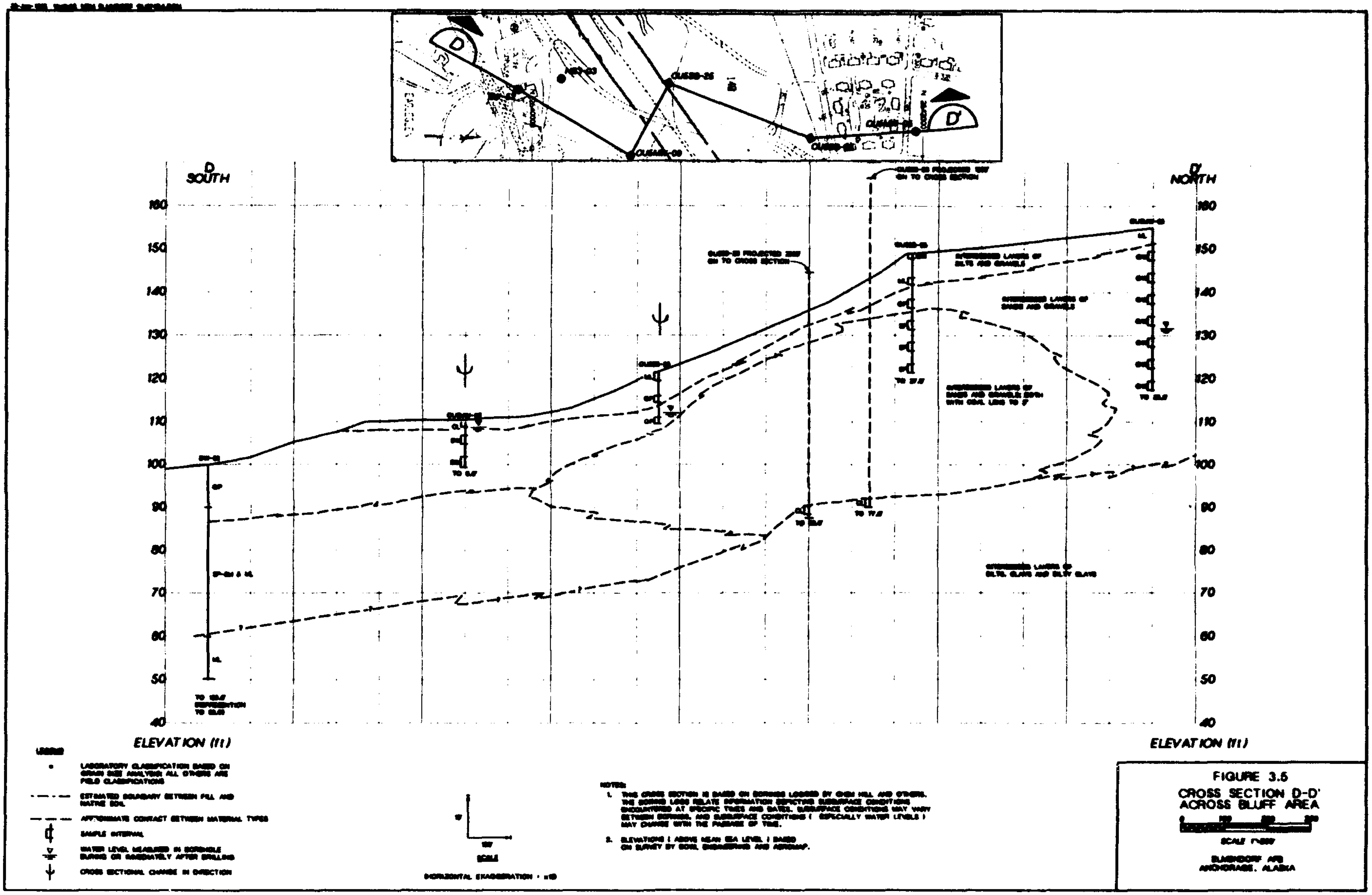
NOTES:

1. THIS CROSS SECTION IS BASED ON BORINGS LOGGED BY CH2M HILL AND OTHERS. THE BORING LOGS RELATE INFORMATION DEPICTING SUBSURFACE CONDITIONS ENCOUNTERED AT SPECIFIC TIMES AND DATES. SUBSURFACE CONDITIONS MAY VARY BETWEEN BORINGS, AND SUBSURFACE CONDITIONS (ESPECIALLY WATER LEVELS) MAY CHANGE WITH THE PASSAGE OF TIME.
2. ELEVATIONS (ABOVE MEAN SEA LEVEL) BASED ON SURVEY BY BOWL ENGINEERING AND AEROMAP.

FIGURE 3.4
CROSS SECTION C-C'
ACROSS BLUFF AREA

0 100 200 300
SCALE 1"=200'

ELMENDORF AFB
ANCHORAGE, ALASKA

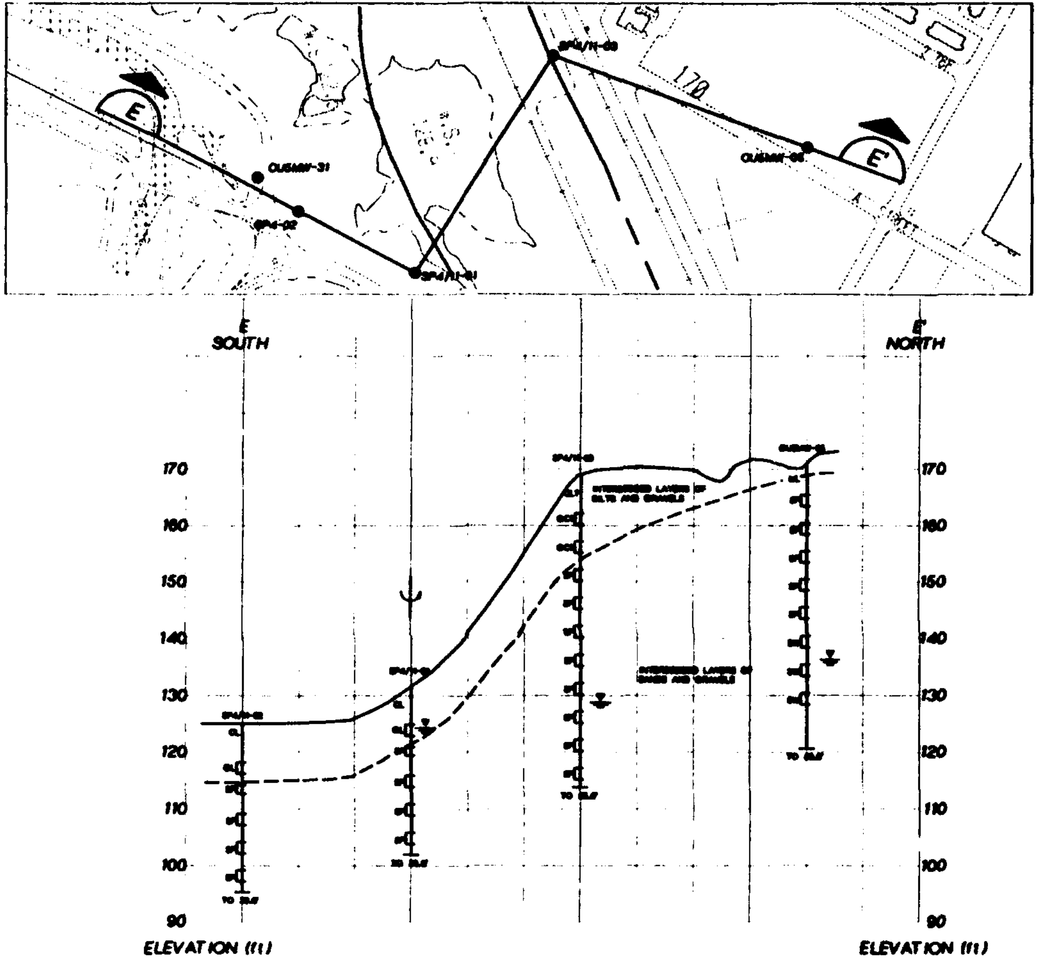


NOTES:

1. THIS CROSS SECTION IS BASED ON BORINGS LOGGED BY CH2M HILL AND OTHERS. THE BORING LOGS RELATE INFORMATION DEPICTING SUBSURFACE CONDITIONS ENCOUNTERED AT SPECIFIC TIMES AND DATES. SUBSURFACE CONDITIONS MAY VARY BETWEEN BORINGS, AND SUBSURFACE CONDITIONS (ESPECIALLY WATER LEVELS) MAY CHANGE WITH THE PASSAGE OF TIME.
2. ELEVATIONS (ABOVE MEAN SEA LEVEL) BASED ON SURVEY BY SOIL ENGINEERING AND AEROMAP.

FIGURE 3.5
CROSS SECTION D-D'
ACROSS BLUFF AREA

ELMENDORF AFB
ANCHORAGE, ALASKA



LEGEND

•	LABORATORY CLASSIFICATION BASED ON GRAIN SIZE ANALYSIS; ALL OTHERS ARE FIELD CLASSIFICATIONS
— · — ·	ESTIMATED BOUNDARY BETWEEN FILL AND NATIVE SOIL
— — —	APPROXIMATE CONTACT BETWEEN MATERIAL TYPES
ɸ	SAMPLE INTERVAL
▽	WATER LEVEL MEASURED IN BOREHOLE DURING OR IMMEDIATELY AFTER DRILLING
⟂	CROSS SECTIONAL CHANGE IN DIRECTION

10'

100'

SCALE

HORIZONTAL EXAGGERATION = x10

NOTES:

1. THIS CROSS SECTION IS BASED ON BORINGS LOGGED BY CH2M HILL AND OTHERS. THE BORING LOGS RELATE INFORMATION DEPICTING SUBSURFACE CONDITIONS ENCOUNTERED AT SPECIFIC TIMES AND DATES. SUBSURFACE CONDITIONS MAY VARY BETWEEN BORINGS, AND SUBSURFACE CONDITIONS (ESPECIALLY WATER LEVELS) MAY CHANGE WITH THE PASSAGE OF TIME.
2. ELEVATIONS (ABOVE MEAN SEA LEVEL) BASED ON SURVEY BY BOWL ENGINEERING AND AEROMAP.

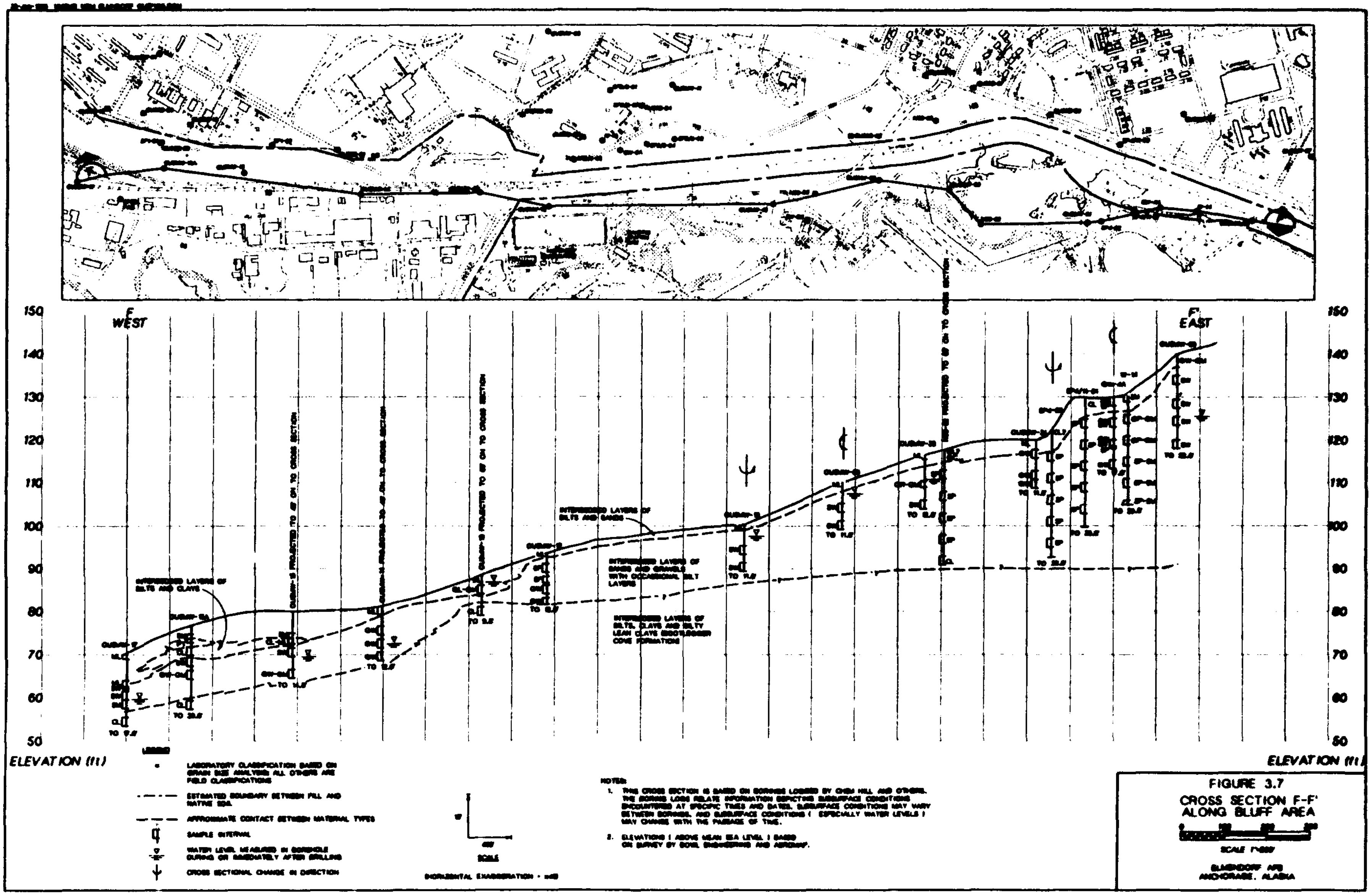
FIGURE 3.6

CROSS SECTION E-E'
ACROSS BLUFF AREA

0 100 200 300

SCALE 1"=200'

ELMENDORF AFB
ANCHORAGE, ALASKA

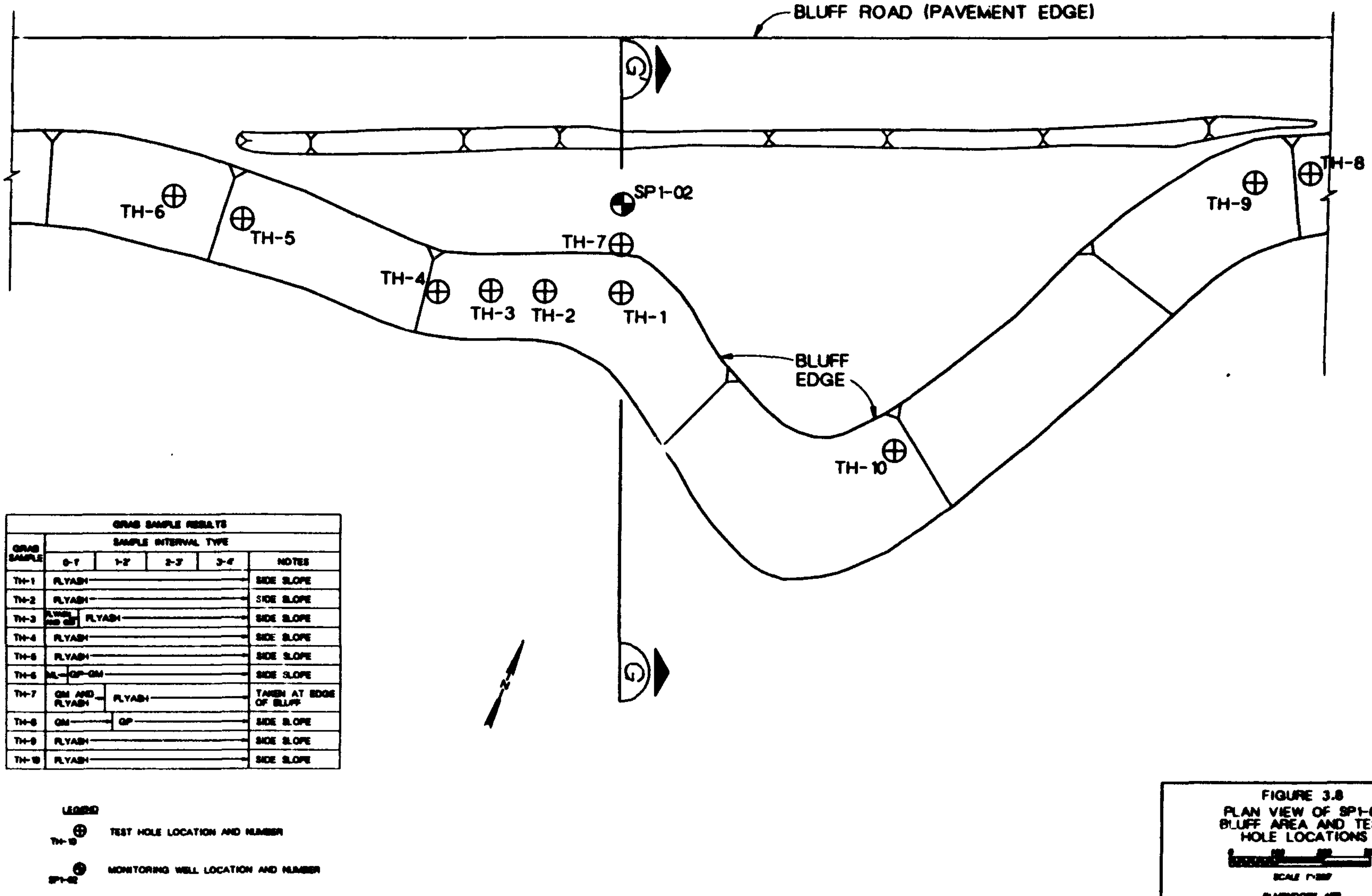


NOTES:

1. THIS CROSS SECTION IS BASED ON BORINGS LOGGED BY CH2M HILL AND OTHERS. THE BORING LOGS RELATE INFORMATION DEPICTING SUBSURFACE CONDITIONS ENCOUNTERED AT SPECIFIC TIMES AND DATES. SUBSURFACE CONDITIONS MAY VARY BETWEEN BORINGS, AND SUBSURFACE CONDITIONS (ESPECIALLY WATER LEVELS) MAY CHANGE WITH THE PASSAGE OF TIME.
2. ELEVATIONS (ABOVE MEAN SEA LEVEL) BASED ON SURVEY BY [illegible] ENGINEERING AND AEROMAP.

FIGURE 3.7

CROSS SECTION F-F' ALONG BLUFF AREA



GRAB SAMPLE RESULTS					
GRAB SAMPLE	SAMPLE INTERVAL TYPE				NOTES
	0-1'	1-2'	2-3'	3-4'	
TH-1	FLYASH				SIDE SLOPE
TH-2	FLYASH				SIDE SLOPE
TH-3	[illegible] AND GM	FLYASH			SIDE SLOPE
TH-4	FLYASH				SIDE SLOPE
TH-5	FLYASH				SIDE SLOPE
TH-6	ML	GP-GM			SIDE SLOPE
TH-7	GM AND FLYASH	FLYASH			TAKEN AT EDGE OF BLUFF
TH-8	GM	GP			SIDE SLOPE
TH-9	FLYASH				SIDE SLOPE
TH-10	FLYASH				SIDE SLOPE

FIGURE 3.8
PLAN VIEW OF SP1-02
BLUFF AREA AND TEST
HOLE LOCATIONS

SCALE 1"=200'

ELMENDORF AFB
ANCHORAGE, ALASKA

Table 3-3

Expanded Legend for Geologic Cross Sections

Group Symbol	Group Name	Group Symbol	Group Name
FA	FLYASH (FILL)	SPandGP	INTERBEDDED SAND AND GRAVEL
OL	ORGANIC SILT	GM	POORLY GRADED SILTY GRAVEL
ML	SILT SILT WITH SAND SILT WITH SAND AND GRAVEL SILT WITH GRAVEL SANDY SILT WITH GRAVEL	GM-GP	POORLY GRADED SILT WITH GRAVEL
		GP-GM	POORLY GRADED GRAVEL WITH SILT
		GC	GRAVEL, VERY CLAYEY
CL	CLAY SILTY CLAY SILTY LEAN CLAY	GP	POORLY GRADED GRAVEL WITH SAND GRAVEL WITH SAND SANDY GRAVEL GRAVEL GRAVEL WITH SAND AND COBBLES
SM	SANDY SILT		
SP	POORLY GRADED SAND WITH SILT POORLY GRADED SAND POORLY GRADED SAND WITH GRAVEL GRAVELLY SAND	GW	WELL GRADED GRAVEL WITH SAND WELL GRADED GRAVEL
		GW-GM	WELL GRADED GRAVEL WITH SILT
SW	WELL SORTED SAND	CL?	CLAY (SUSPECT DESCRIPTION)
		GC?	CLAYEY GRAVEL, (SUSPECT DESCRIPTION)

— · — ESTIMATED BOUNDARY BETWEEN FILL AND NATIVE SOIL

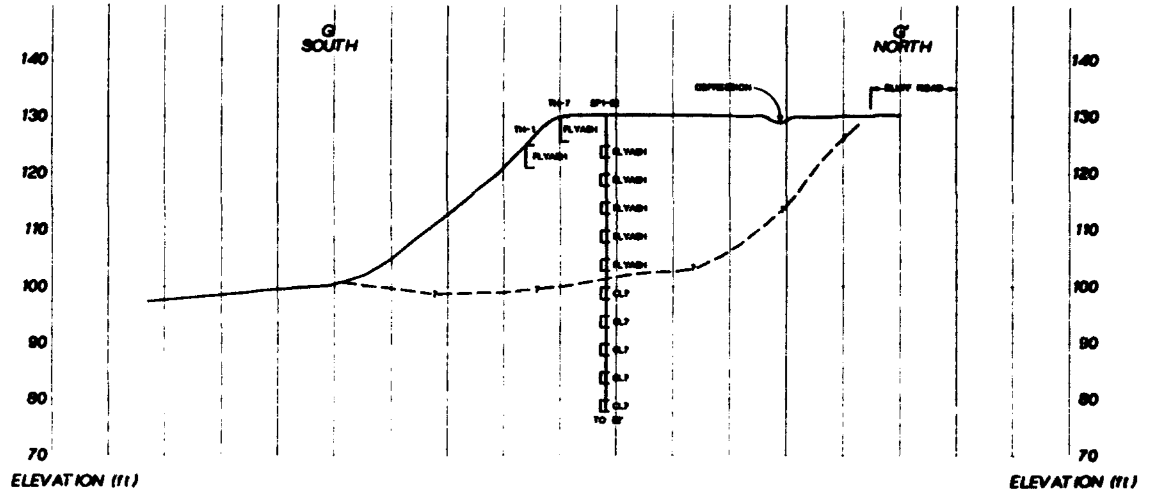
• • • • GRADATIONAL CONTACT; BASED ON MATERIAL TYPE OR DEPOSITIONAL TYPE

╪ SAMPLE INTERVAL

▽ WATER LEVEL MEASURED IN BOREHOLE DURING OR IMMEDIATELY AFTER DRILLING

SOIL BORING LOGS ARE IN APPENDICES B AND C.

↙ CROSS SECTIONAL CHANGE IN DIRECTION



LEGEND

—?— — APPROXIMATE BOUNDARY BETWEEN FLYASH AND NATIVE SOIL

SAMPLE INTERVAL AND TYPE

10'
10'
SCALE

NOTES:

1. THIS CROSS SECTION IS BASED ON BORINGS LOGGED BY CH2M HILL AND OTHERS. THE BORING LOGS RELATE INFORMATION DEPICTING SUBSURFACE CONDITIONS ENCOUNTERED AT SPECIFIC TIMES AND DATES. SUBSURFACE CONDITIONS MAY VARY BETWEEN BORINGS, AND SUBSURFACE CONDITIONS (ESPECIALLY WATER LEVELS) MAY CHANGE WITH THE PASSAGE OF TIME.

2. ELEVATIONS (ABOVE MEAN SEA LEVEL) BASED ON SURVEY BY [illegible] ENGINEERING AND AEROMAP.

FIGURE 3.9
CROSS SECTION G-G'
ACROSS BLUFF AREA
0 100 200 300
SCALE 1"=200'
ELMENDORF AFB
ANCHORAGE, ALASKA

3.2.3.1 Soil Profile

Soil found in the bluff running along the POL pipeline differed distinctly from soil found at the base of the bluff in the Ship Creek floodplain. The soil running through and along the top of the bluff following the POL pipeline corridor generally consisted of three layers: a thin veneer of loess, glacioalluvial deposits, and the glacioestuarine deposits that comprise the Bootlegger Cove Formation.

The loess, a ubiquitous windblown silt, ranged from less than 1 foot to 8.5 feet in thickness, and was found in all borings, except SB26 and SB27. The windblown silt was medium to very stiff and contained fine sand seams. Underneath the loess was a gradational layer of granular material. This gradational layer ranged from 2 to 6 feet in thickness and consisted of loose- to medium-dense, poorly sorted, interbedded layers of silty sands, sands, and gravels. The underlying glacioalluvial deposits generally contained interbedded layers of sands and gravels, along with an occasional coal lens as thick as 2 inches and coal fragments. This granular material was loose to dense and ranged from about 60 to 90 feet in thickness. Interbedded layers of stiff clay and silts characteristic of the Bootlegger Cove Formation were found 53.5, 47, 58, and 75.5 feet below the surface in borings SB19, SB21, SB23, and SB28, respectively.

Fly ash appears to have been used as fill along the shoulder of the bluff in a 500-foot-long area surrounding Monitoring Well SP1-02, and at least a 1,000-foot-long area surrounding Monitoring Wells SP2/6-03, SP2/6-04, GW-6A, and SP2/6-05. The extent of fly ash surrounding SP1-02 is described in more detail in Section 3.2.3.3.

The soil along the bottom of the bluff generally contained recent alluvial deposits and, to a lesser degree, fill and colluvial deposits lying on beds of silt and clay from the Bootlegger Cove Formation.

Alluvial deposits were found in all borings along Cross Section 3-8 and ranged in thickness from 7 to 30 feet. These deposits are associated with the Ship Creek floodplain and alluvial fans; they generally consisted of interbedded layers of well-graded, loose- to medium-dense silty clay, silty sands, sands, and gravels.

Borings MW13, MW14, MW15, and MW16 also contained soil that can be characterized as colluvial or alluvial fan deposits. These deposits ranged from about 10 to 12 feet in thickness, and included interbedded layers of peat (in MW16), silty clay, clays, silts, sands, and gravels. The fine material was medium stiff to hard; the granular material was loose to medium dense. Silt and clay beds from the Bootlegger Cove Formation were found at depths of 14, 7.5, and 15 feet in borings MW13, MW16, and MW17, respectively.

Boring MW08 also contained well-graded gravel with sand and silt, which had been used as subgrade road fill. This material was very dense and also contained cobbles as large as 8 inches in diameter.

3.2.3.2 Soil Physical Analyses

Five soil samples were reexamined in the CH2M HILL Redding Laboratory to either verify their field classifications or evaluate their fine material fractions. Soil samples were collected from borings SB01, SB19, SB21, and SB28, and were tested to measure liquid and plastic limits (or lack of), plasticity index, and, in the case of SB28, particle size distribution. With the exception of a silty clay sample collected from an interval of 76 to 78 feet, the fine fraction was so limited that liquid and plastic limits and plastic index could not be measured. Boring sample 5SB28-76 had a liquid limit of 19.5 and a plastic limit of 14.4 along with a moisture content of 13.2 percent. Based on the USCS, this sample of the Bootlegger Cove Formation is classified as silty clay.

3.2.3.3 Fly Ash Observations Near Well SP1-02

As mentioned above, soil samples and cuttings from the boring for Monitoring Well SP1-02 contained fly ash. Fly ash was a by-product of coal used by Elmendorf AFB power plants until the late 1960s when the plants were converted to natural gas. A power plant is about 1000 feet north and east of SP1-02, across Bluff Road.

Well SP1-02 is 8 feet in from the shoulder of the bluff and was drilled to 52 feet. According to the boring log, fly ash was found from depths of 0.5 to 22.5 feet below the surface, and soil with interbedded fly ash was found up to 46 feet below ground surface. Groundwater in SP1-02 was measured at depths ranging from 31.5 to 32.6 feet in the summer and fall of 1992.

The bluff in this area had a relief of about 30 feet with a 2:1 slope facing south. About 30 to 40 feet on the north side of SP1-02, a linear depression ran parallel to and following Bluff Road (Figure 3-8). Vegetation on the bluff consisted of grass; vegetation on the slope consisted of brush with willow and alder trees. The diameter of the tree trunks ranged from less than about 8 inches in the immediate slope area around SP1-02, to greater than 12 inches in the areas 300 feet north and 300 feet south on the sideslope.

To further define the areal and vertical extent of fly ash in the vicinity of SP1-02, 10 test holes were dug to 4 feet and grab samples were obtained for visual identification from the bluff shoulder and sideslope (Figures 3-8 and 3-9). Collecting grab samples at the shoulder and on the bluff sideslope allowed confirmation of the boring log description for fly ash in SP1-02.

Grab samples were collected from test hole TH-7 at the top of the bluff. Fly ash was found from 0.5 feet to the bottom of the test hole at 4 feet. Samples were collected along the slope about 8 feet from the shoulder on a sideslope surface to a depth of 4 feet. Fly ash was found from surface to a depth of 4 feet in test holes TH-1, TH-2, TH-3, TH-4, and TH-5. Test holes TH-6 (170 feet west of SP1-02) and TH-8 (235 feet east of SP1-02) contained interbedded layers of silt, silty gravel, and sandy gravel to a depth of 4 feet.

Sampling results indicated that fly ash is found as a continuous, horizontal layer, at least 8 feet thick and about 500 feet long, from SP1-02 to the edge of the bluff. By combining and extrapolating sampling results with drilling results and an inspection that identified the existence of a depression and new growth trees, the fly ash can be interpreted to exist in a 500-foot-long area that varies from 40 to 70 feet in width and is probably about 20 to 30 feet deep.

During the 1992 investigation, field confirmation was not performed for the reported fly ash around wells SP2/6-03, SP2/6-04, GW-6A, and SP2/6-05.

3.3 Hydrology

3.3.1 Hydrogeology

The hydrogeology of OU 5 was evaluated using lithologic data collected during drilling operations and water level and slug test data collected at monitoring wells. The drilling results were used to confirm previously reported lithologic characteristics of an unconfined aquifer that constitutes the uppermost of three hydrostratigraphic units. The water level and slug test data were used to evaluate groundwater flow within the unconfined aquifer. Groundwater flow characteristics of the confined aquifer are discussed briefly using existing data (no groundwater flow characterization of the confined aquifer was performed as part of the OU 5 investigation). The interaction between unconfined groundwater and flow in Ship Creek is also discussed.

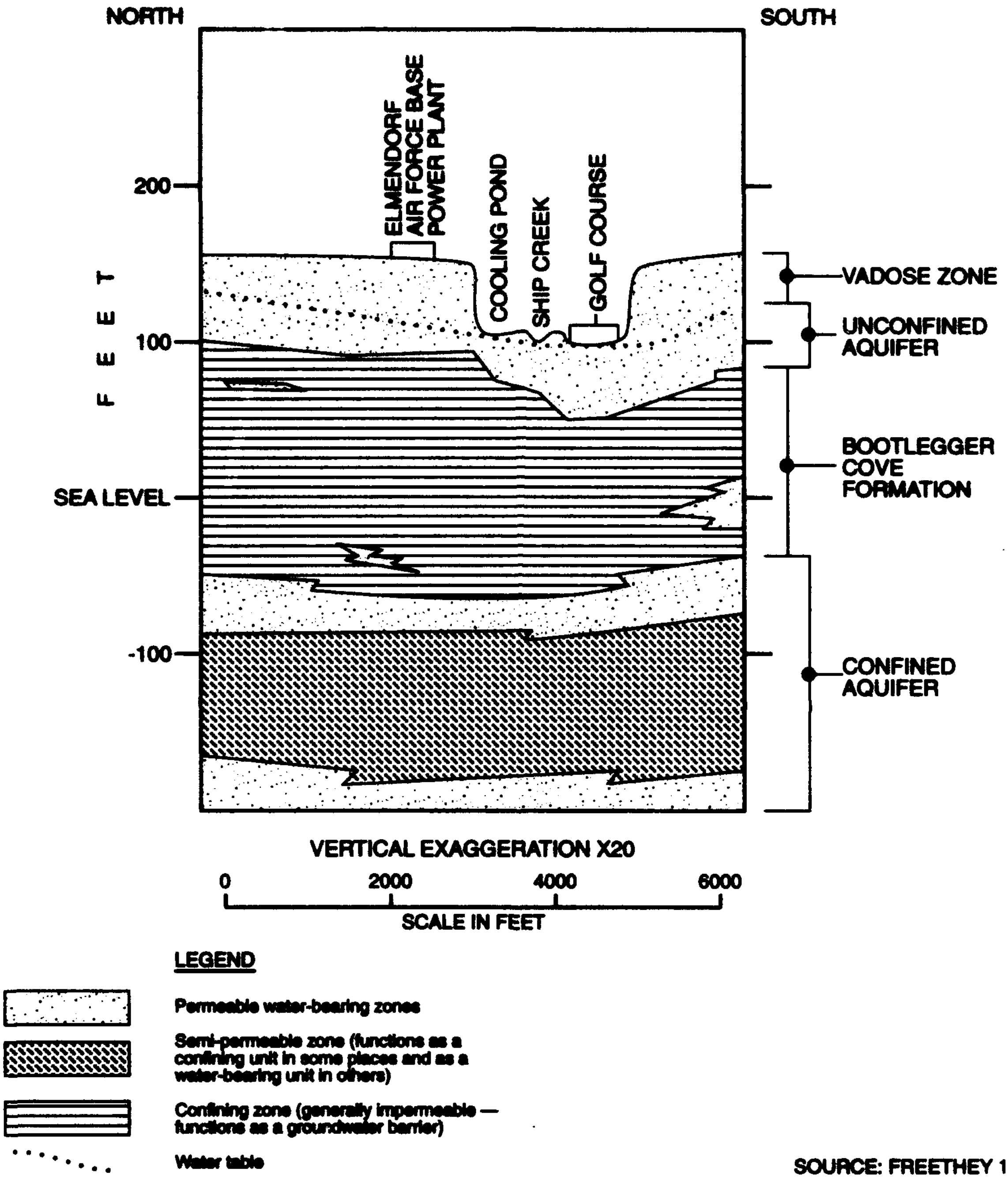
3.3.1.1 Hydrostratigraphic Units

The principal waterbearing units within OU 5 are a layered sequence of unconsolidated sediments that range in lithology from coarse sands and gravels to low permeability silts. The coarser sediments are of glacial and glaciofluvial origin and were deposited during the late Pleistocene. The fine-grained sediments are of glacioestuarine origin. The full sequence of sediments has been separated into three major hydrostratigraphic units. The stratigraphic relationship between these three units is depicted in Figure 3-10. The uppermost unit, referred to as the unconfined aquifer, consists predominantly of interbedded sands and gravels with thin, discontinuous, silty zones. The middle unit is the Bootlegger Cove Formation, which consists primarily of silt and clay and acts as a confining unit (or aquitard) separating the two aquifers. The lower unit, referred to as the confined aquifer, consists of interlayered silts and sands. The confined aquifer has been tapped by water supply wells on base and in other parts of the Anchorage area. The general lithologic characteristics of each unit are summarized below.

Unconfined Aquifer

The unconfined aquifer consists predominantly of sandy and gravelly sediments deposited as outwash near the terminus of the coalesced Matanuska and Knik glaciers. Within OU 5, the unconfined aquifer consists of these outwash deposits at higher elevations, and of recent alluvial sediments found at lower elevations in the Ship Creek flood plain. The unconfined aquifer ranges in thickness from less than 10 feet within the Ship Creek flood plain to as much as 80 feet in areas of higher surface elevation.

The bluffs along the north side of Ship Creek are the most significant topographic feature in OU 5 and are cut entirely into the sands and gravels of the unconfined aquifer. The cross sections in Figures 3-2 through 3-7 and 3-9 illustrate the stratigraphic and topographic features of the unconfined aquifer. Detailed descriptions of the stratigraphy of the unconfined aquifer in OU 5 are provided in the boring logs in Appendixes B and C.



SOURCE: FREETHEY 1976

Figure 3.10. Hydrogeologic Cross Section of OU 5, Elmendorf AFB, Anchorage, Alaska

ELMF310.FH3 - VMG 6/6/93 SAC

Confining Unit

The Bootlegger Cove Formation consists predominantly of silt and clay deposited during the late stage of the Naptowne glaciation, near the time of maximum ice extent (Ulery and Updike, 1983). Regionally this unit extends across the Knik Arm and underlies the surficial sands throughout most of the Anchorage area (Ulery and Updike, 1983; Cederstrom et al, 1964). Within the Ship Creek drainage, the Bootlegger Cove Formation pinches out near the Chugach Mountains, eliminating the confining layer between the confined and unconfined aquifers in the area where both aquifers are recharged. The unit thickens toward the west, and the upper surface rises in elevation so that it is exposed along the coast and prevents unconfined groundwater from discharging along the Knik Arm eastern shoreline (Freethey et al, 1976). Within OU 5, the Bootlegger Cove Formation separates the confined and unconfined aquifers and is approximately 50 to 200 feet thick, according to historical well logs (Cederstrom et al, 1964).

Confined Aquifer

The confined aquifer consists of interlayered sand, silty sand, and clay. Well logs for water supply wells drilled on or near Elmendorf AFB indicate that the confined aquifer is approximately 550 feet thick (Cederstrom et al, 1964). The majority of the sediments logged in this zone are either glacial till or fine-grained. The upper 50 to 100 feet appear to be the most productive zone in which to screen a water supply well.

3.3.1.2 Groundwater Flow

The process of evaluating groundwater flow within OU 5 involved several steps. In the initial step, existing literature was reviewed and a conceptual understanding of regional groundwater flow was established. The data collected during the OU 5 investigation were then evaluated and interpreted within the context of the regional setting. Because the unconfined aquifer is most vulnerable to contamination by surface sources, emphasis was placed on understanding its flow characteristics. Groundwater flow data from the confined aquifer were not collected as part of this investigation.

Regional Groundwater Flow

Regional hydrogeologic studies have shown that the unconfined aquifer is recharged by infiltration over its entire area of exposure. The highest recharge rate of the aquifer occurs along the slopes of the Chugach Mountains and along the upper reaches of Ship Creek, and discharges along the lower reaches of Ship Creek (Weeks, 1970; Cederstrom et al, 1964; Waller, 1964; Somers and Marcher, 1965). The Elmendorf Moraine acts as a low-flow barrier to the north, and the upper surface of the Bootlegger Cove unit performs the same function to the west and along the base of the unconfined aquifer. The Bootlegger Cove Formation acts as a flow barrier to the west because its upper surface rises to the ground surface along the coast, which prevents unconfined groundwater from discharging directly into Knik Arm. These barriers cause unconfined groundwater to flow toward the lower reaches of Ship Creek. A water table contour map of the Anchorage area (Dearborn and Freethey, 1974) shows that unconfined groundwater flows toward lower Ship Creek from the south and the north, then moves down the Ship Creek valley toward Knik Arm. This pattern suggests that unconfined groundwater in the Ship Creek drainage basin flows toward the creek, either entering the creek as base flow or moving down the valley as groundwater in the recent alluvial sediments. This flow pattern places OU 5 downgradient of nearly all of Elmendorf AFB, and in an area of groundwater discharge to Ship Creek and Knik Arm.

These same studies indicate that Ship Creek is a gaining stream in its lower reaches. The unconfined aquifer is recharged through alluvial fans along the front of the Chugach Mountains east of Anchorage. Natural groundwater flow is believed to be westward with discharges in Cook Inlet and Knik Arm. Because of these flow constraints, it is probable that unconfined groundwater is contributing to base flow in the lower reaches of Ship Creek.

Water-Level Monitoring Results

The data used to evaluate unconfined groundwater flow characteristics in OU 5 included three rounds of water level data collected at each monitoring well in August, September and October. In addition, hydraulic conductivity estimates based on slug test data for 11 newly installed wells were used to evaluate flow rates. These data are summarized in Appendix E.

Local Groundwater Flow

The OU 5 data are used to illustrate the groundwater flow direction for the unconfined aquifer using water level contour (Figure 3-11). As with the basewide groundwater contour map, this map was generated by kriging water level data collected at OU 5 monitoring wells using SURFER®, and was verified by comparing to a hand-drawn map created using linear interpolation. The groundwater flow direction and flow gradient illustrated on this map represent conditions on September 24 and 25, 1992, the days when the data were collected.

The flow lines on Figure 3-11 indicate that groundwater flows toward the southwest on the eastern end of OU 5 and toward the south-southwest on the western end.

This pattern is consistent with the hypothesis that groundwater enters Ship Creek as base flow in the vicinity of OU 5. The flow gradient also steepens on the western end of OU 5 in response to the thinning of the unconfined aquifer at the base of the bluff.

3.3.2 Groundwater-Surface Water Interactions

Based on published studies of regional flow in the Ship Creek drainage (Patrick, 1989; Freethey, 1976; Weeks, 1970; Dearborn and Freethey, 1974), it is believed that unconfined aquifer groundwater discharges to the surface in the vicinity of OU 5. This

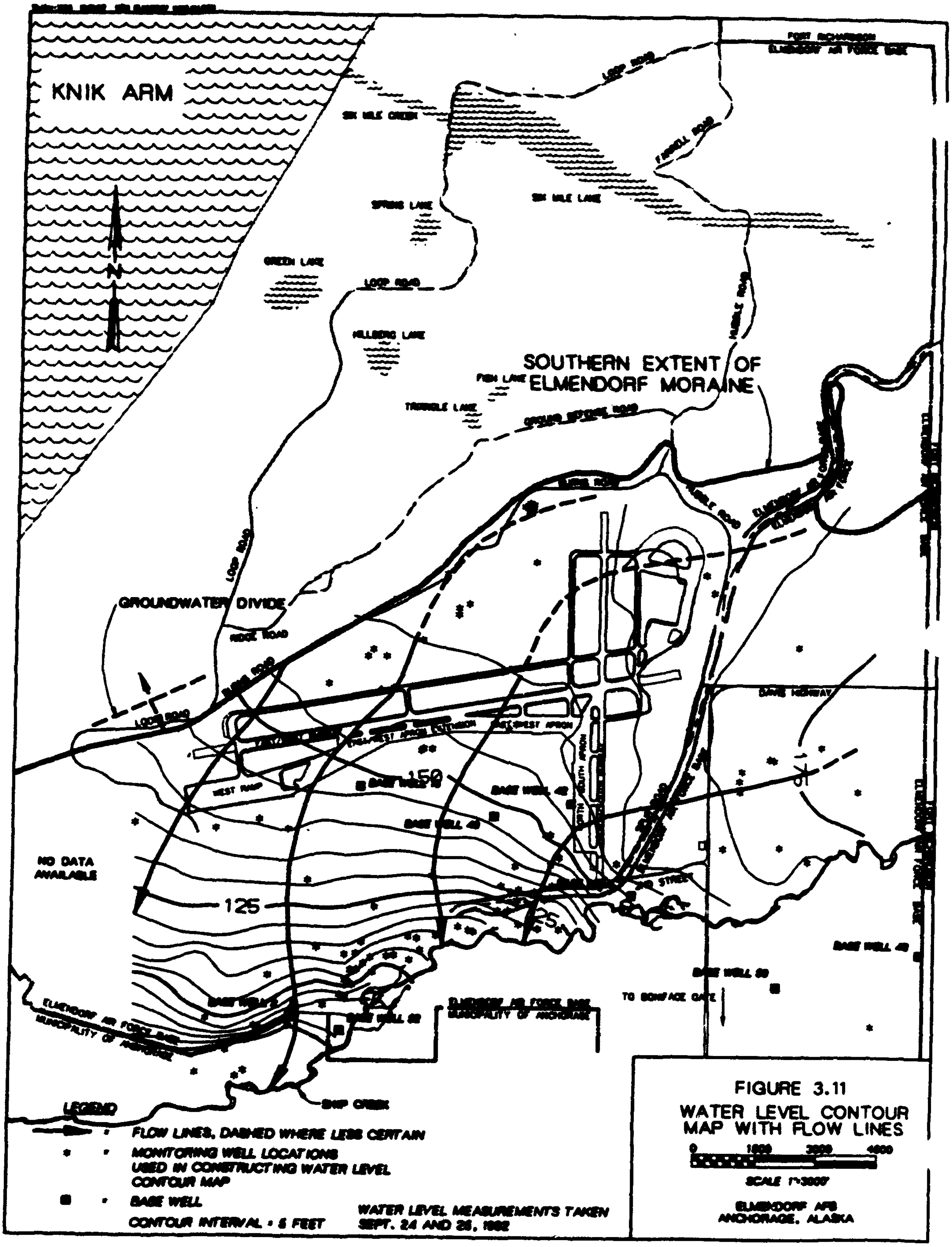


FIGURE 3.11
WATER LEVEL CONTOUR MAP WITH FLOW LINES

discharge is manifested in several forms such as seeps and springs, wetland ponds, and as base flow in Ship Creek.

The seeps observed along the bluff occur at an elevation similar to that of the water table, which suggests a groundwater source. Water has also been observed to flow from at least some of these seeps during early winter months when snow covers the ground, further suggesting that these seeps are fed by groundwater contiguous with the OU 5 saturated zone, and are not caused by localized perched water tables. Water emerging from the majority of these seeps is routed to Ship Creek through the local storm water drainage network. Although no measurements of seep flow volume have been made, most appear to be relatively low-volume seeps (generally less than several gallons per minute).

The ponds within the OU 5 study area include beaver ponds along the terraces of the OU 5 bluff, and low-lying wetland-bog pond depressions along the base of the bluff. These ponds drain from north to south, and depending on their location downgradient from specific OU 5 source areas, are potential receptors of contaminants of concern. The ponds, in turn, discharge to drainage ditches that route OU 5 runoff to Ship Creek.

The water table contour maps generated for OU 5 indicate that groundwater flows toward Ship Creek. Water not discharged as seeps or into ponds flows into Ship Creek alluvium. It has not been determined how much groundwater discharges to the creek as base flow, and how much flows through the alluvium as underflow. Regardless of which flow path was followed, the data collected as part this investigation are consistent with published studies, which indicate that unconfined groundwater flows into the Ship Creek valley and ultimately to Knik Arm.

3.3.3 Streams

Ship Creek is the only stream identified during field investigations as being potentially affected by OU 5 source area runoff (Figure 2-7). Other stream channels within

OU 5 serve to connect the wetland pond systems or drain them to Ship Creek as discussed in the following section. Five sample stations were selected for the survey of the creek, three above the Ship Creek Hatchery Dam (SW/SE01, SW/SE02, and SW/SE03), and two downstream of the dam (SW/SE11 and SE12).

The headwaters of Ship Creek are in the Chugach Mountains east of Anchorage. Numerous mountain tributaries combine to form a channel approximately 24 miles long, which ultimately discharges into Knik Arm. The total area of the drainage basin is 117 square miles. A 4.2-mile stretch of Ship Creek traverses Elmendorf AFB. From 1970 to 1980, the mean annual flow for this section was 144 cubic feet per second (cfs) (USGS, 1981).

Before 1942, the entire length of Ship Creek was open to spawning salmon. Five dams were built along Ship Creek between 1942 and 1962. The Chugach Dam at the Chugach Electric Association power plant is about one-third mile from Knik Arm, and the Ship Creek Hatchery Dam and the Central Dam (since removed) are within Elmendorf AFB in the lower Ship Creek basin. The Fort Richardson Dam and the Anchorage water diversion dam are on the Fort Richardson Army Post, upstream of Elmendorf AFB. Three of the dams were once total barriers to salmon migrating upstream; however, fish ladders have been installed at the dams in the lower Ship Creek basin to allow fish to reach spawning areas upstream.

Although the ADFG blocked the fish ladders at the Ship Creek Hatchery Dam because they were concerned that salmon dying after spawning upstream might introduce infectious organisms into the hatchery, some adult salmon were observed above this dam by Rothe et al (1983). Therefore, the Ship Creek Hatchery Dam is not a complete barrier. However, the uppermost dam, the Anchorage water diversion dam, located 10.5 miles upstream from Knik Arm, is 40 feet high and forms a complete barrier to salmon.

Flows in Ship Creek are a function of precipitation, snow melt, diversions for municipal and/or industrial use, and recharge (loss) to the groundwater system. Ship Creek is used for municipal and military water supplies and for cooling water for three power plants (Elmendorf AFB, Fort Richardson, and Chugach Electric Association). Average annual diversions for the power plants are about 11 cfs (COE, 1979), but most of this is returned to the creek. Water diverted at the Anchorage water diversion dam supplies about one-half of the municipal and military demand for Anchorage, Elmendorf AFB, and Fort Richardson.

The Bootlegger Cove Formation that forms the essentially impermeable layer between the shallow unconfined groundwater system at Elmendorf AFB and the underlying confined Anchorage aquifer is present under the lower 6 miles of Ship Creek. Above that point, flows in Ship Creek apparently recharge the Anchorage aquifer. Long-term flow data at the Anchorage water diversion dam and at an Elmendorf AFB gaging station 4.7 miles upstream from Knik Arm indicate that some upper sections of Ship Creek are losing-stream sections. Apparently, about 17 cfs of creek water is lost through the glacial outwash material into the deeper groundwater system (Weeks, 1970). The lower 5 or 6 miles of Ship Creek is a gaining stream because flows increase as surface water and shallow groundwater flow into the creek and are retained within the surface drainage by the underlying Bootlegger Cove Formation.

Peak flows occur in Ship Creek in June or July as a result of snow melt in the watershed; low flows occur in March, before breakup. Based on records at the Elmendorf AFB gaging station, from 1970 to 1980 (USGS, 1980) the mean annual discharge of Ship Creek ranged between 91 and 260 cfs, with an average of 144 cfs. Both minimum and maximum discharges during this 10-year period were recorded in 1971: 5.8 cfs in March and 1600 cfs in August. Rothe et al (1983) observed that a section of Ship Creek from the Fort Richardson and Elmendorf AFB boundary downstream to the eastern end of the golf course was dry or completely frozen during March 1983. It has also been stated that during the early spring, the entire flow in Ship Creek may be withdrawn for cooling water at the Elmendorf AFB power plant or used by the fish hatchery[b].

3.3.4 Ponds

Four ponds located between the middle and bottom of the OU 5 bluff were investigated during this RI. As depicted on Figure 2-7, they are (from east to west): a beaver pond just northeast of the old power plant cooling pond (SW/SE13), the golf course beaver pond located just northwest of the old power plant cooling pond (SW/SE04 and SW/SE05), the beaver pond below the snow disposal area and just east of Building 22-002 (SW/SE07), and a pothole pond on the bluff below the COE building (SW/SE08).

The pond at SW/SE13 is 1 to 2 acres in size and is contained between the bluff and the gravel haul road connecting Post Road and the golf course clubhouse. Inlets and discharge points were not readily observed during the survey, but it appears that the seeps and springs prevalent along the bluff pass water into the pond, while seeps under the road pass water into a lower gradient pond on the opposite side of the road.

The golf course beaver pond, located between the railroad tracks and Ship Creek, is approximately 2 acres in size with a maximum depth of about 8 feet (average 2 to 3 feet). The water sources for the pond are a drainage ditch (located between the bluff and the JP-4 tanks) that drains the upland wetlands, and seeps SL22 and SL23 (Figure 2-2). During both spring and summer sampling periods, the pond appeared to be discharging at two points along the beaver dam at about 10 gallons per minute (gpm). As shown on Figures 2-2 and 2-7, the discharge routes are through small terraced wetland ponds and streams that ultimately discharge directly into Ship Creek.

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[b] This information was obtained during personal communications with Allen Richmond, the Elmendorf AFB natural resources planner, on October 8-10, 1991, and subsequent phone conversations.

The beaver pond below the snow disposal area is also about 2 acres in size (depth not determined), and was observed to drain into the wetlands between the base of the bluff and the railroad tracks. Discharge flows were observed to be about 5 to 10 gpm during the spring sampling period.

The pothole pond (downgradient of the COE building) is at the end of a haul road about halfway down the side of the bluff. It is a small pond about 300 square feet in surface area. The pond's water source is most likely fed by springs or seeps, as well as supplied from precipitation runoff from the bluff slope.

3.4 Land Use

3.4.1 Population

The current resident population of Elmendorf AFB is about 8600 people, consisting mostly of young men and women with families (CH2M HILL, 1992b). Children (defined as less than 18 years of age) make up 37 percent of the base population (Harding Lawson Associates, 1988b). Most military personnel and their families probably do not spend more than 5 years at Elmendorf AFB. Some civilian personnel who work on base but do not live there can be expected to spend 40 hours per week at the base for several years. The current population of Anchorage surrounding Elmendorf AFB is about 240,000.

Only two residences are immediately downgradient of OU 5. They are located at the fish hatchery and house families of employees of the Alaska Department of Fish and Game (ADFG). Each dwelling houses two adults and two children.[c] The other areas downgradient of OU 5 are primarily used for industrial or recreational purposes.

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[c] Information on the hatchery was obtained in a telephone conversation with Darrell Keifer, hatchery manager, ADFG, on October 8, 1992.

An unknown, but small, number of homeless adults occupy tents along Ship Creek and the bluff in the industrial area west of the OU 5 study area. The number of homeless living along Ship Creek can be expected to decline during winter months because of colder temperatures. During the RI field activities in the summer of 1992, shelters made of plastic sheeting were observed on the bluff between the COE building (Building 21-700) and the railroad tracks. At the same time, camps were observed near a beaver pond between Ship Creek and the ARRC railroad yard, approximately two-thirds mile west of the COE building.

3.4.2 Use and Access

General land uses at OU 5 are shown on Figure 3-12 and described below.

- Post Road is used as a major access route onto the base.
- Bluff Road carries traffic along the southern part of the base to the power plant and COE building.
- The railroad schedules several trains a day through the area near OU 5 in the summer, fewer in the winter. Some maintenance, switching, and storage of rail cars occurs at the western end of OU 5.
- The Elmendorf AFB golf course in the southern part of OU 5 serves military personnel and guests during the summer and provides a cross-country skiing area in the winter.
- A popular picnic area is located along Ship Creek between the Post Road gate and the golf course.
- The hill on the west side of Source SS53 is a popular sledding area for military families during the winter.
- A winter snowmobile route parallels the pipeline at Sources SD40/ST46.
- A limited trout and salmon fishery occurs on Ship Creek. Fishing for trout and Dolly Varden occurs mostly in the late summer and early fall above the Chugach Dam. Fishing below the Chugach Dam is primarily for returning salmon during the summer.

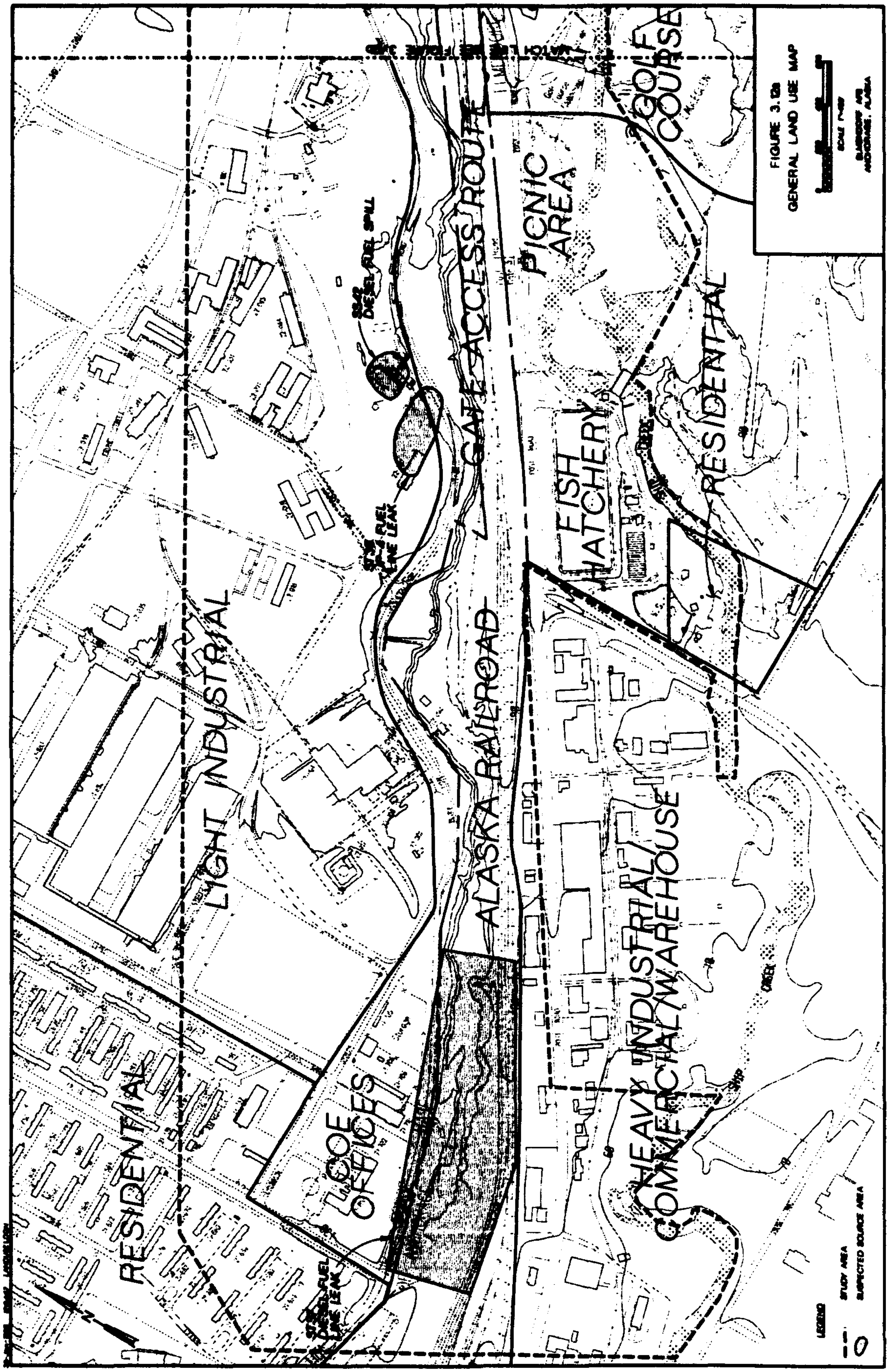

FIGURE 3.12a
GENERAL LAND USE MAP

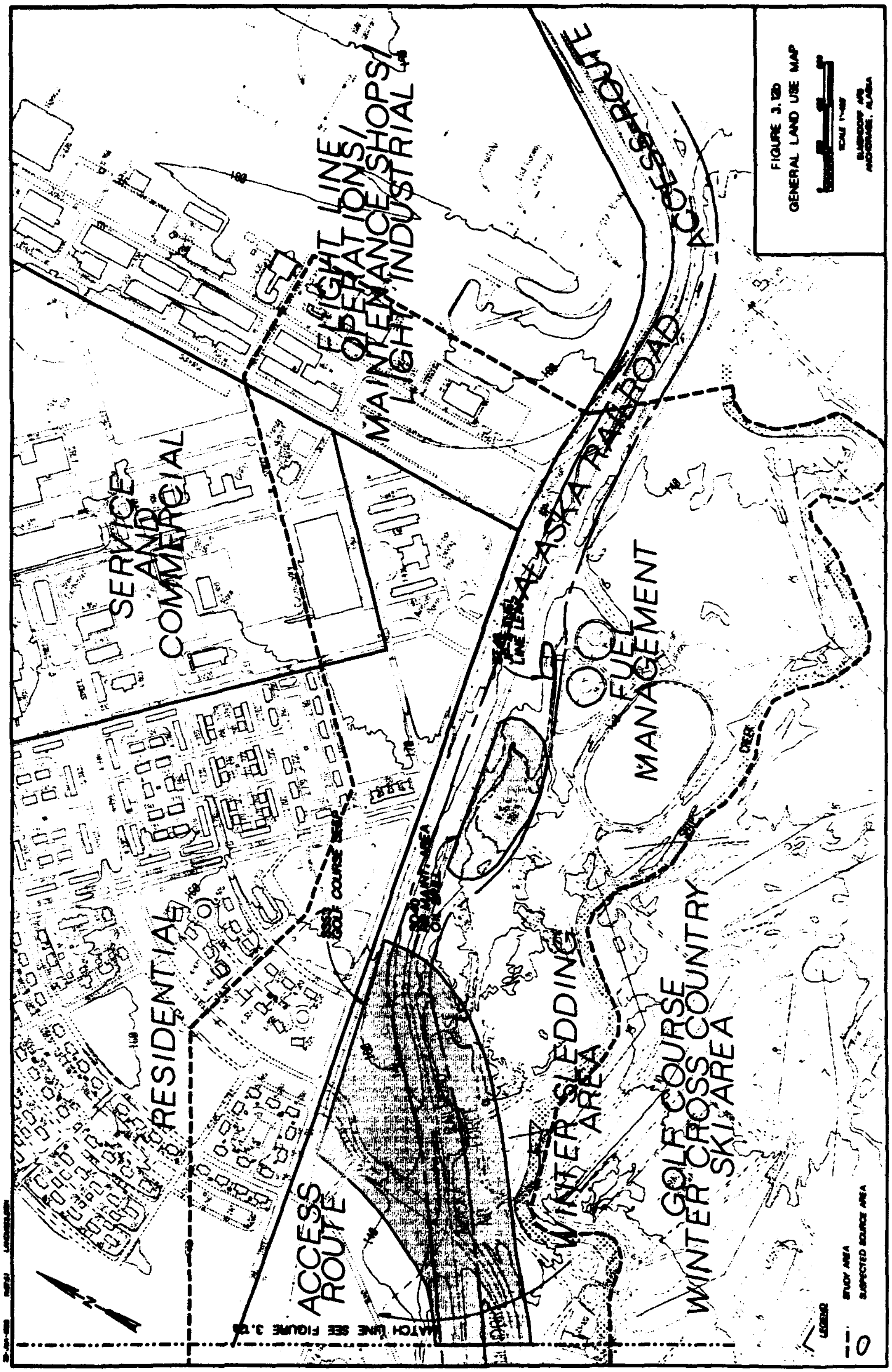
FIGURE 3.12b
GENERAL LAND USE MAP

ELMENDORF AFB
ANCHORAGE, ALASKA

- The fish hatchery has a viewing area on Ship Creek that attracts approximately 55,000 visitors per summer to observe salmon returning to spawn.
- The area southwest of OU 5 is used as a major industrial, warehouse, and commercial area for Anchorage. This area is zoned I-2, heavy industrial, by the Municipality of Anchorage (MOA).
- North of the pipelines, across Bluff Road and 2nd Street, are major residential, commercial, and industrial areas of the base.
- Walking trails are routed along the bluff area.

During the RI, field crews noted the following activities:

- Two adult women were collecting mushrooms on the bluff south of the COE building in late August and early September.
- Two teenagers were collecting golf balls in Ship Creek just above the dam at the fish hatchery. They indicated that this was a frequent activity in the summer months.
- Two elementary-age children were playing at the beaver ponds near Sources SD40/ST46. The children had built and launched a raft. The children stated that they and their friends often played in the area.
- All along the bluff area there was evidence, such as handmade "forts" and bicycle tracks, that children play in the woods during the summer months.

Access to the base is restricted by gates and fences and is limited to residents, workers, and authorized visitors. Visitors generally have to enter the base by the Boniface Parkway gate rather than the Post Road gate. At OU 5, only the underground tanks at Source SS42 are restricted by fences. The railroad property south of Sources SS37 and SS38 is generally accessible by the casual visitor and worker; however, the ARRC has posted signs to discourage use of the right-of-way.

3.5 Water Use

This subsection describes the water use downgradient of and at OU 5. The information presented comes from interviews with personnel from the USAF and ADFG. Additional information on water use came from surveys mailed to tenants of the ARRC property southwest of OU 5 and follow-up interviews. Literature searches and computer searches of USGS and Alaska Department of Natural Resources (ADNR) files were also conducted to identify wells downgradient of OU 5 and obtain drillers' logs or well construction logs of those wells. Finally, observations of recreational use of Ship Creek and ponds in OU 5 were recorded by the CH2M HILL field team during the field investigations.

3.5.1 Upper Aquifer

Development of the unconfined (shallow) groundwater in the lower Ship Creek valley (Boniface Parkway to Cook Inlet) has been limited. An infiltration gallery constructed in 1946 by the ARRC (then owned by the U.S. Department of Transportation) withdrew water from the creekbed alluvium through a 24-inch corrugated pipe at a capacity of about 5 million gallons per day (mgd). This gallery was about 2 miles downstream of the Elmendorf AFB boundary. The water has not been used since 1952 because of contamination (Freethey et al, 1976).

Elmendorf AFB well 1 was used as a backup drinking-water well until the late 1980s when TPH and chlorinated solvents were found in the water. Well 1 (Building 23-990) is a shallow well (16 feet deep) located just upgradient of the OU 5 study area on the north side of Ship Creek and near the north-south runway.

From the mid-1970s to the mid-1980s, water from the upper groundwater aquifer at OU 5 was used for fish production activities at the fish hatchery. The hatchery is located on military land, and is operated by the ADFG under a cooperative agreement with Elmendorf AFB. A gallery well was located east of the cooling pond and another well was located east of the hatchery shop building. These wells were abandoned because of low production and problems with suspected fuel contamination. Other shallow exploratory wells were drilled in the vicinity of the cooling pond and the golf course in 1969 by the USGS, and in 1975 by ADFG, but these wells are not currently used as a water supply.

3.5.2 Lower Aquifer

The water drawn from the lower groundwater aquifer at OU 5 is used for the following purposes:

- Drinking water and other domestic uses;
- Industrial purposes;
- Cooling water for the power plant; and
- Fish production at the fish hatchery.

The following paragraphs discuss the lower aquifer uses in more detail. Figure 3-13 shows the location of wells and the location of businesses contacted during the water use survey.

On military land in OU 5, four wells are screened into the lower aquifer: Base Supply Wells 2 and 52, and Hatchery Wells 2 and 3. (Hatchery Well 1 was a shallow production well that was abandoned and filled in because of low yield.) Base Supply Well 2 supplies cooling water for the power plant during low flow periods in Ship Creek and serves as a backup drinking-water well for Elmendorf AFB when Fort Richardson is unable to meet the demand. In spring 1992, sand was drawn into the well; as a result, the well was taken out of use in the fall of 1992 until repairs can be made.[4]

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[4] Information on Base Wells 2 and 52 was obtained in a telephone conversation with John Barbour, Elmendorf AFB Water and Wastewater Office, on October 13, 1992.

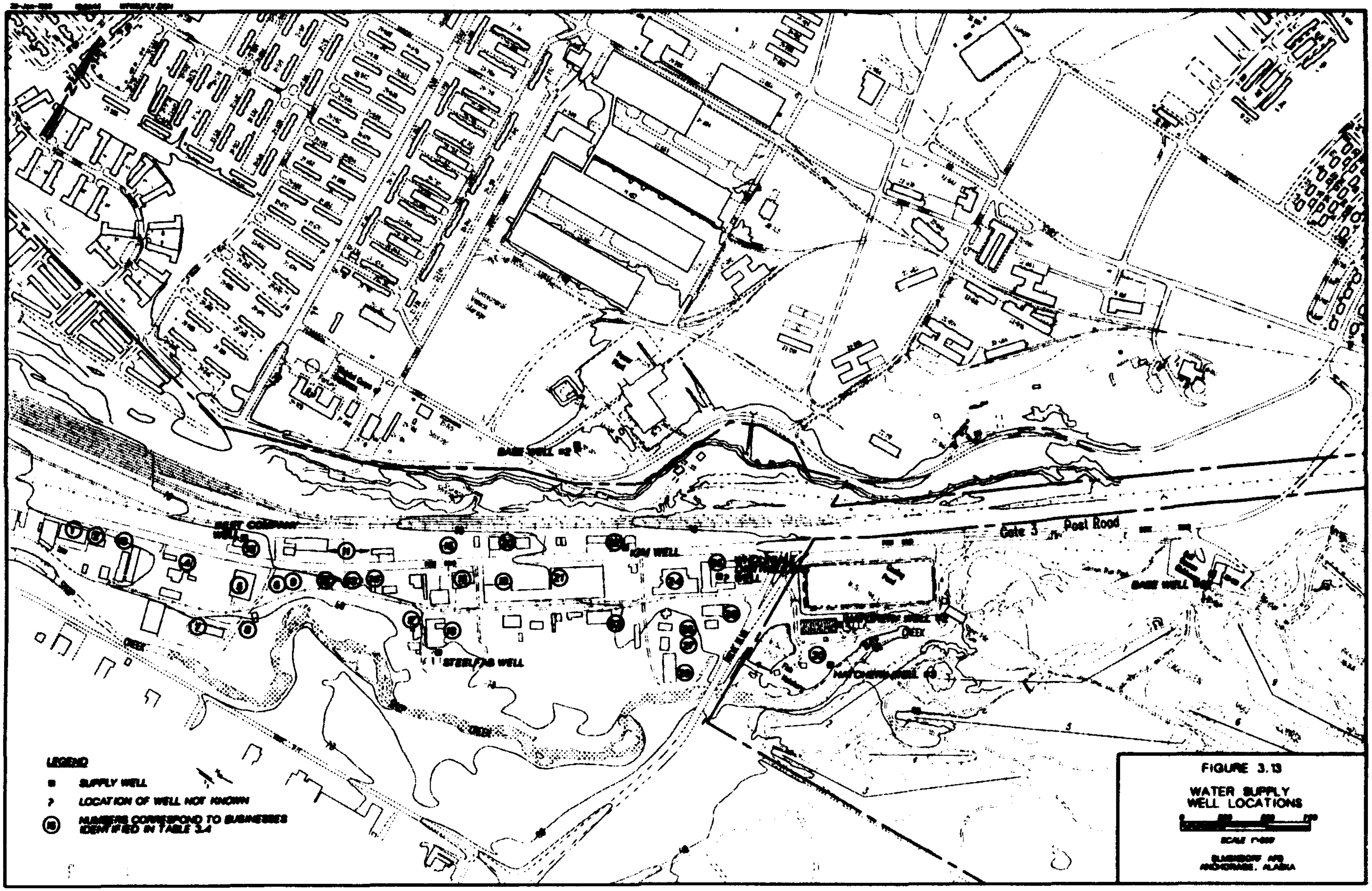

FIGURE 3.13

WATER SUPPLY WELL LOCATIONS

ELMENDORF AFB
ANCHORAGE, ALASKA

Base Supply Well 52 serves the golf course clubhouse. The water is used for drinking water, food preparation in the restaurant, and in the restrooms. The water is also used for cleaning golf carts. The clubhouse is in operation from approximately April to the first week in October, depending on the weather. The facility is occasionally opened during the winter months for parties and special events.

Hatchery Wells 2 and 3 were installed into the lower aquifer at the fish hatchery in 1985 and 1991, respectively. Hatchery Well 2 operates approximately 11 months, from July to the first of June; the water is used for incubation. Hatchery Well 3 operates for approximately 6 months each year—July, August, and February through May. The two production wells are not used for drinking water because the facility, including the two residences at the fish hatchery, are connected to municipal water supplies.[a]

Thirty water use surveys were mailed to land tenants in or near the industrial area southwest of OU 5 (Table 3-4). No responses were obtained from two of the tenants after follow-up phone calls or visits. An additional five tenants did not know the source of their water supply. It is assumed that those tenants who did not respond or did not know the source of their water, do not have water on their property, or are on public (MOA) water supplies.

The following four ARRC tenants reported an onsite well:

- Inlet Company (1833 Post Road);
- IGM (2433 Post Road);
- SteelFab (2132 Railroad Avenue), which also supplies water for Testing Institute of Alaska (2114 Railroad Avenue); and
- Wholesale Distributors of Alaska, Inc. (2548 Post Road).

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[a] Information on the hatchery wells was obtained in a telephone conversation with Darrell Keifer, hatchery manager, ADFG, on October 8, 1992.

Table 3-4

Results of Water Use Survey

Location on Figure 3-13	Property/Tenant/Phone	Responded to Survey	Source of Water Known	Drinking Water Source				Number of Years on Water Source[a]	Number of Workers on Property	Comments
				Well	Public (Municipal) Supply	Bottled	None			
1	Joe's Body Paint and Frame 1648 Post Road 278-2816	No	—	—	—	—	—	—	—	—
2	Dave Bates, Inc. 1700 Post Road 279-4353	Yes	Yes		x	—	—	4	0	—
3	Jackovich Industrial & Construction 1716 Post Road 277-1406	Yes	Yes	—	x	—	—	NR	NR	—
4	Chris Berg, Inc. 1748 Post Road 279-7736	Yes	Yes		X	—	—	NR	NR	—
5	Newberry Alaska, Inc. 1848 Post Road 258-9073	Yes	No	—	—	—	—	NR	NR	—
6	Alaska Crate and Pallet 1860 Post Road 279-7736	Yes	Yes	—	—	—	X	17	1	—
7	Eyak Trucking 1820 Railroad Avenue 258-6092	Yes	Yes	—	X	—	—	NR	2	—

Table 3-4

(Continued)

Location on Figure 3-13	Property Tenant/Phone	Responded to Survey	Source of Water Known	Drinking Water Source				Number of Years on Water Source[a]	Number of Workers on Property	Comments
				Well	Public (Municipal) Supply	Bottled	None			
8	LL Towing 1860 Railroad Avenue 337-7700	No	—	—	—	—	—	—	—	—
9	Prescott Equipment, Inc. 1860 Post Road 276-0537	Yes	Yes	—	X	—	—	NR	NR	—
10	Inlet Company 1833 Post Road 274-1551	Yes	Yes	X	—	—	—	26	8	A
11	Northern Consolidators, Inc. 1907 Post Road 276-5776	Yes	Yes	—	X	—	—	5	NR	—
12	Guardian Security 1940 Post Road 274-5275	Yes	No	—	—	—	—	—	—	—
13	Longstaff Engineers 2002 Post Road 276-7933	Yes	Yes	—	X	—	—	NR	5	—
14	Bills Services Auto Repair 2014 Post Road 276-0072	Yes	Yes	—	—	X	—	NR	2	—
15	F&M Small Engine 2121 Post Road 258-1942	Yes	Yes	—	X	—	—	NR	2	B

Table 3-4

(Continued)

Location on Figure 3-13	Property Tenant/Phone	Responded to Survey	Source of Water Known	Drinking Water Source				Number of Years on Water Source[a]	Number of Workers on Property	Comments
				Well	Public (Municipal) Supply	Bottled	None			
16	Alaska Plumbing & Heating 2132 Post Road 272-2451	Yes	Yes	—	X	—	—	30	15	—
17	Testing Institute of Alaska 2114 Railroad Avenue 276-3440	Yes	Yes	X[b]	—	—	—	NR	NR	—
18	SteelFab 2132 Railroad Avenue 278-5773	Yes	Yes	X	—	—	—	40+	<20	—
19	Air Van Lines, Inc. 2216 Post Road 272-0536	Yes	Yes	—	X	—	—	NR	30	—
20	Auto Electric 2217 Post Road 276-2606	Yes	Yes	—	X	—	—	NR	NR	—
21	Keystone Distribution 2320 Post Road 277-6536	Yes	Yes	—	X	—	—	13	25	—
22	IGM 2433 Post Road 276-4454	Yes	Yes	X	—	—	—	11	14-18	C

Table 3-4

(Continued)

Location on Figure 3-13	Property Tenant/Phone	Responded to Survey	Source of Water Known	Drinking Water Source				Number of Years on Water Source[a]	Number of Workers on Property	Comments
				Well	Public (Municipal) Supply	Bottled	None			
23	Standard Steel & Metals Company 2400 Railroad Avenue 272-8558	Yes	Yes	—	—	X	—	NR	1	—
24	Pacific Movers 2510 Post Road 276-5737	Yes	Yes	—	X	—	—	NR	35	—
25	Wholesale Distributors of Alaska, Inc. 2548 Post Road 277-8584	Yes	Yes	X	—	—	—	NR	NR	D
26	Paul's Services 2530 Railroad Avenue 258-4581	Yes	No	—	—	—	—	—	—	—
27	Aurora Glass 2530 Railroad Avenue 277-1058	Yes	No	—	—	—	—	—	—	—
28	Beeson Plumbing & Heating 2600 Railroad Avenue 278-4546	Yes	No	—	—	—	—	—	—	—
29	Ditomaso's Fruit and Vegetables 601 Yakutat 276-8343	Yes	Yes	—	X	—	—	NR	20	—

Table 3-4

(Continued)

Location on Figure 3-13	Property Tenant/Phone	Responded to Survey	Source of Water Known	Drinking Water Source				Number of Years on Water Source[a]	Number of Workers on Property	Comments
				Well	Public (Municipal) Supply	Bottled	None			
30	Elmendorf Fish Hatchery Alaska Department of Fish & Game 274-0065	Yes	Yes	—	x	—	—	NR	Approximately 4 workers; 8 residents	E

[a] Number of years on water source: Question was, "How long have you been obtaining water this way?" Respondents may have indicated the number of years they have leased the property or the number of years the property has been on the stated water supply.

[b] Testing Institute of Alaska gets water from SteelFab.

Comments:

A Well built approximately 1955. Depth approximately 120 feet. No known physical problems or damage to steel casing. No problems with water quality. No water treatment on well. No children or elderly persons.

B Considering installing a well for cleaning purposes only.

C Well drilled approximately 20-30 years ago. Installed pump. Steel casing. Lock on cover. No physical problems/damage with wells. Water has smell and taste of fuel. No water treatment on well. No children or elderly persons.

D Five buildings on property but only one tied into water well. No problems with water; it is tested annually.

E Two wells on property into lower aquifer. Use wells in fish production operation. All drinking water comes from Municipality of Anchorage. Four adults and four children reside on property.

NR = No response.

Tap water from Inlet Company and IGM was sampled during the RI field investigation because of their proximities to the Elmendorf AFB boundary. Both companies are located on the north side of Post Road next to the railroad. Inlet Company is approximately 600 feet south of the Elmendorf AFB boundary, and IGM is approximately 300 feet south of the Elmendorf AFB boundary. The water is used as drinking water by employees. No residences are connected to the wells. No children or elderly persons drink the water on a regular basis. An IGM employee reported that the drinking water had the smell and taste of fuel, although sampling results did not show any evidence of organic contamination in that water.

Data on the eight wells used for drinking water or fish production in the OU 5 area are shown in Table 3-5.

3.5.3 Surface Water

Surface water from Ship Creek or nearby ponds is used for the following purposes:

- Irrigation at the golf course;
- Cooling water for the power plant;
- Fish production at the fish hatchery; and
- Recreation.

Surface water from Ship Creek is used by the Elmendorf AFB power plant (Building 22-004) for cooling water, and by the fish hatchery for fish rearing. The USAF supplies warm water from the power plant to the fish hatchery. ADFG supplies the fish that are used to stock the lakes on Elmendorf AFB and operates the intake system for the cooling pond. Surface water is diverted from Ship Creek at the intake building located east of the cooling pond. The water is carried to the cooling pond by a 36-inch-diameter line or directly

Table 3-5

Data on Water Supply Wells in Vicinity of OU 5

Well Location	Elmendorf AFB Building 22-001 Near Power Plant	Elmendorf AFB Building 23-100 Golf Course Clubhouse	ADFG Elmendorf Hatchery	ADFG Elmendorf Hatchery	Inlet Company [illegible] Post Road	[illegible] 2433 Post Road	[illegible] [illegible] Railroad Avenue	[illegible] of Alaska, Inc. [illegible] Post Road
Well ID	Base well 2	Base well 52	Hatchery well 2	Hatchery well 3	NA	NA	NA	NA
Waller (1962) Field No.	NA	NA	NA	NA	31	37	NA	NA
USGS Local No.	SB01300308 DAAA1-001	SB01300309 ACAC1-020	NA	NA	SB01300308 DCAC1-009	SB01300309 CBBC1-029	SB01300308 DDAA1-011	NA
Date Constructed	1953	1970	1984-1985	1991	1954	1955	1958	NA
Latitude--North	61°13'52"	61°14'04"	61°13'50"	61°13'48"	61°13'37"	61°13'50"	61°13'41"	NA
Longitude--West	149°50'12"	149°49'00"	149°49'45"	149°49'45"	149°50'46"	149°50'05"	149°50'13"	NA
Total Depth (ft-bgs)	850	166	257	171	185	159	330	NA
Intake Intervals (ft-bgs)	208-237, 342-451, 458-530	161-166	232-247	153-168	175-185	159	>317	NA
Type of Screen	Perforated	60-slot screen	180-slot screen	100-slot screen	80-slot screen	Open end	NA	NA
Aquifer	Lower	Lower	Lower	Lower	Lower	Lower	Lower	NA
Source of Geologic Log	USGS	USGS	ADFG	ADFG	USGS	USGS	USGS	NA
Source of Well Completion Information	USGS	USGS	ADFG	ADFG	USGS	USGS	NA	NA

NA = Not available

to the hatchery by a 30-inch-diameter line. From the cooling pond, the water is piped to the power plant. Warm water is returned to the cooling pond and mixed with cool water before being used in the rearing ponds of the fish hatchery, or before being discharged into Ship Creek below the hatchery.[f]

ADFG reports that an average of approximately 4000 gpm of water flows through the hatchery during the year. Peak use occurs in March with 6400 gpm, and low use occurs in July and August with 2,400 gpm. These figures include water from Ship Creek and some from the wells on the property, but not the heated effluent from the power plant. ADFG estimates the daily water draw from Ship Creek for the power plant to be 1,200 to 1,500 gpm from 11:00 p.m. to 6:00 a.m.; 4,000 to 5,000 gpm from 6:00 a.m. to 4:00 p.m., and 6,000 gpm from 4:00 p.m. to 11:00 p.m.

Surface water from Ship Creek is also used for irrigating the grounds when the golf course is open. Water from the creek is routed to a pond, where a pump lifts the water into the sprinkler system.[g]

Recreational uses of the surface water in OU 5 also have included fishing, wading, and fish viewing, as previously discussed under Land Use, Section 3.4.

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[f] Information on the use of surface water at the hatchery and power plant was obtained in telephone conversations with Darrell Keifer, hatchery manager, ADFG, on October 8 and 13, 1992.

[g] Information on irrigation at the golf course was obtained in a telephone conversation with John Barbour, Elmendorf AFB Water and Wastewater Office, on October 13, 1992.

3.6 Ecology

3.6.1 Aquatic Communities

3.6.1.1 Ship Creek

Physical Characteristics

The results of the physical measurements observed during the field study are summarized in Appendix J. The predominant land use in the background sampling area (MI01, Figure 2-7) was considered forest/wetland although the site was located within the confines of a military installation. Downstream sampling stations within the OU 5 study area were considered commercial (at the golf course, at Salmon Run Park, and at the fish hatchery, Figure 2-7). One sample station (MI11) was located adjacent to a culvert at the end of Yakutat Street. This area would be classified as industrial due to the scrap metal yard next to the sample area.

The stream bank height, which varies with depth, was estimated as the distance from the surface of the water to the top of the bank. Bank height at the reference station was less than 3 feet. Downstream stations varied and ranged from less than 3 feet and up to 5 feet. The creek width in the areas sampled ranged from 30 feet at Station MI11 to 120 feet at the reference station (MI01).

The high water mark, evidenced by stain lines and debris in vegetation along the creek, was estimated to be 1.5 to 3 feet above the bank. Portions of the banks adjacent to the sampling areas were undercut. The canopy cover over the water was generally less than 5 percent (open).

The stream bottom was composed largely of gravel, cobble, and sand. There was little difference in substrate material among sites except for Station MI12, which exhibited more cobble size substrate. Silt and/or clay substrate materials were absent from sample stations. Extensive organic substrate material was generally absent within the study area. The organic material that was present consisted of logs, twigs, and leaf packs (coarse particulate organic matter, or CPOM). There was little or no silt and mud (fine particulate organic matter, or FPOM) present. The substrate material exhibited no unusual odors, deposits, or oils.

Water Quality

The in-situ water quality measurements taken at the Ship Creek sampling stations indicated that the creek was in good condition, and the parameters measured were within state and federal criteria for the propagation and maintenance of fish and wildlife (Appendix J).

Habitat Assessment

The habitat assessment followed the procedures of Plafkin et al (1989). Each habitat parameter was evaluated and numerically scored along with a rating of excellent, good, fair, or poor. The ratings obtained at the reference station (5MI01) were considered the base condition. All other stations were compared to the reference site. Habitat assessments for each station are shown in Appendix J. All stations were considered comparable to the reference site, except Station M11 (≥90 percent of reference evaluation score, Appendix J, Table J.3), which was considered supporting (75 to 80 percent of reference score, Appendix J, Table J.3).

Fauna: Benthic Macroinvertebrates. A list of the benthos collected from Ship Creek at each station during the spring and fall sampling periods are presented in Appendix J. The benthic macroinvertebrate data were evaluated using several ecological variables (metrics) that were appropriate for the site conditions. The rapid bioassessment protocols for use in streams and rivers (RBP) (Plafkin et al, 1989) provide a source of metrics for measuring the benthic community and population structure; the metrics that were used assisted in assessing the biotic integrity of Ship Creek. A summary of the benthic macroinvertebrate sampling results for Ship Creek is presented in Table 3-6 and is discussed below.

The community structure of Ship Creek benthos during the spring collections was dominated by organisms of the order Diptera (flies, mosquitoes, and midges); family Chironomidae and the class Oligochaeta (aquatic worms); families Lumbriculidae and Niadidae. Ephemeroptera (Mayflies) were also an important component at Sample Station MI01 (reference site) and MI05 (Salmon Run Park) (Figure 2-7). Stoneflies (Plecoptera) and caddis flies (Trichoptera) were less numerous.

The benthic species richness between the reference station and the downstream sites varied little. There was a trend toward increased taxa richness downstream. Likewise, the EPT index remained relatively constant throughout the study area. The EPT/C abundance ratio, which increases as the abundance of more sensitive organisms increases, was low at both the reference site and downstream locations. Species diversity was comparable at both locations.

The dominant community functional guild was collector-gatherers. This functional feeding group displayed little difference between the reference site and downstream locations. Other significant groups were the predator-engulfers, shredders, and scrapers. Predator-engulfers decreased in abundance in downstream reaches while shredders increased. Scrapers decreased below reference levels only at Station MI03.

In general, the spring collection showed good similarity in macroinvertebrate community structure and function between the reference site and downstream sites from the spring collection (Appendix J, Table 15).

Table 3-6

Results of Benthic Macreinvertebrate Collections and Analysis from Ship Creek

[illegible]	[illegible]			[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NEMATODA								1
ANNELIDA Oligochaeta								
Lumbriculidae	5	15	28	26		3	6	18
Kincaidiana hexatheca				1				
Niadidae								
Nais sp.	41	47	110	4	40	38	76	5
Pristinella sp.					1			
Tubificidae w.h.c.			1	3	2		25	
Limnodrilus sp.							7	
PLATYHELMINTHES Turbellaria								
Tricladida				1				
ARTHOPODA Arachnoidea								
Hydracarina		2		3			2	
Insecta								
Ephemeroptera								
Baetidae								
Baetis sp.	4	10	7	3		1		
Ephemerellidae								
Drunella doddsi	2	6	4	202	75	81	4	22
Ephemerella inermis				6			1	
Heptageniidae								
Cinygmula sp.	1	2		28				
Epeorus sp.	5	2		91	11	17		9
Plecoptera								
Chloroperlidae								
Suwallia sp.	6	1	4					
Nemouridae								

Table 3-6

(Continued)

SPECIES	SPRING [illegible]			FALL [illegible]				
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Zapada sp.			1		3	1	1	
Perlodidae								
Isoperla sp.			1	1				
Trichoptera								
Glossosomatidae								
Glossosoma sp.				56	119	54	26	56
Hydropsychidae								
Cheumatopsyche sp.				1				
Limnephilidae								1
Ecclisomyia sp.				1	3	1	2	1
Nemotaulius hostilis							1	
Rhyacophilidae								
Rhyacophila sp.	1							
Diptera								
Ceratopogonidae								
Bezzia/Palpomyia sp. sp.	1	2	3	1				
Chironomidae	19	19	26	4	11	18	11	7
Brillia sp.		1					2	
Cardiocladius sp.				1				7
Cricotopus sp.	14	13	52		23	18	19	19
Diamesa sp.	5	9	21					
Eukiefferiella gracei sp.sp.	5	29	36		5	89	19	1
Eukiefferiella sp.				1				
Eukiefferiella cf. claripennis sp.sp.							6	
Orthocladius sp.	5	2	9			58	28	
Pagastia sp.	2	1	3	7	11	13	6	2
Phaenopsectra sp.		1						
Potthastia sp.					1			
Rheocricotopus sp.			1					
Synorthocladius semivirens		1						

Table 3-6

(Continued)

[illegible]	[illegible]			[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tanytarsus sp.			2					
Tvetenia bavarica sp.gp.	1	6	22					1
Empididae								
Chelifera sp.		3	6	1				
Muscidae				1				
Limnophora sp.							3	
Psychodidae								
Pericoma sp.			1					
Simuliidae					1			
Cnephia sp.	1	1	3	8	1	11		5
Tipulidae								
Dicranota sp.		3	5		2			
Ormosia sp.							5	
MOLLUSCA Gastropoda								
Planorbidae	1							
TOTAL NUMBER OF ORGANISMS	119	176	346	451	309	403	250	155
TAXA RICHNESS	18	22	22	23	16	14	20	15
EPT	6	5	5	9	5	6	6	5
EPT/Chironomidae abundance ratio	0.37	0.26	0.10	43.2	4.14	0.79	0.38	2.41
Diversity (H')	3.204	3.473	3.281	2.585	2.628	3.071	3.391	2.940
Evenness (J')	0.768	0.779	0.736	0.571	0.657	0.807	0.785	0.752
FUNCTIONAL GROUPS								
Collector-gatherers	92 (77.3%)	141 (80.0%)	265 (76.6%)	9 (2.0%)	2 (0.6%)	11 (2.7%)	0	5 (3.3%)
Collector-filterers	1 (0.8%)	1 (0.7%)	5 (1.4%)	147 (32.6%)	85 (27.5%)	238 (59.1%)	187 (74.8%)	45 (29.0%)
Predator-engulfer	14 (11.8%)	11 (6.3%)	20 (5.8%)	9 (2.0%)	5 (1.6%)	1 (0.2%)	11 (4.4%)	7 (4.5%)
Scrapers	8 (6.7%)	9 (5.1%)	4 (1.2%)	286 (63.4%)	194 (62.8%)	135 (33.5%)	30 (12.0%)	78 (50.3%)
Shredders	4 (3.4%)	14 (7.9%)	52 (15.0%)	0	23 (7.4%)	18 (4.5%)	22 (8.8%)	20 (12.9%)

The benthic community structure of Ship Creek during the fall collections was dominated by the order Ephemeroptera, family Ephemerellidae and Heptageniidae; order Diptera, family Chironomidae; order Trichoptera, family Glossosomatidae; and class Oligochaeta, families Lumbriculidae, Niadidae, and Tubificidae. Mayflies were the dominant taxa at the reference site (Station MI01), and decreased in numerical abundance in a downstream direction, especially at Station MI11. Diptera increased in numerical abundance in a downstream direction, particularly Stations MI03 and MI11. Trichoptera abundance increased at Station MI02, but was generally the same as the reference site at Stations MI03, MI11, and MI12. The aquatic worm population also increased in abundance in a downstream direction, particularly at Station MI11.

Species richness decreased at Stations MI02, MI03, and MI12, but was near the reference station value at Station MI11. EPT also decreased in a downstream direction, and the EPT/C abundance ratio was lowest at Stations MI03 and MI11. Diversity and evenness were generally higher at Stations MI03 and MI11, reflecting the increased abundance of midges and aquatic worms.

Community functional guilds fluctuated considerably within the study area. Scrapers were dominant at the reference (Station MI01) and Station MI02 (Salmon Run Park), but were replaced in dominance by collector-gatherers at Stations MI03 and MI11. Station MI12 had a more even mix of trophic guilds with the addition of a greater abundance of shredders.

There was less similarity in benthic community structure and function between the reference site and that of the downstream stations in the fall collection, especially Station MI11. Downstream Station MI02 was more similar to Stations MI03 and MI12 than Station MI11, and Station MI11 was more similar to Station MI03 (Appendix J, Table 15).

Fish

Fish sampling was attempted with a backpack electrofisher at Sample Stations MI01, MI02, and MI03 (Figure 2-7). Based on a review of Rothe et al, 1983, it appeared that resident populations of fish would be apparent in the Ship Creek study area. However, only incidental collections of fish occurred. Two rainbow trout (*Oncorhynchus mykiss*), each about 6 inches in length, were collected from pools at Reference Station MI01, and about 30 slimy sculpins (*Cottus cognatus*) measuring from 1 to 2 inches were collected overall from Sample Stations MI02 and MI03. Based on the limited fish population observed above the Elmendorf AFB hatchery dam, resident fish occurrence will not be considered as an indicator of habitat suitability based on potential OU 5 contamination.

3.6.1.2 Golf Course Beaver Pond

Physical Characteristics

The physical characteristics observed in the beaver pond are presented in Appendix J.

Land use was predominantly commercial with the ARRC right-of-way to the north, the golf course to the east and west, and JP-4 tanks to the east. The pond was formed by a beaver dam at the west end. Canopy cover was generally open. Sediment odors were considered normal at MI04, but the distinct smell of petroleum was present at MI05. Sediment oils were considered slight at MI04, appearing as a sheen on the surface water of Ponar samples before sieving. Sediment oils were considered moderate at MI05. Qualitatively the inorganic substrate material at MI04 was composed largely of sand, some fine gravel material with 1 or 2 inches of fine silt on top. Station MI05 inorganic substrate was composed mainly of silt with some sand. The organic substrate component at MI04 was composed of fine particulate material (muck-mud), while that of MI05 was largely composed of detritus (leaf packs, twigs, stumps, and submerged logs).

Water Quality

Dissolved oxygen (DO) was good, except at Station MI05 in the spring where a DO of 3.7 mg/L was recorded. Temperatures fluctuated little between stations and seasons. Likewise, conductivity remained relatively constant at each station and each sampling. The pH was at or near 7.0 with some fluctuation between sampling events at MI05.

Habitat Assessment. A formal habitat assessment similar to the creek was not conducted due to the lack of sufficient criteria statements for lentic systems. A qualitative narrative describing the beaver pond habitat is presented as an alternative. The bottom substrate material varied within the beaver pond proper. The northeast corner, adjacent to seep SL23, was comprised of leaf packs, twigs, decaying log, and stumps. Beaver have downed many trees adjacent to the northeast and southeast corners of the pond, which have fallen into the water. There is more CPOM in this area of the pond then in the center or near the beaver dam itself. The area next to the dam was open with little detrital material on the bottom. Dead, but standing, trees were also present in the southern area of the pond. Cover in terms of canopy was considered open. Vegetation cover within the pond was essentially nonexistent.

Erosion associated with the area surrounding the pond was not present. Pond edge stability and vegetation were sufficient to curb any runoff into the pond.

Fauna: Benthic Macroinvertebrates. A list of the benthos collected from the golf course beaver pond at each station during the spring and fall sampling periods is presented in Table 3-7.

The benthic community structure in the beaver pond was dominated by organisms from the order Diptera, especially the family Chironomidae. Members of the class Oligochaeta also played an important role in community structure definition. The

Table 3-7

Results of Benthic Macroinvertebrate Collection and Analysis from the Golf Course Beaver Pond and Wetland Pond (5M106) - Spring and Fall 1992

	Spring		Fall		Spring
SPECIES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NEMATODA		1			
ANNELIDA Oligochaeta					
Lumbriculidae	44	1	120	4	56
Kincaidiana hexatheca	13		7		22
Lumbriculus sp.	4		5		
Niadidae	8				
Nais sp.	1		10	12	
Nais communis	12				
Pristinella sp.			7	1	
Slavina appendiculata	4				
Stylaria lacustris	4				
Tubificidae w.h.c.			7		6
Tubificidae w.o.h.c.	4				34
Limnodrilus sp.					140
Limnodrilus cf. hoffmeisteri	1				
Rhyacodrilus montana	8				
ARTHOPODA Arachnoidea					
Hydracarina			2		
Crustacea					
Amphipoda					
Talitridae					
Hyalella azteca	1		15		
Cladocera					
Daphnidae					
Daphnia cf. pulex		12	3	4	
Copepoda					
Cyclopoida					
Ostracoda			1	2	

Table 3-7

(Continued)

SPECIES	Spring		Fall		Spring
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Insecta Ephemeroptera					
Baetidae					
***Baetis* sp.**			1		
Heptageniidae					
***Stenonema* sp.**	1				
Heteroptera					
Corixidae					
***Arctocorisa* sp.**		1			
Diptera					
Ceratopogonidae					
Bezzia/Palpomyia sp. gp.	2		5		4
Chironomidae	45	6	9	1	1
***Chaetocladius* sp.**					63
Chironominae A					2
***Chironomus* sp.**		3		6	20
***Cricotopus* sp.**	59		1	1	8
***Dicrotendipes* sp.**			11	2	
Diplocladius cultriger				1	
***Glyptotendipes* sp.**		3	1		
Orthocladiinae A					10
Orthocladiinae B					2
***Orthocladius* sp.**					39
***Pagastia* sp.**					1
***Pagastiella* sp.**					
***Paramerina* sp.**				1	8
***Paracladopelma* sp.**	5				
Parakiefferiella bathophila		2			
***Paratanytarsus* sp.**	39	10			
***Phaenopsectra* sp.**		3		46	552
***Polypedilum* sp.**					1

Table 3-7

(Continued)

[illegible]	[illegible]		[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Polypedilum cf. convictum	5				
Potthastia sp.			38		
Procladius sp.	44	3	29	40	
Prodiamesa sp.					1
Psectrocladius sp.	33	2	11		12
Psectrotanypus sp.				117	
Rheotanytarsus sp.	4	15	3	7	
Tanypus sp.				5	
Tanytarsus sp.	729	148	235	32	5
Empididae					
Chelifera sp.			1		
Coleoptera					
Dytiscidae					1
Dytiscus sp.		2			
MOLLUSCA Gastropoda					
Planorbidae					
Gyraulus (Torquis) sp.	4				
Pelecypoda					
Sphaeriidae					
Pisidium milium	6		20		
TOTAL NUMBER OF ORGANISMS	1080	212	542	282	988
TAXA RICHNESS	25	15	23	17	22
Diversity (H')	2.107	1.868	1.850	2.677	2.403
Evenness (J')	0.454	0.478	0.415	0.655	0.539
FUNCTIONAL GROUPS # (%)					
Collector-gatherers	231(21.4)	18(8.5)	255(47.0)	67(23.8)	409(41.4)
Collector-filterers	778(72.0)	185(87.3)	262(48.3)	45(16.0)	5(0.5)
Predator-engulfers	2(0.2)	3(1.4)	8(1.5)	123(43.5)	13(1.3)
Scrapers	4(0.4)	3(1.4)	0	46(16.3)	552(55.9)
Shredders	65(6.0)	3(1.4)	17(3.2)	1(0.4)	9(0.9)

dipteran abundance was greater at Station MI04 than at Station MI05, both in spring and in fall. There was a decrease in dipteran abundance at Station MI04 between spring and fall collections, and an increase in dipteran abundance at Station MI05 during the same sampling timeframe. This was attributed, at least in part, to seasonal changes. Numerical abundance of aquatic worms was low at Station MI05 when compared to Station MI04, especially in the spring collection.

Species richness was higher at Station MI04 than at Station MI05. Comparison of collection periods for both locations indicated essentially little seasonal differences. Diversity and evenness were low at both locations and differed between location depending on the sampling period (Table 3-7). Standing water habitats (lentic systems) generally exhibit lower taxonomic diversity than flowing water habitats (lotic systems).

Macroinvertebrate functional guilds were dominated by collector-filterers in the spring sampling at both sites. The midge *Tanytarsus* sp. was the principal representative, and was probably acting in several trophic feeding roles within this system. Although this taxa remained a dominant factor at Station MI04 in August, other trophic components began to dominate (collector-gatherers). Likewise the trophic structure at Station MI05 changed in the fall with an increase in the number of predators.

At Station MI04, community structure between the two sample periods (spring and fall) was very similar. Likewise there was some similarity between both Station MI04 samples and that of the June sample at Station MI05. The August sample at Station MI05 was different in community structure due to a loss of some similar taxa (Appendix J).

Fauna: Fish. Fish sampling was attempted with a backpack electrofisher at Sample Stations MI04 and MI05; however, no fish were observed inhabiting the golf course beaver pond.

3.6.1.3 Ponds, Seeps, and Drainage Ditches

Physical Characteristics

Physical characteristic associated with several seeps and pools sampled within the OU 5 area are presented in Appendix J.

Predominant land use was considered commercial due to the location of these sites near the ARRC right-of-way and yard, and proximity to Elmendorf AFB operations. Canopy was generally shaded except for MI07, which was open.

Sediment odors, oils and deposits varied between locations. A distinct smell of petroleum was evident in sediments from MI06 and MI08. Ferric hydroxide (rust colored flocculent material) was quite prevalent at MI06. Organic substrate composition also varied between locations and was dependent on the amount of canopy cover (source of detrital material). Inorganic substrate composition was similar at Stations MI06 and MI08. The pool associated with the snow melt area was composed mostly of a thin layer of fine organic material over sand and fine gravel.

Water Quality

The in-situ water quality measurements taken at the seep and pool areas are presented in Appendix J.

In-situ water quality parameters measured at seeps and pools were considered adequate for the support of invertebrate populations. Dissolved oxygen at Stations MI06 and MI08 was less than 5 mg/L, which may not support higher vertebrate organisms (fish). Petroleum odor was also noted in the water taken at MI06 and MI08, and a sheen on the surface water was observed at Station MI06.

Habitat Assessment

A formal habitat assessment similar to that done at the creek was not conducted due to the lack of sufficient criteria statements for lentic systems. Substrate material varied between all three locations.

The bottom material associated with MI06 (pool/wetland area adjacent to seep ST36) was composed of silt and vegetable detritus. although stream bank stabilization and cover was good, the size and depth of the area would probably preclude its use by fish.

Substrate material at MI07 was composed of packed sand/gravel covered with a thin layer of silt. No aquatic vegetation was noted that could provide cover for aquatic vertebrates. The vegetative cover associated with the riparian zone generally stabilized the area from erosion, except in front of the snowmelt pile, which contained large amounts of dirt and debris.

Site MI08 (bluff pond) was a small pool filled with leaf litter and detritus. Human debris (old tires, construction materials, grass clippings, and leaf litter collections) were prevalent in areas adjacent to the pool. Pond-side vegetation and bank stability were adequate, but erosion from a road leading to the pool was evident.

Fauna: Benthic Macroinvertebrates. A list of the benthos collected from wetland pond (MI06) during the June sampling period is presented in Appendix J. The benthic macroinvertebrate data were evaluated using the same ecological variables (metrics) that were used for the golf course beaver pond.

The benthic community structure at Station MI06 was dominated by taxa representing the order Diptera, family Chironomidae; and the class Oligochaeta, families Lumbriculidae and Tubificidae. Dominant representatives of these groups are considered especially tolerant of organic pollution.

Species richness was good, and quite similar to Station MI04 in the beaver pond. Diversity and evenness were also considered similar to that of the beaver pond.

Functionally, Station MI06 was dominated by both scrapers (*Phaenopsectra* sp.) and collector-gatherers (aquatic worms).

Because of its unique habitat, the community structure at Station MI06 was not similar to any other stations within the study area. The closest similarity would be Station MI05 (August).

Qualitative invertebrate collections (RBP I) from MI07 and MI08 was less in spring of 1992 contained mostly cladocerans (water fleas), culicid (mosquito) pupa, and chironomid (midge) larvae. The physical structure of these ponds was considered unique to the study area (closed systems for the most part) and as such, influence the biota present. The presence of cladocerans in the water column suggest that at least that portion of these two pools supports some aquatic life. Likewise, the near-bottom sediments of MI07 which contained some chironomids would also appear to support a restrictive benthic community. The bottom substrate of MI08 (bluff pond) was apparently devoid of organisms and may not support aquatic life use.

Fauna: Fish. Drainage ditches were not sampled for fish. However, following a dye tracer study conducted in September 1992, approximately a dozen fish were observed in a surface drainage ditch. Juvenile (barred) salmonids (not collected or identified) were observed swimming in a drainage ditch where a stormwater culvert surfaces at the junction of Post Road and Whitney Road, approximately 1500 feet northeast of Ship Creek (Sample Station SW/SE 10). It appears that the fish had moved from the excavated pit/wetland beaver pond next to Ship Creek, and followed the flow in the drainage ditch that parallels the railroad spur as shown in Figure 2-2. Although fish could not be observed in the culvert, they were observed orienting to the flow at the face of the culvert. When disturbed, they disappeared into the undercuts and vegetation overgrowth of the drainage ditch.

Juvenile salmonids were observed seeking cover within the entire drainage ditch during further visual survey.

3.6.1.4 Summary and Conclusions

Ship Creek

Macroinvertebrates. The land use within the study area along Ship Creek changes from forested/wooded at the reference site to commercial (golf course, park, fish hatchery, scrap metal yard) at downstream locations, which may influence aquatic communities in the downstream reaches of the creek. Instream physical characteristics remain relatively the same between locations, and the habitat assessment suggests that all stations should be capable of supporting similar community structure and function.

Macroinvertebrate community structure and function were relatively the same between the reference site and downstream sites during the spring sampling. However, there were noticeable differences in the fall sampling event. The fall collections indicated a shift in community structure and function from a dominance in intolerant species to a community structure that was considered more tolerant, particularly at Station MI11.

Fish. Fish sampling resulted in the incidental collection of two rainbow trout in pools at the upstream reference sample station, and about 30 slimy sculpins at the downstream sample stations within OU 5. Physical anomalies were not apparent and no conclusions can be drawn about potential OU 5 effects to fish, because of the limited sample size and restricted habitat in this reach of Ship Creek.

Golf Course Beaver Pond

Macroinvertebrates. The land use within the vicinity of the pond was primarily commercial. Physical characteristics between the two sample stations were different. Bottom material at MI05 had more detritus than MI04. Likewise the distinct smell of petroleum products was evident at MI05.

The benthic community differed between these two sample stations, particularly in the June collection. There was also a decrease in tolerant taxa associated with bottom sediments at 5MI05, indicative of severe impact.

Fish. No fish were observed inhabiting the pond, although the habitat may be suitable if aquatic vegetation and other cover features were present.

Wetland Pond MI06

Macroinvertebrates. The prominent land use was commercial. The physical environment was dominated by detrital material, with a distinct smell of petroleum product. An orange/rust colored material (iron bacteria) was prevalent.

The macroinvertebrate community was dominated by organisms that are considered tolerant. Although the community structure was restricted, physical conditions did not preclude the existence of aquatic life.

Fish. The physical habitat is not suitable for fish species.

Snowmelt Pond MI07 and Bluff Pond MI08

Macroinvertebrates. Qualitative invertebrate collections conducted at both of these ponds indicated the presence of aquatic life. Invertebrate community structure was considered restricted.

Fish. The snowmelt pond appears to provide suitable physical habitat for fish, although none were observed. The bluff pond is not suitable for fish habitation.

3.6.2 Terrestrial Communities

3.6.2.1 Habitats and Vegetation

The general habitat features within OU 5 are illustrated on Figure 3-14, and the various habitat types are described in the following sections.

Distribution and Composition

The distribution and composition of habitat types within OU 5 are generally similar to their occurrence in 1982 (Rothe et al, 1983, CH2M HILL, 1992c) to the extent that they were described. Within OU 5, the habitat mapping by Rothe et al (1983) did not include the areas between the bluff and railroad tracks west of the junction of Reeve Boulevard and Post Road; these areas are outside Elmendorf AFB. However, from the aerial photographs taken in 1982, most of that area (including all of Source ST37) appeared to have been a balsam poplar (*Populus balsamifera*) forest, as it was during the 1992 surveys.

From the snow disposal area (near SL28) eastward to Post Road, most areas between the bluff and the railroad tracks were occupied by a mixture of woody species. The area included trees, shrubs and understory species typical of the closed balsam poplar forest and closed alder (*Alnus* sp.) tall scrub-shrub that were mapped in this area (Rothe et al, 1983). One notable exception was the apparent absence of devil's club (*Echinopanax horridum*) and lower abundance of highbush cranberry (*Viburnum edulae*) and American red currant (*Ribes triste*) than that of cow parsnip (*Heracleum lantanum*) in the understory. Between the railroad tracks and Post Road, the habitat was largely open with species characteristic of the bluejoint grass mesic graminoid herbaceous type. In addition to grasses and sedges, there were various herbaceous plants such as fireweed, cow parsnip, yarrow (*Achillea borealis*), and horsetail in this area. Trees and shrubs were limited to a few small stands.


Parking
Storage
BASE
POST ROAD
LEGEND
TREES/SHRUBS
GRASS/SEDGE
OPEN WATER
DISTURBED
MIXED TREE/SHRUB/GRASS
WETLANDS
STRUCTURES, ROADS, OR GRAVEL

②

③

FIGURE 3.1
GENERAL HABITAT

ELMENDORF A
ANCHORAGE, AL

② 1 ③

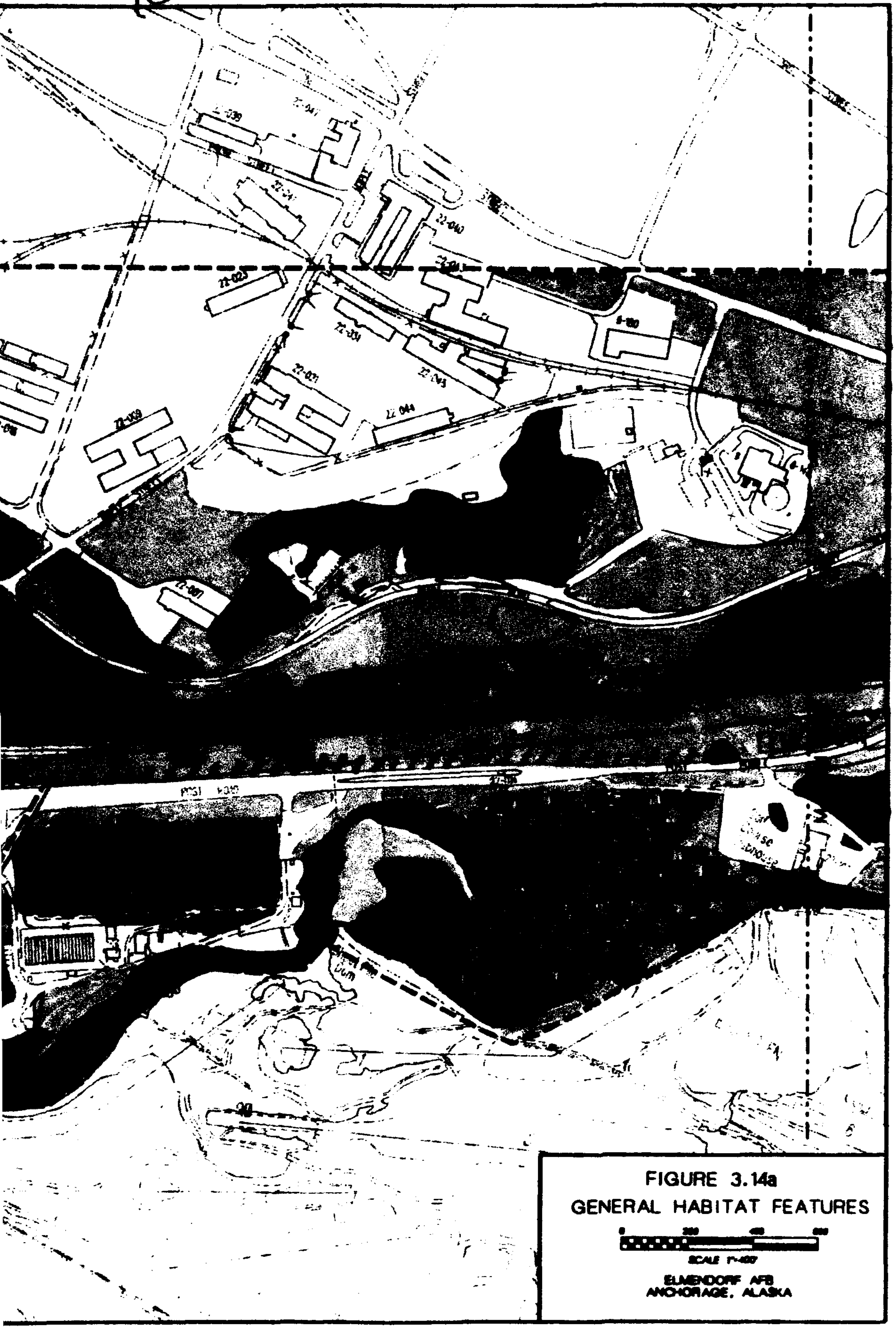
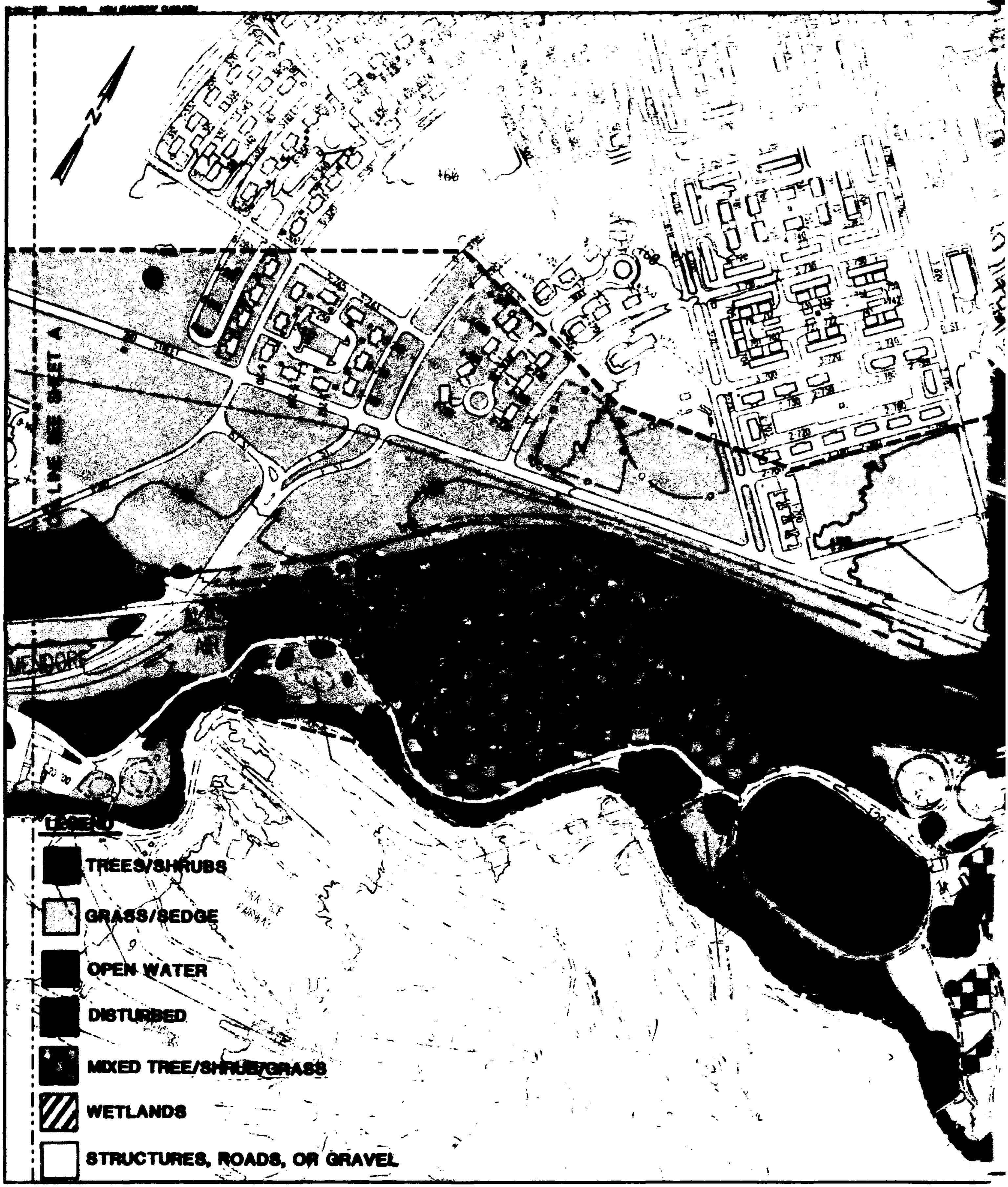


FIGURE 3.14a
GENERAL HABITAT FEATURES

ELMENDORF AFB
ANCHORAGE, ALASKA

Q


N
MATCH LINE SEE SHEET A
STREET
MENDORF
LEGEND
TREES/SHRUBS
GRASS/SEDGE
OPEN WATER
DISTURBED
MIXED TREE/SHRUB/GRASS
WETLANDS
STRUCTURES, ROADS, OR GRAVEL

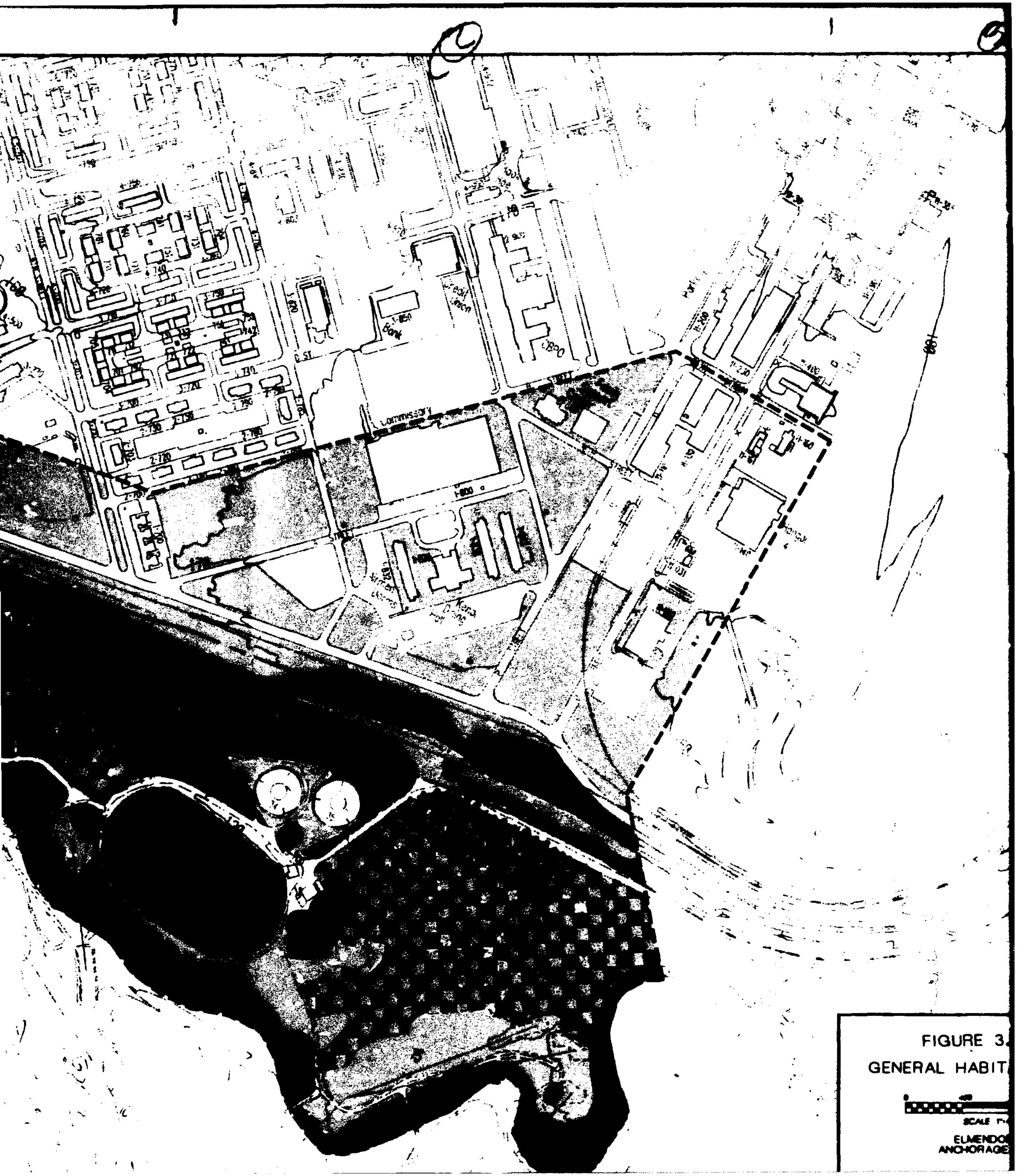


FIGURE 3.

GENERAL HABIT

SCALE 1"=

ELMENDO

ANCHORAGE

C 3

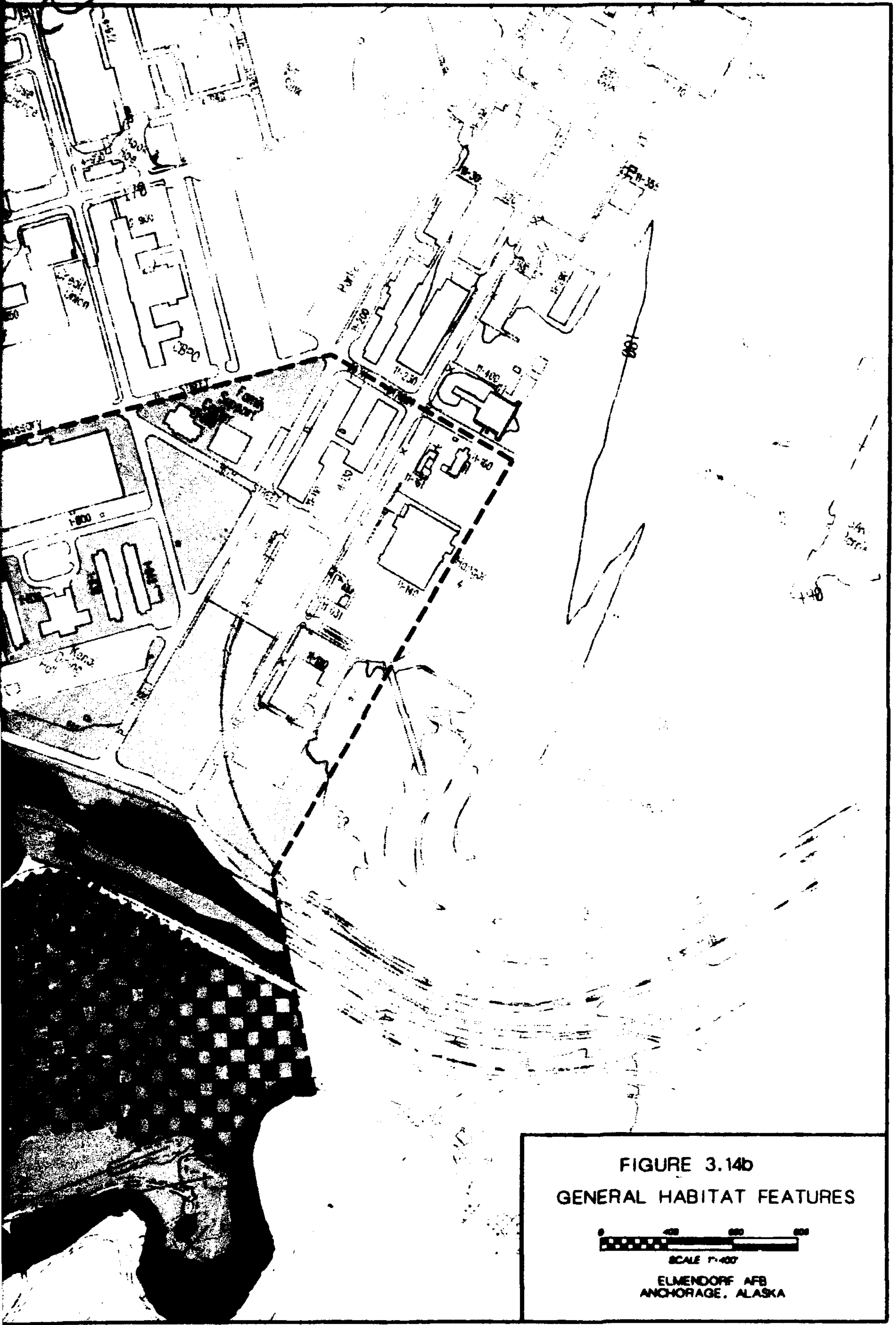


FIGURE 3.14b
GENERAL HABITAT FEATURES

ELMENDORF AFB
ANCHORAGE, ALASKA

Most areas between Bluff Road and the bluff are mowed periodically; the vegetation observed during the investigation was limited to short grass. (This was also typical of other areas north of Bluff Road.) Woody vegetation was limited to the upper edge of the bluff in most of those areas. East of Post Road, most of the grass between Second Street and the ARRC railroad tracks and in a small area southeast of the railroad crossing on Post Road was mowed. However, in the vicinity of SL31 (see Figures 2-1 and 3-14), the vegetation consisted primarily of grasses and herbaceous plants that had not been mowed.

A narrow strip of balsam poplar forest also occurred along the low bluff north of the railroad to the east of Post Road. In that area, there was much less topographic relief than along the bluff west of Post Road. This string of woodland extended from Source SS53 eastward beyond Source ST46, along the north side of the railroad tracks.

Most of the area east of Post Road between the ARRC railroad tracks and Ship Creek was a mosaic of habitats dominated by trees and shrubs. The habitat types were similar to those mapped by Rothe et al (1983). They included floodplain open cottonwood (*Populus trichocarpa*)-white spruce (*Picea glauca*) forest and closed alder tall scrub-shrub, along with mesic graminoid herbaceous (sedges/bluejoint grass) habitat.

Wetlands

Wetlands of varying sizes and types occur throughout OU 5. They were commonly noted as pools or streams along the lower edge of the bluff west of Post Road, with the larger ones near SL05, SL06, SL07, the snow disposal area (and downstream beaver ponds between there and the railroad tracks), SL16 eastward to SL25, and the area east of SL19 (refer to Figure 2-1 for locations). East of Post Road, several beaver ponds represented the largest wetland areas and contributed to water retention between the railroad tracks and Ship Creek. These wetlands occurred from SL32 to SL23 south to Ship Creek, and at SL29. The largest and oldest beaver pond appeared to be receiving drainage from seeps at

SL22 and SL23 in Source SD40. This beaver pond had much less aquatic vegetation than the ones at SL29 (east of the JP-4 tanks).

It should be noted that many areas below the bluff, other than those mentioned here or illustrated on Figure 3-14, are at least seasonally wetlands; the wetlands were not mapped in detail and jurisdictional wetlands were not delineated in this survey.

Disturbance

The area between Building 22-002 and SL12 has been disturbed by snow being disposed of over the bluff and by activities associated with the ARRC (Figure 3-14). These latter activities include the cutting of some woody vegetation, disposal of scrap material from railroad tracks, and the renovation of a spur track that was under way during the June 1992 survey. Consequently, the trees in that area are smaller than those in other areas.

In recent years, trees have also been cut in the area northwest of the large beaver pond (near SL22), and in an area north of the JP-4 fuel tanks. The history of these disturbances was not investigated; some are evident in the 1982 aerial photographs.

Although visible effects on the habitat types were less obvious in 1992, two areas of irregular topography were noted, suggesting that disposal activities had occurred there in the past. One area (between SL06 and SL08) was wooded; the other (north of SL26) was a grassy peninsula extending from the bluff to the wetland. Both areas had numerous truckload-sized mounds that contained apparent construction debris and other materials. In addition, concrete and metal debris was observed at several other locations, especially below the bluff.

Reference Sites

Three areas were surveyed as potential reference sites for the wetlands in OU 5, but none was found to be suitable for comparison. A large beaver pond east of the Ship Creek Hatchery Dam appeared to have very different characteristics (including water source, depth, and vegetation) from those north of Ship Creek in OU 5. Another beaver pond east of the JP-4 fuel tanks (SL29) was initially considered (in May 1992) to be a better reference site for the large SD40 beaver pond. In June, however, vegetation in this pond was noted as showing stress similar to that at SL19, SL25, and SL26. For this reason, it was considered unsuitable as a reference site. Another apparently natural wetland was located west of the Loop Road and a little south of the east-west runway's west approach (between the approach and some gravel pits). This wetland, which is clearly visible in the 1982 aerial photos, was observed to contain vegetation that was mostly sedges in the water and grasses and heavily browsed alder above the water level. This habitat is not comparable to wetlands in OU 5. Several small wood frogs were observed around this wetland.

Further surveys may be needed to identify reference sites. However, it appears that other areas of Elmendorf AFB will not be readily comparable to the wetlands along the bluff within OU 5.[b] For sampling in the OU 5 wetlands, it may be possible to compare affected areas to nonaffected areas in the same wetland.

Miscellaneous

It was noted that walking through the large beaver pond in the vicinity of SL22 (Figure 2-1) caused an oil sheen to appear on the water surface. The sheen was accompanied by a strong petroleum odor. At SL24, which is downstream from Source ST46 and flows into the large beaver pond, oil floated to the water surface although the sediment in this channel was not disturbed. The sheens at these two locations were caused by oil,

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[b] This information was obtained from Allen Richmond, natural resource planner at Elmendorf AFB, during a site visit on June 29, 1992.

which was detected in the surface water and sediment samples, but sheens observed at many other identified seeps (see Section 2.1) were apparently caused by bacteria. However, petroleum odors had been noted at many of those seeps.

3.6.2.2 Fauna

Mammals

Trapping of small mammals showed that voles and shrews live close to seeps and at the margins of wetlands near those locations. A total of 25 voles and 17 shrews were captured (Table 3-8). Trapping success varied by location and season, as well as the type of trap. Some nights the live traps were more productive; on other nights, the snap traps captured more animals.

Most of the voles from the steeper, wooded bluff habitats were red-backed voles (*Clethrionomys rutilus*), whereas all of the voles from more open and grassy habitats appeared to be meadow voles (*Microtus pennsylvanicus*). The shrew species have yet to be identified, but most shrews appeared to be masked shrews (*Sorex cinereus*). Positive identification would require dissection of the skulls; this may not be necessary for current purposes.

Beavers and muskrats were observed in the pond below the snow disposal area and in the beaver ponds at SL23, SL24, and SL29.

Among the larger mammals, moose were observed near the snow disposal area (between SL10 and SL11), where they were feeding. Their droppings were found throughout much of OU 5. Bear scat was observed at two locations near SL23. Although the age of the scat could not be determined, the droppings were probably from the spring of 1992. No other large mammals (or signs of their presence) were observed.

Table 3-8

Results of Small-Mammal Trapping Survey

	May					June				
	22	23	24	25	Total	25	26	27	28	Total
Shrews Captured	2	0	0	1	3	2	6	3	3	14
Voles Captured	0	2	4	3	9	4	3	3	6	16
Trapping Success[a]	0.03	0.03	0.05	0.05	0.04	0.08	0.12	0.19	0.28	0.14

[a] Animals captured per trap-night; other values are numbers of animals captured.

Birds

A wide variety of bird species was observed during surveys in OU 5 (Table 3-9). About half the species reported by Rothe et al (1983) in the basewide natural resource study were not observed during the surveys of OU 5, which was not surprising; the latter surveys were conducted in a smaller area over a limited time. However, the surveys indicate that wetlands in OU 5 are used by more than 15 species of waterfowl and shorebirds, and that several species nest there during spring and early summer.

In addition to waterfowl and shorebirds, other species were observed in various OU 5 habitats, including grouse, kingfishers, woodpeckers, swallows, magpies, ravens, and 13 species of songbird (Table 3-9). The feeding habits of these birds vary widely; some forage in the forest canopy whereas others, such as robins, eat mainly invertebrates taken from the ground.

Amphibians

Adult-size wood frogs were observed on 2 days near SL23, and one wood frog that was about one-half adult size was observed near SL29 on 1 day. Wood frog tadpoles were caught in nets during the surveys of aquatic invertebrates in the beaver pond near SL22 and SL23.[i] No frog eggs were observed in any of the OU 5 wetlands during either survey.

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[i] This information was obtained in a telephone conversation with Steve Hope, an aquatic ecologist with CH2M HILL, on June 22, 1992.

Table 3-9

Bird List for Elmendorf Air Force Base

Birds observed during [illegible] Natural Resource Study[a]				Birds observed during [illegible] OU-5 surveys					
				May			June		
Common Name	Scientific Name	Nesting[b]	Status	Seen	Nests	Broods	Seen	Nests	Broods
Red-throated Loon	*Gavia stellata*								
Arctic Loon	*Gavia arctica*	C							
Common Loon	*Gavia immer*								
Horned Grebe	*Podiceps auritus*								
Red-necked Grebe	*Podiceps grisegena*	C		X			X		
Tundra Swan	*Cygnus columbianus*		AR						
Canada Goose	*Branta canadensis*		H	X	X	X	X		X
Green-winged Teal	*Anas crecca*	C	H	X	X		X		X
Mallard	*Anas platyrhynchos*		H	X		X	X		X
Northern Pintail	*Anas acuta*	S	H						
Blue-winged Teal	*Anas discors*		H						
Northern Shoveler	*Anas clypeata*		H	X					
American Wigeon	*Anas americana*	C	H	X	X		X	X	X
Ring-necked Duck	*Aythya collaris*		AT, H						
Greater Scaup	*Aythya marila*		H						
Lesser Scaup	*Aythya affinis*		H						
Scaup Species			H	X					
Harlequin Duck	*Histrionicus histrionicus*	S	H	X					
White-winged Scoter	*Melanitta fusca*		H						
Common Goldeneye	*Bucephala clangula*		H						

Table 3-9

(Continued)

Birds observed during [illegible] Natural Resource Study[a]				Birds observed during [illegible] OU-5 surveys					
				May			June		
Common Name	Scientific Name	Nesting[b]	Status	Seen	Nests	Broods	Seen	Nests	Broods
Barrow's Goldeneye	*Bucephala islandica*	C	H	X					
Bald Eagle	*Haliaeetus leucocephalus*			X					
Northern Harrier	*Circus cyaneus*								
Swainson's Hawk	*Buteo swainsoni*								
Red-tailed Hawk	*Buteo jamaicensis*	C							
Golden Eagle	*Aquila chrysaetos*		FS						
Spruce Grouse	*Dendragapus canadensis*	C	FS, H				X		
White-tailed Ptarmigan	*Lagopus leucurus*								
Willow Ptarmigan	*Lagopus lagopus*								
Northern Bobwhite Quail	*Colinus virginianus*								
Sandhill Crane	*Grus canadensis*								
Semipalmated Plover	*Charadrius semipalmatus*	S							
Greater Yellowlegs	*Tringa melanoleuca*			X					
Lesser Yellowlegs	*Tringa flavipes*			X					
Yellowlegs Species		C							
Spotted Sandpiper	*Actitis macularia*	S		X	X		X	X	X
Whimbrel	*Numenius phaeopus*			X					
Western Sandpiper	*Calidris mauri*								

Table 3-9

(Continued)

Birds observed during [illegible] Natural Resource Study[a]				Birds observed during [illegible] OU-5 surveys					
				May			June		
Common Name	Scientific Name	Nesting[b]	Status	Seen	Nests	Broods	Seen	Nests	Broods
Least Sandpiper	*Calidris minutilla*	S		X					
Short-billed Dowitcher	*Limnodromus griseus*	S							
Long-billed Dowitcher	*Limnodromus scolopaceus*			X					
Red-necked Phalarope	*Phalaropus lobatus*	C		X			X		
Common Snipe	*Gallinago gallinago*	C		X			X	X	
Bonaparte's Gull	*Larus philadelphia*	S		X					
Mew Gull	*Larus canus*	C		X	X		X	X	X
Glaucous-winged Gull	*Larus glaucescens*								
Arctic Tern	*Sterna paradisaea*								
Aleutian Tern	*Sterna aleutica*								
Rock Dove	*Columba livia*	S	H	X			X		
Great Horned Owl	*Bubo virginianus*	C							
Belted Kingfisher	*Ceryle alcyon*	S		X	X				
Downy Woodpecker	*Picoides pubescens*								
Hairy Woodpecker	*Picoides villosus*	C					X		
Three-toed Woodpecker	*Picoides tridactylus*	C							
Black-backed Woodpecker	*Picoides arcticus*	S							
Northern Flicker	*Colaptes auratus*	C							

Table 3-9

(Continued)

Birds observed during 1982 Natural Resource Study[a]			Status	Birds observed during 1993 OU-5 surveys					
				May			June		
Common Name	Scientific Name	Nesting[b]		Seen	Nests	Breeds	Seen	Nests	Breeds
Olive-sided Flycatcher	*Contopus borealis*	S							
Western Wood-pewee	*Contopus sordidulus*	S							
Alder Flycatcher	*Empidonax alnorum*	S							
Tree Swallow	*Tachycineta bicolor*	C							
Violet-green Swallow	*Tachycineta thalassina*	C		X			X		
Bank Swallow	*Riparia riparia*	C							
Cliff Swallow	*Hirundo pyrrhonota*	C					X		
Gray Jay	*Perisoreus canadensis*	C							
Black-billed Magpie	*Pica pica*			X	X		X		X
Common Raven	*Corvus corax*	C		X			X		
Black-capped Chickadee	*Parus atricapillus*	C		X					
Boreal Chickadee	*Parus hudsonicus*	C							
Red-breasted Nuthatch	*Sitta canadensis*								
Brown Creeper	*Certhia americana*	C							
American Dipper	*Cinclus mexicanus*	S		X			X		
Golden-crowned Kinglet	*Regulus satrapa*	S							
Ruby-crowned Kinglet	*Regulus calendula*	C		X			X		
Swainson's Thrush	*Catharus ustulatus*	C							
Hermit Thrush	*Catharus guttatus*								

Table 3-9

(Continued)

Birds observed during 1982 Natural Resources Study[a]			Status	Birds observed during 1995 OU-5 surveys					
				May			June		
Common Name	Scientific Name	Nesting[b]		Seen	Nests	Broods	Seen	Nests	Broods
American Robin	*Turdus migratorius*	C		X			X	X	X
Varied Thrush	*Ixoreus naevius*	C							
Gray-cheeked Thrush	*Catharus minimus*								
Bohemian Waxwing	*Bombycilla garrulus*								
Northern Shrike	*Lanius excubitor*								
Orange-crowned Warbler	*Vermivora celata*	C		X			X	X	
Yellow Warbler	*Dendroica petechia*	S		X					
Yellow-rumped Warbler	*Dendroica coronata*	C					X		
Townsend's Warbler	*Dendroica townsendi*								
Wilson's Warbler	*Wilsonia pusilla*								
Blackpoll Warbler	*Dendroica striata*	S							
Northern Waterthrush	*Seiurus noveboracensis*								
Savannah Sparrow	*Passerculus sandwichensis*	S		X					
Fox Sparrow	*Passerella iliaca*	C							
Song Sparrow	*Melospiza melodia*	S							
Lincoln's Sparrow	*Melospiza lincolnii*	C							
Golden-crowned Sparrow	*Zonotrichia atricapilla*			X					

Table 3-9

(Continued)

Birds observed during 1983 Natural Resource Study[a]				Birds observed during 1993 OU4 surveys					
				May			June		
Common Name	Scientific Name	Nesting[b]	Status	Seen	Nests	Broods	Seen	Nests	Broods
White-crowned Sparrow	*Zonotrichia leucophrys*	C		X			X		
American Tree Sparrow	*Spizella arborea*								
Dark-eyed Junco	*Junco hyemalis*	C					X		
Lapland Longspur	*Calcarius lapponicus*								
Rusty Blackbird	*Euphagus carolinus*	C		X			X	X	
Great-tailed Grackle	*Quiscalus mexicanus*								
Pine Grosbeak	*Pinicola enucleator*								
White-winged Crossbill	*Loxia leucoptera*	S							
Pine Siskin	*Carduelis pinus*			X			X		

AT =Alaska Threatened
AR =Alaska Rare
FS =Forest Service Sensitive
H =Harvested (Hunted)[a]
C =Confirmed Nesting
S =Suspected Nesting
Source: Roth et al. (1983)[b]

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LIST OF TABLES (CONTINUED)

4.0 NATURE AND EXTENT OF CONTAMINATION

In this section, the nature and extent of contamination at OU 5 are summarized using data obtained during the 1992 field investigation. Results of previous investigations are discussed when necessary to complete the summary.

In keeping with the objectives for this RI (Section 1.1), the sampling program was designed to determine the influence of upgradient contaminant sources on the OU 5 areas, the approximate extent and nature of contamination in the OU 5 area, and the potential for offsite migration of OU 5 contaminants and subsequent impacts on Ship Creek. To facilitate an evaluation of the data in terms of these three objectives, the OU 5 study area was divided into the following seven study subareas:

- The upgradient area;
- The pipeline corridor;
- The waste paint tank area;
- The lower bluff;
- The Post Road corridor;
- The golf course beaver pond; and
- Ship Creek.

The study subareas are shown on Figure 4-1. Potential contamination within the industrial area between Post Road and Ship Creek was not evaluated as part of this investigation.

The upgradient area includes soil and groundwater data collected from the installation of seven monitoring wells located hydraulically upgradient of the OU 5 source areas. The groundwater data provide information on whether contamination is migrating

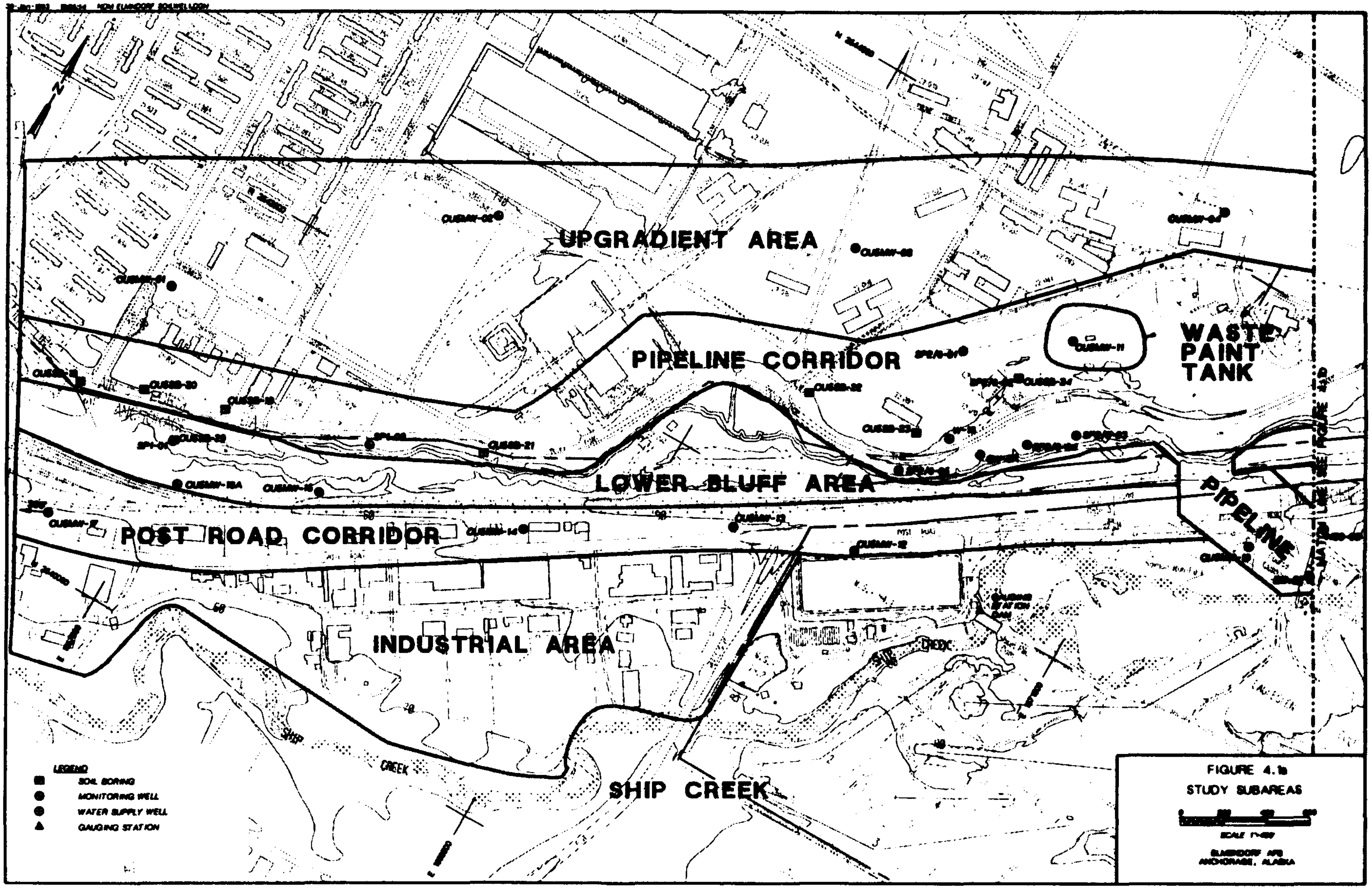

FIGURE 4.1a
STUDY SUBAREAS

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ANCHORAGE, ALASKA

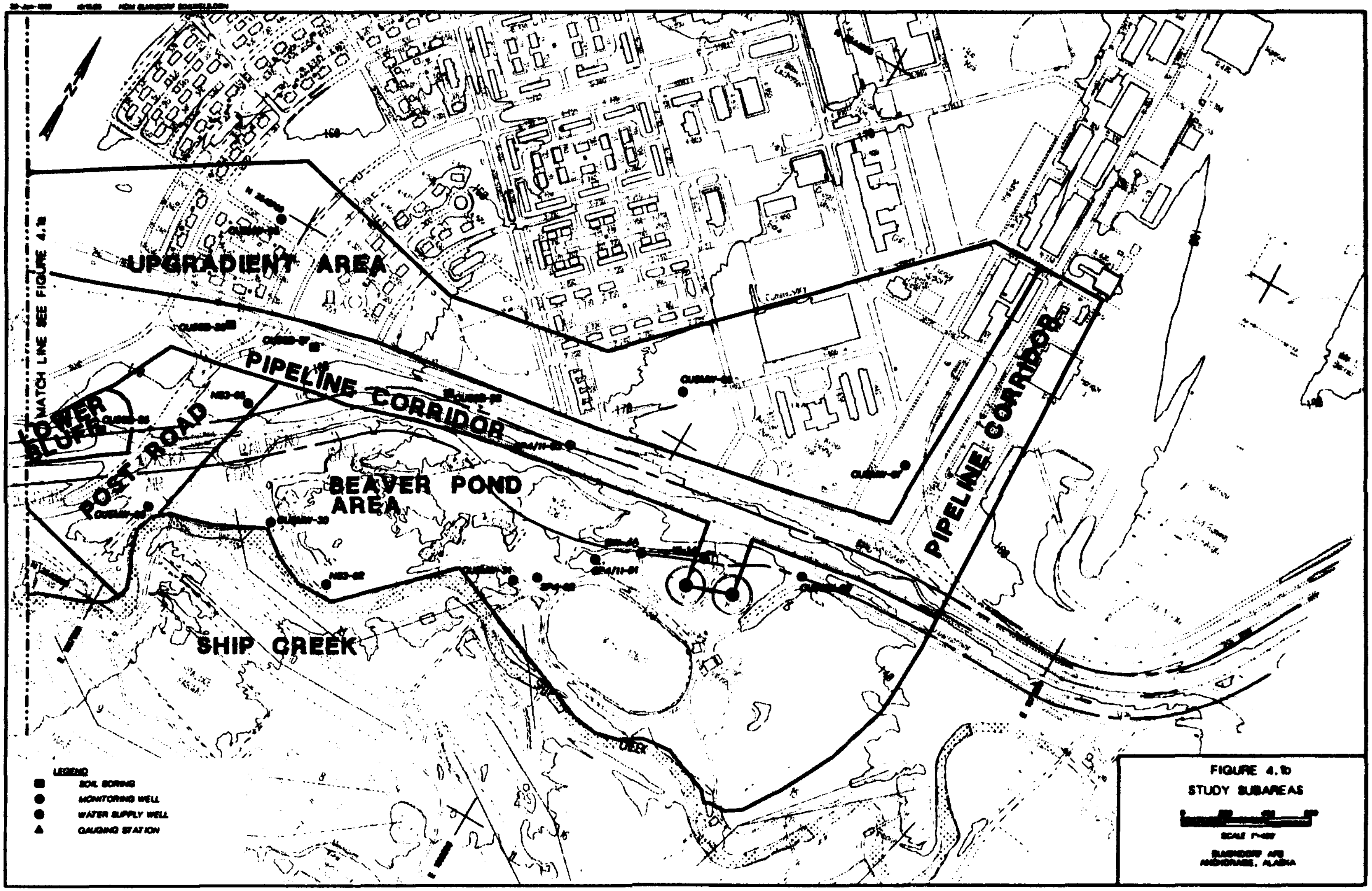

FIGURE 4.1b
STUDY SUBAREAS
SCALE 1"=400'
ELMENDORF AFB
ANCHORAGE, ALASKA

from upgradient sources into the OU 5 areas, and the soil data from these borings is a useful reference for soil data collected within and downgradient from the OU 5 sources. All of the known OU 5 source areas occur along a pipeline corridor that runs east-west along the top of the bluff. If undiscovered leaks have occurred in the pipeline, their impact would be observed within this subarea. Soil data collected from the vadose zone within the pipeline corridor will be evaluated to determine if areas of contaminated soil are currently contaminating groundwater beneath OU 5. A smaller area within the pipeline corridor, the waste paint tank area, was evaluated separately using data from soil boring and monitoring well MW11 because the waste paint tank source area is different from the OU 5 petroleum contamination sources.

The remaining study subareas are located hydraulically downgradient from the pipeline corridor and are useful for evaluating the potential for offsite migration of OU 5 contaminants and their impacts on Ship Creek. The lower bluff area is adjacent and immediately downgradient of the western half of the pipeline corridor. This hillside is well vegetated with trees and shrubs and there are numerous groundwater seeps along the bank. Similarly, the golf course beaver pond area is adjacent and downgradient of the eastern half of the pipeline corridor. This area is also well vegetated and contains beaver ponds and wetland areas. Both of these subareas are of interest for the ecological assessments because aquatic and terrestrial receptors could be affected by contaminated groundwater seeping out of the bluffs or entering the shallow groundwater table. Soil, groundwater, surface water and sediment data, terrestrial plants and animals, and aquatic biota are evaluated within this study subarea.

The Post Road corridor is a group of six monitoring wells located along a business district of Post Road and the ARRC right-of-way. This area represents the offsite location closest to OU 5 where human activities occur on a daily basis. If groundwater contaminants are migrating away from source areas in the western half of OU 5, it is expected that they would be detected in the shallow Post Road corridor wells. This area is also hydraulically upgradient from the industrial area south of Post Road, where known and potential sources of contamination could interfere with evaluating contaminants migrating from OU 5 sources. As discussed in Section 1.2.1, this RI does not address potential impacts caused by offsite sources in the Post Road industrial area.

Ship Creek is the recipient of groundwater and surface water drainage from the southern part of Elmendorf AFB. Surface water and sediment data and aquatic biota in Ship Creek were evaluated to determine the nature and extent of contamination from OU 5 sources that could affect Ship Creek.

The division of OU 5 into subareas does not necessarily represent differences in observed site contamination. Rather, the division provides a convenient way to organize the discussion of the large quantity of data obtained during the field investigation. Some contaminants may, in fact, be present in all areas, and may be attributed to the same source(s).

In addition to the division of OU 5 into seven study subareas, much of the discussion on observed contaminants is divided into three categories:

- Petroleum hydrocarbons (including gasoline, diesel, JP-4, BTEX, and polycyclic aromatic hydrocarbons [PAHs]);
- Nonpetroleum organics (including halogenated volatile organics and PCBs); and
- Metals.

These chemical categories represent, in most situations at OU 5, different sources, different impacts on human and biological receptors, and different fate and transport mechanisms. A summary of the analytical data is presented with each section. Although all pre-existing and new monitoring wells and new borings were sampled during the field investigation, the data summary tables and figures in Section 4 only present detected results. Therefore, if sampling in a specific study subarea did not yield any detectable analytes, the summary tables omit the subarea from the summary and no data is posted for the sampling location on the figures. Complete analytical results for the field investigation are presented in Appendix K.

Summaries of analytical results are presented for each medium discussed in Section 4 to summarize the constituents detected and present several descriptive statistics (range of detected values, geometric mean, arithmetic mean, number of detections versus number of samples, and percent of samples with detections. Geometric means are computed by converting the data to $\log_{10}$ values, calculating the mean, and converting the $\log_{10}$ mean back to an arithmetic value. Both the arithmetic and geometric means are calculated using one-half the detection limit for non-detection results. Therefore, when the number of detections versus number of samples is low, the calculated means will be influenced more by the analytical detection limits than by the results for detected constituents. In some cases, the calculated mean values may be less than the lower detected value or greater than the highest detected value because of this calculation method. Therefore, it is necessary to consider the number of detections versus the sample size when interpreting the mean values in the summary tables.

The discussion of the nature and extent of contamination will be presented in six sections:

- Soil gas and groundwater screening;
- Soil;
- Groundwater and seeps;
- Surface water and sediments;
- Aquatic biota; and
- Terrestrial plants and animals.

It is understood that there will be significant chemical interaction between media in some situations. This interaction will be discussed in this chapter and further refined in Section 5, Conceptual Model.

4.1 Soil Gas and Groundwater Screening

4.1.1 Results

Field screening of soil gas and groundwater samples was performed to give relative, order-of-magnitude estimates of the presence of VOCs and petroleum hydrocarbons at OU 5, and to focus the placement of soil borings and monitoring wells around suspected source areas. The soil gas screening results are qualitative and indicate the absence or presence of constituents and their relative concentrations. The soil gas results are presented as unitless quantities because the field screening instruments were not calibrated to independent gaseous standards. Groundwater screening results are considered to be semiquantitative to a minimum concentration of approximately 0.5 μg/L for VOCs and 10 μg/L for BTEX compounds. The petroleum hydrocarbon scans (C_4-C_9 and C_{10}-C_x) are considered estimates of fuel contamination because quantitations were based on estimates of both retention times and response factors for fuel hydrocarbons.

A summary of the compounds detected in the soil gas and groundwater screenings surveys are presented in Tables 4-1 and 4-2, respectively. Figures 4-2, 4-3, and 4-4 display the locations of the detections for an order-of-magnitude comparison of results. Areas that appeared to have relatively high concentrations of VOCs or petroleum hydrocarbons were targeted for soil borings and monitoring wells during the field investigation.

Table 4-1

Summary of Screening Results for Soil Gas

Study Subarea	Detected Compound	Range of Detected Values (no units)	Geometric Mean	Arithmetic Mean	No. of Detections/ No. of Samples	Percent of Samples
Pipeline Corridor	1,1,1-Trichloroethane	0.0002 - 0.084	4.37×10^{-4}	4.93×10^{-3}	22/88	25
	Tetrachloroethylene (PCE)	0.0005 - 0.06	2.98×10^{-4}	2.48×10^{-3}	20/90	22
	Trichloroethylene (TCE)	0.0003 - 0.5	3.82×10^{-4}	1.00×10^{-2}	13/90	14
	TVHC C10-X	7 - 290	2.91×10^{-1}	4.42×10^{0}	4/90	4
	TVHC C4-9	0.6 - 610	3.13×10^{-1}	8.02×10^{0}	6/90	7
	cis-1,2-Dichloroethylene	0.02 - 0.4	1.88×10^{-2}	3.44×10^{-2}	20/90	22

Note: Soil gas results are unitless.

Table 4-2

Summary of Screening Results for Groundwater

Study Subarea	Detected Compound	Range of Detected Values (μg/l)	Geometric Mean (μg/l)	Arithmetic Mean (μg/l)	No. of Detections/ No. of Samples	Percent of Samples
Golf Course Beaver	Trichloroethylene (TCE)	0.7 - 12	5.43×10^{-1}	1.46×10^{0}	13/40	33
Pond Area	TVHC C10-X	27 - 9300	2.58×10^{1}	6.35×10^{2}	14/40	35
	TVHC C4-9	11 - 510000	8.07×10^{1}	2.91×10^{4}	20/40	50
	cis-1,2-Dichloroethylene	0.8 - 53	1.30×10^{0}	4.47×10^{0}	23/40	58
Lower Bluff Area	1,1,1-Trichloroethane	1 - 2	2.87×10^{-1}	3.50×10^{-1}	2/25	8
	Trichloroethylene (TCE)	0.6 - 1	2.83×10^{-1}	3.08×10^{-1}	3/25	12
	TVHC C10-X	43 - 11000	5.02×10^{1}	1.51×10^{3}	10/25	40
	TVHC C4-9	12 - 91000	1.71×10^{2}	5.83×10^{3}	17/25	68
	cis-1,2-Dichloroethylene	0.9 - 45	6.26×10^{-1}	2.88×10^{0}	9/25	36
	trans-1,2-Dichloroethene	0.7 - 9	4.06×10^{-1}	1.14×10^{0}	5/25	20
Pipeline Corridor	TVHC C10-X	19 - NA	NA	NA	1/11	9
	TVHC C4-9	16 - 1000	1.13×10^{1}	1.01×10^{2}	3/11	27
	cis-1,2-Dichloroethylene	0.6 - 32	5.08×10^{-1}	3.33×10^{0}	3/11	27
Post Road Corridor	TVHC C10-X	58 - 540	9.25×10^{0}	4.75×10^{1}	3/17	18
	TVHC C4-9	24 - 19000	3.47×10^{1}	1.87×10^{3}	8/17	47
	trans-1,2-Dichloroethene	0.8 - NA	NA	NA	1/17	6
Ship Creek Area	TVHC C4-9	19 - NA	NA	NA	1/4	25
	cis-1,2-Dichloroethylene	1 - 2	8.41×10^{-1}	1.06×10^{0}	3/4	75

NA = Not Applicable due to only one reported value.

⑪

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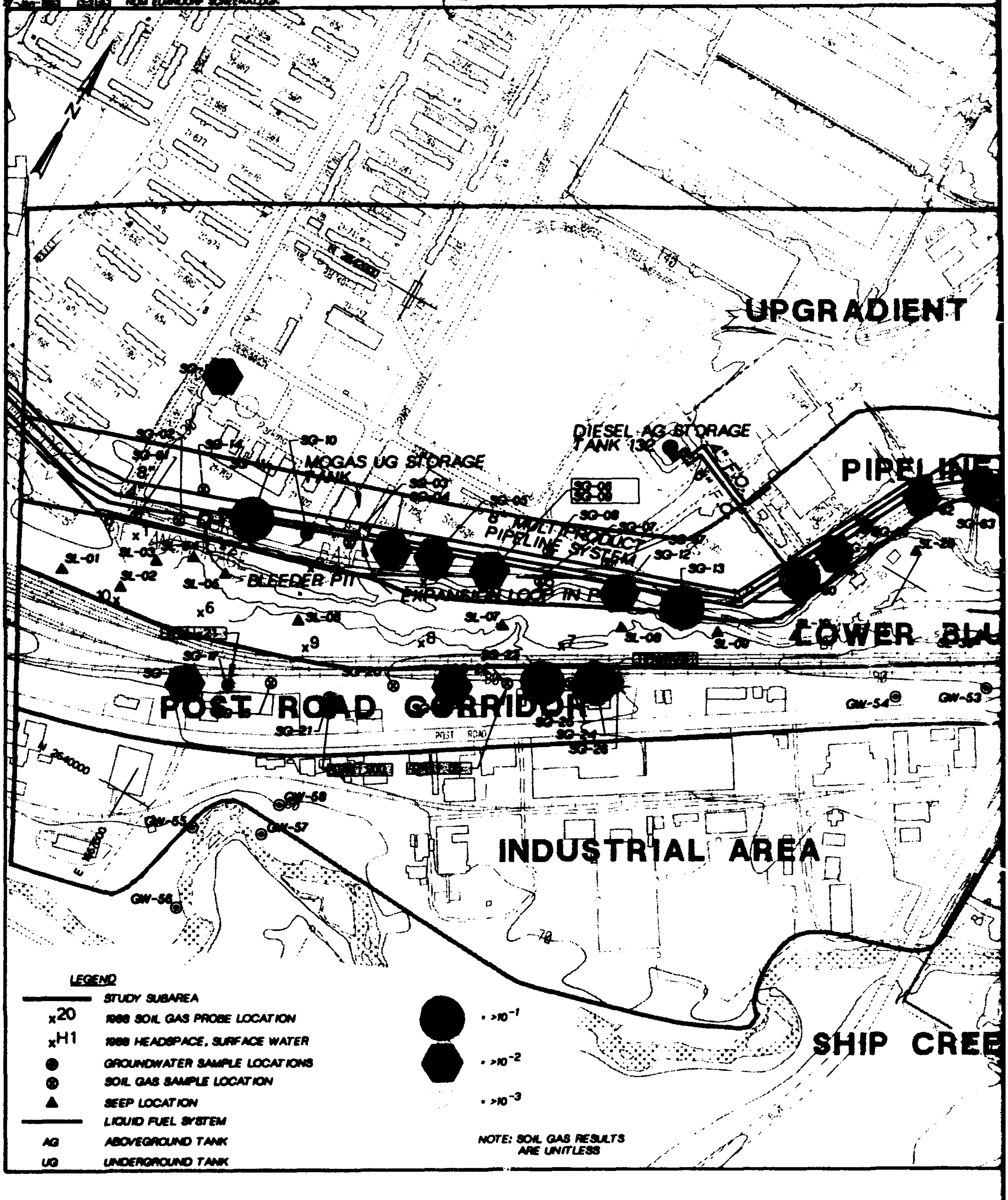

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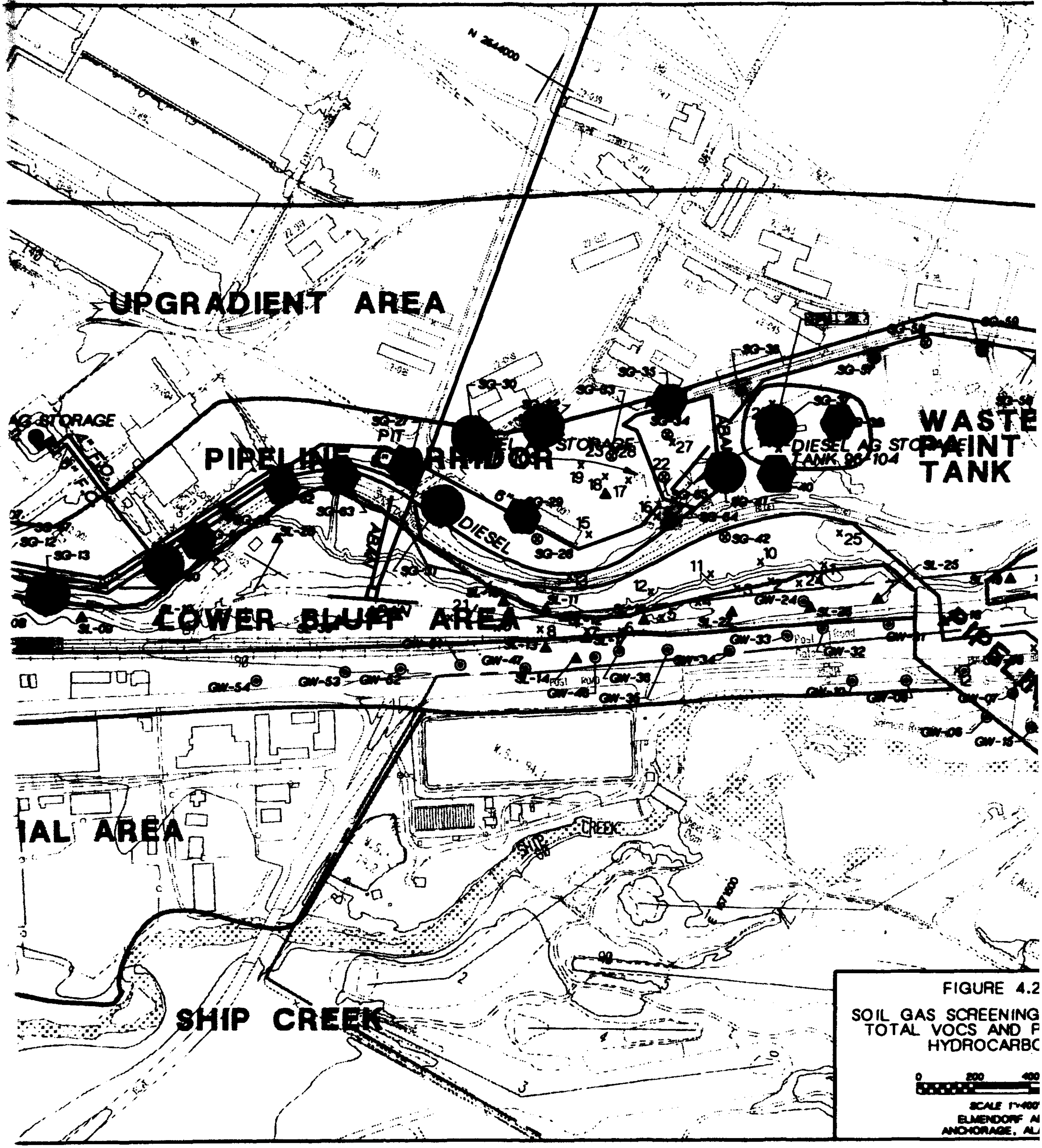

FIGURE 4.2

SOIL GAS SCREENING

TOTAL VOCS AND

HYDROCARBO

0 200 400

SCALE 1"=400'

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ANCHORAGE, AL

② ③

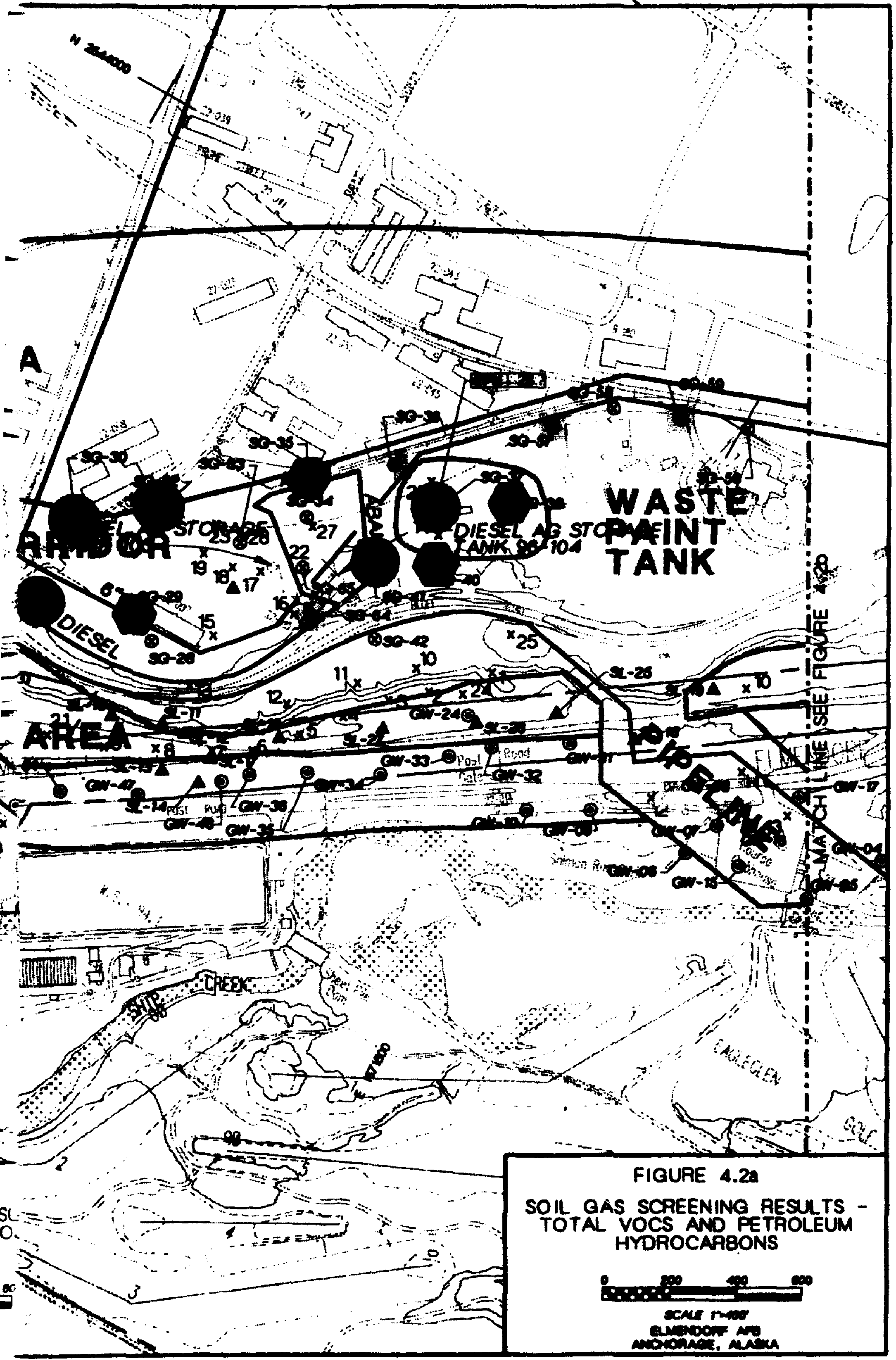

FIGURE 4.2a

SOIL GAS SCREENING RESULTS - TOTAL VOCS AND PETROLEUM HYDROCARBONS

0 200 400 800

SCALE 1"=400'

ELMENDORF AFB
ANCHORAGE, ALASKA

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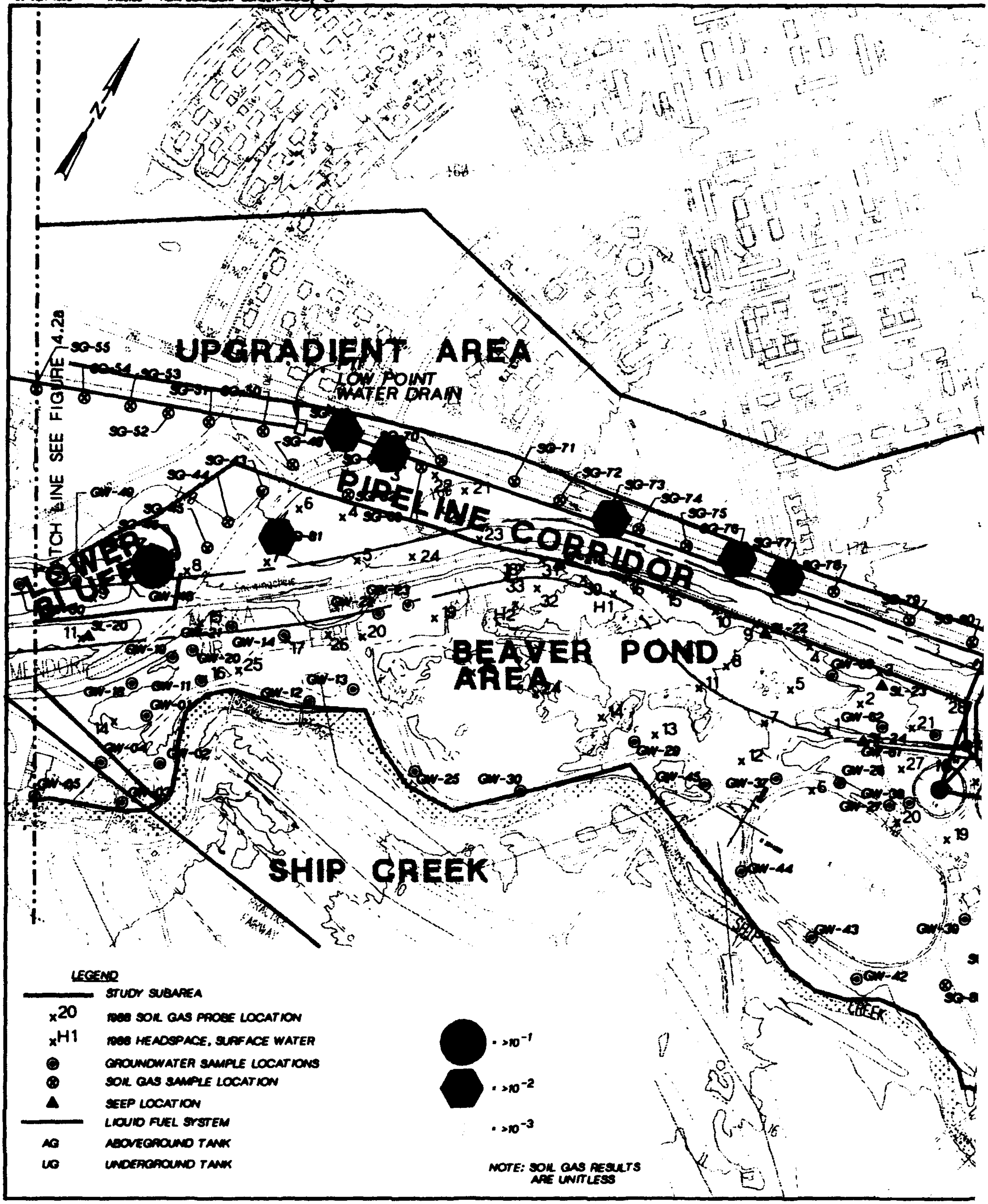

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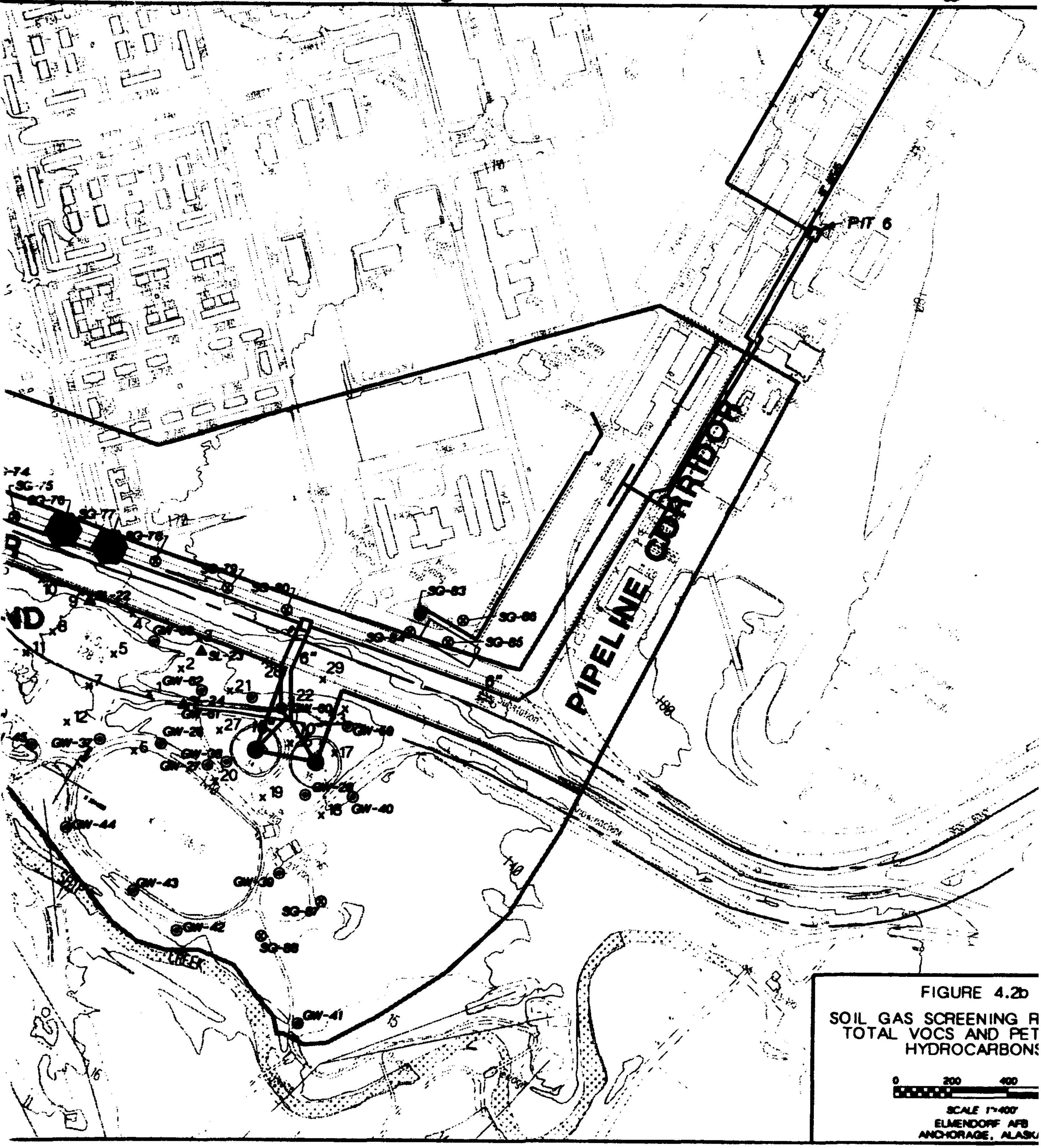

FIGURE 4.2b

SOIL GAS SCREENING R
TOTAL VOCS AND PET
HYDROCARBONS

3

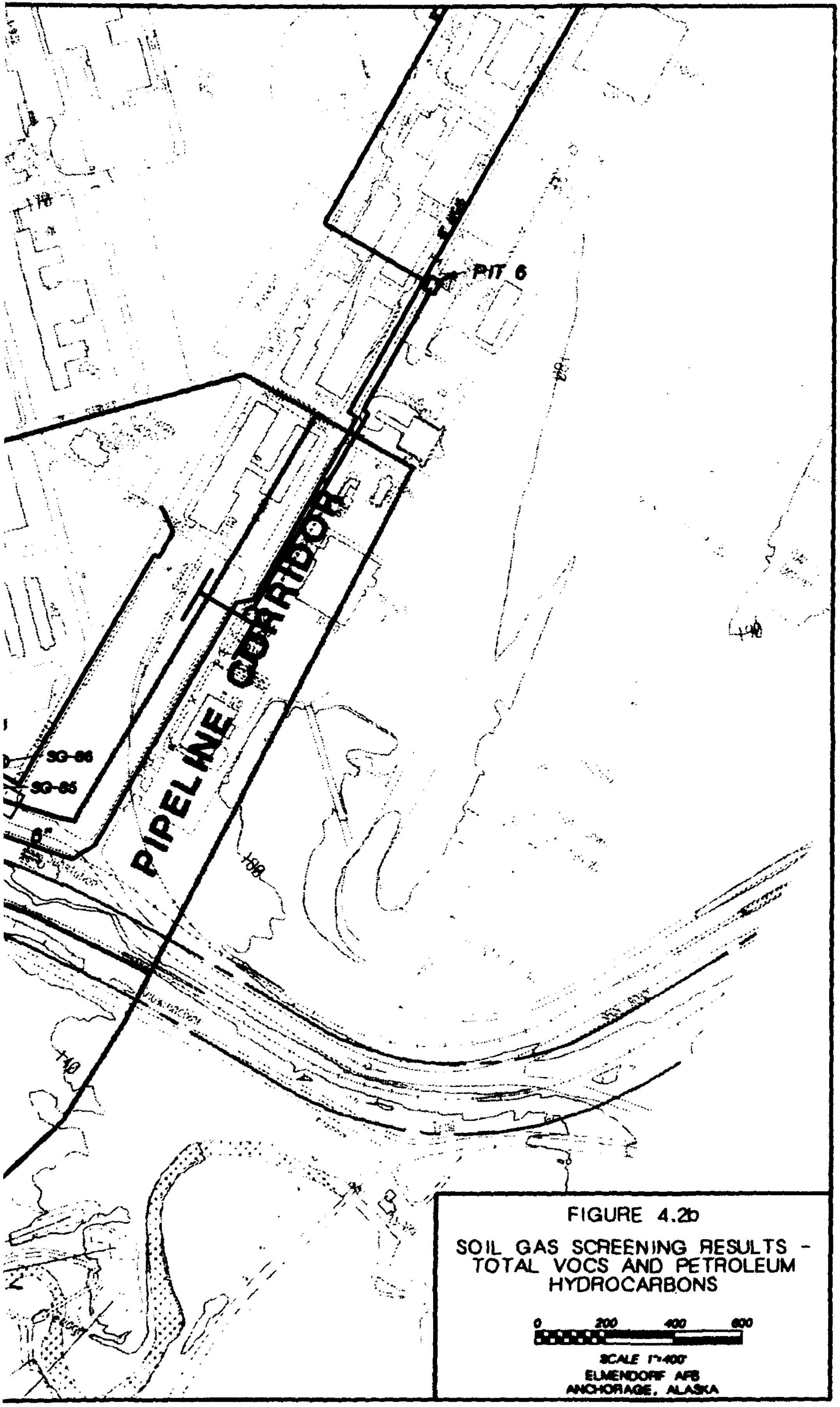

FIGURE 4.2b

SOIL GAS SCREENING RESULTS - TOTAL VOCS AND PETROLEUM HYDROCARBONS

SCALE 1"=400'

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ANCHORAGE, ALASKA

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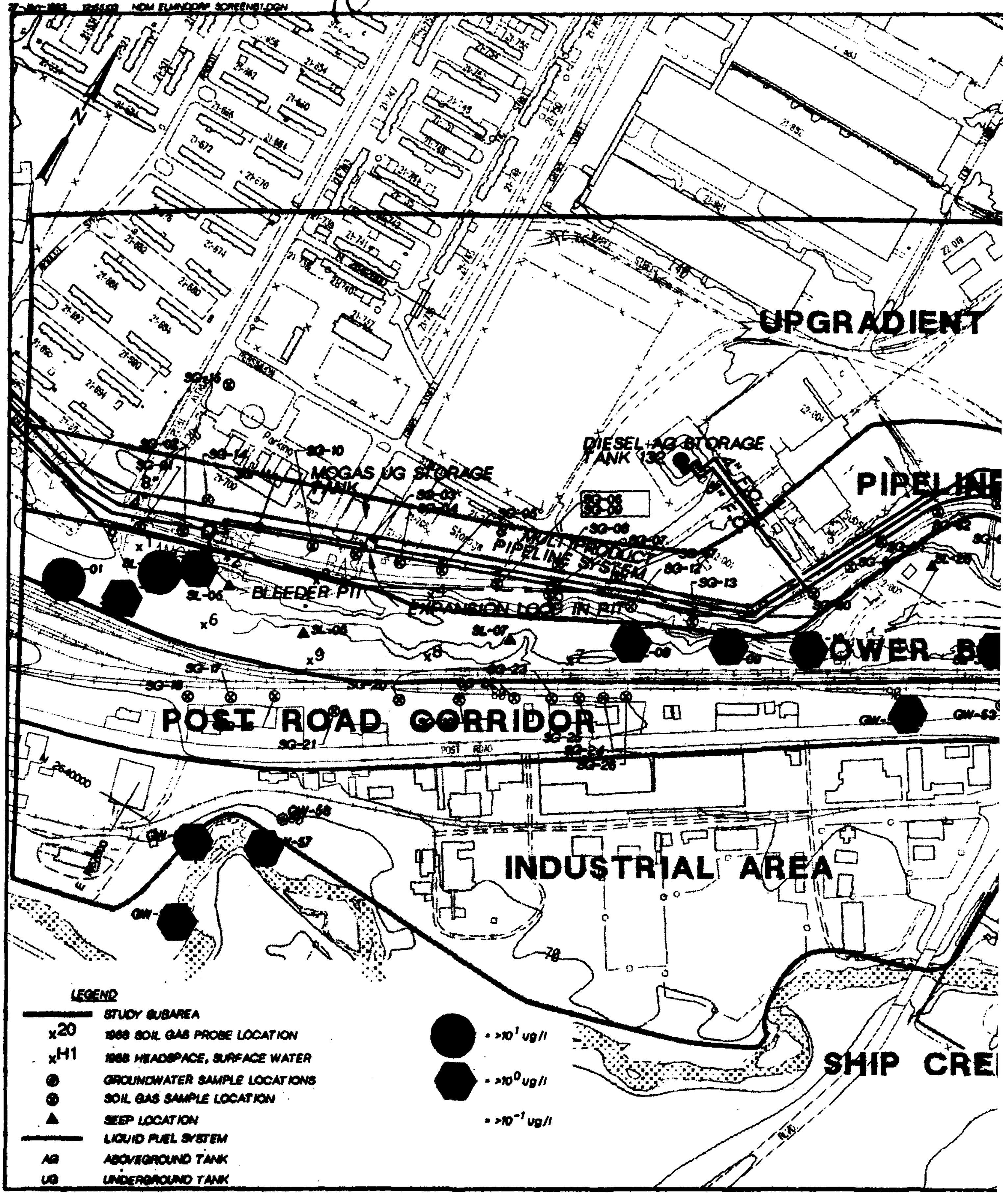

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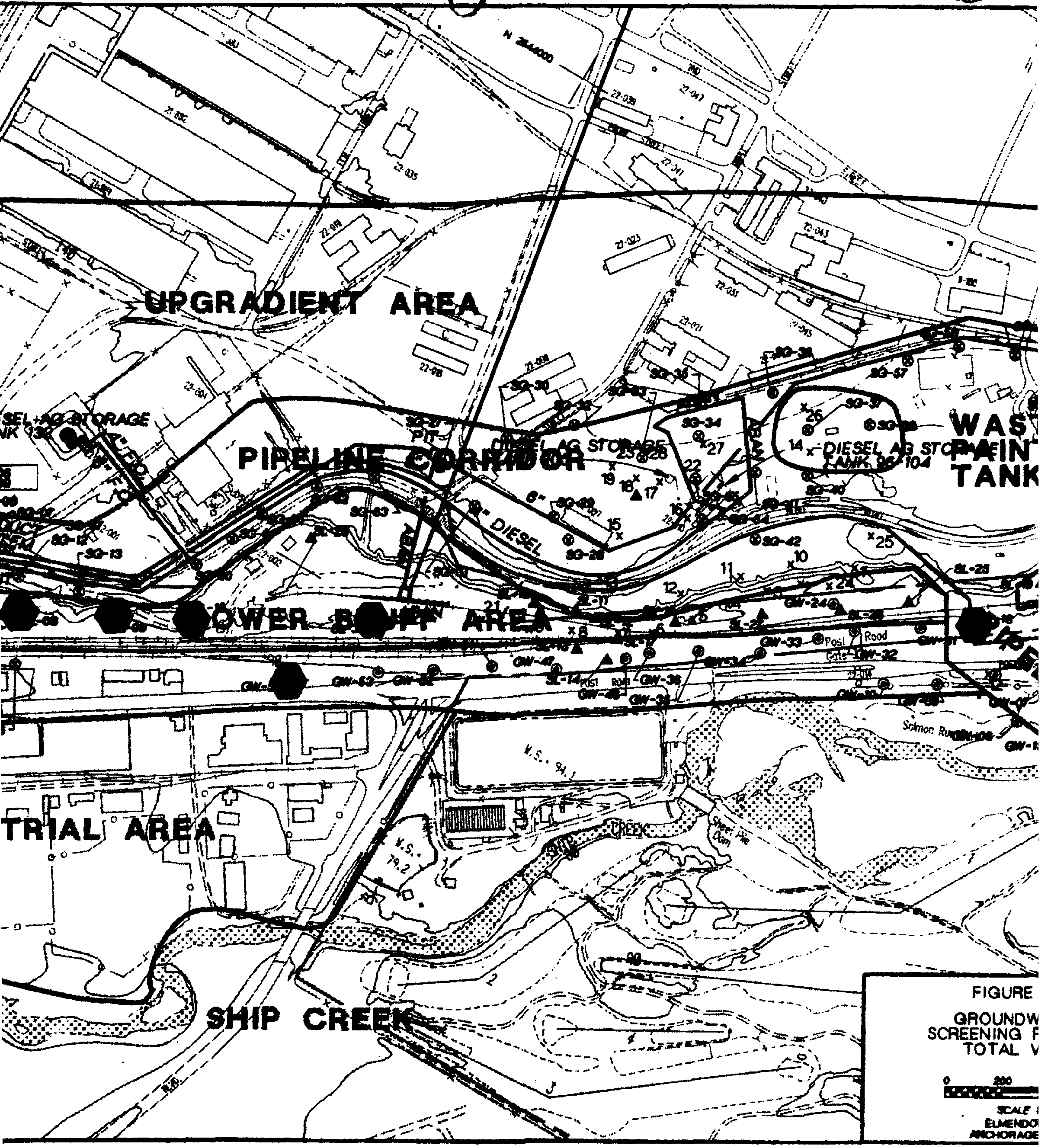
UPGRADIENT
PIPELINE
DIESEL-AG STORAGE TANK 132
MOGAS UG STORAGE TANK
MULTI-PRODUCT PIPELINE SYSTEM
BLEEDER PIT
EXPANSION LOOP IN PIT
LOWER B
POST ROAD CORRIDOR
POST ROAD
INDUSTRIAL AREA
SHIP CRE
SG-01
SG-02
SG-03
SG-04
SG-05
SG-06
SG-07
SG-08
SG-09
SG-10
SG-11
SG-12
SG-13
SG-14
SG-15
SG-16
SG-17
SG-20
SG-21
SG-22
SG-23
SG-24
SG-25
SG-26
SL-05
SL-06
SL-07
GW-57
GW-58
GW-53
N 2640000
78
LEGEND
STUDY SUBAREA
x20 1988 SOIL GAS PROBE LOCATION
xH1 1988 HEADSPACE, SURFACE WATER
GROUNDWATER SAMPLE LOCATIONS
SOIL GAS SAMPLE LOCATION
SEEP LOCATION
LIQUID FUEL SYSTEM
AG ABOVEGROUND TANK
UG UNDERGROUND TANK
= >10^1 ug/l
= >10^0 ug/l
= >10^-1 ug/l


UPGRADIENT AREA
PIPELINE CORRIDOR
LOWER BLUFF AREA
TRIAL AREA
SHIP CREEK
DIESEL AG STORAGE
DIESEL AG STORAGE TANK 96/104
WAS
PAIN
TANK
8" DIESEL
N 264000
SG-30
SG-32
SG-34
SG-37
SG-40
SG-42
SG-57
SG-26
SG-12
SG-13
GW-24
GW-33
GW-32
GW-47
GW-48
GW-36
GW-35
GW-53
GW-52
SL-14
SL-25
Post Road
Salmon Run
Sheet Pile Dam
W.S. = 94.1
W.S. = 79.2
CREEK
FIGURE
GROUNDW
SCREENING F
TOTAL V
0 200
SCALE
ELMENDO
ANCHORAGE

1

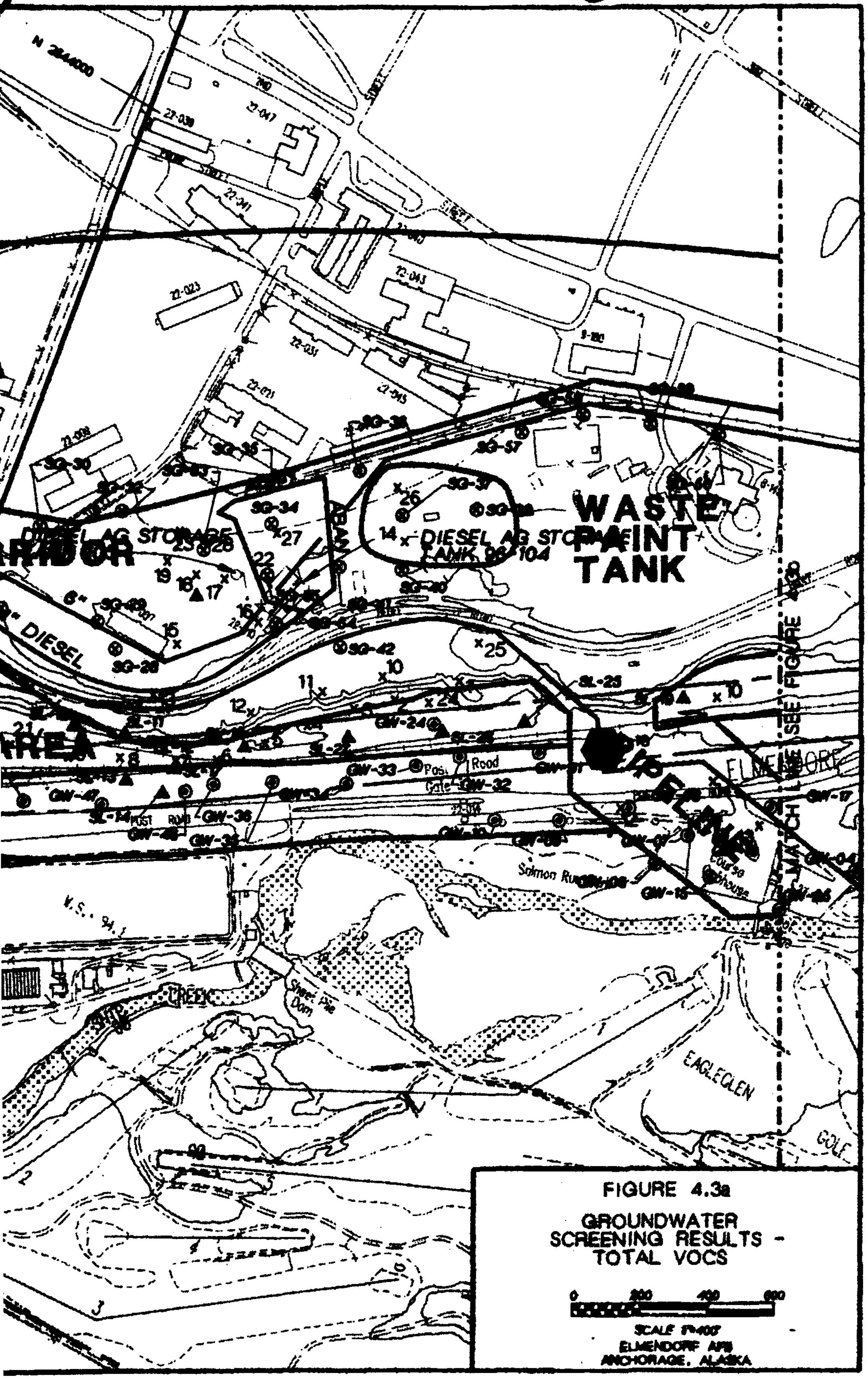


FIGURE 4.3a

GROUNDWATER SCREENING RESULTS - TOTAL VOCS

0 200 400 600

SCALE 1"=400'

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ANCHORAGE, ALASKA

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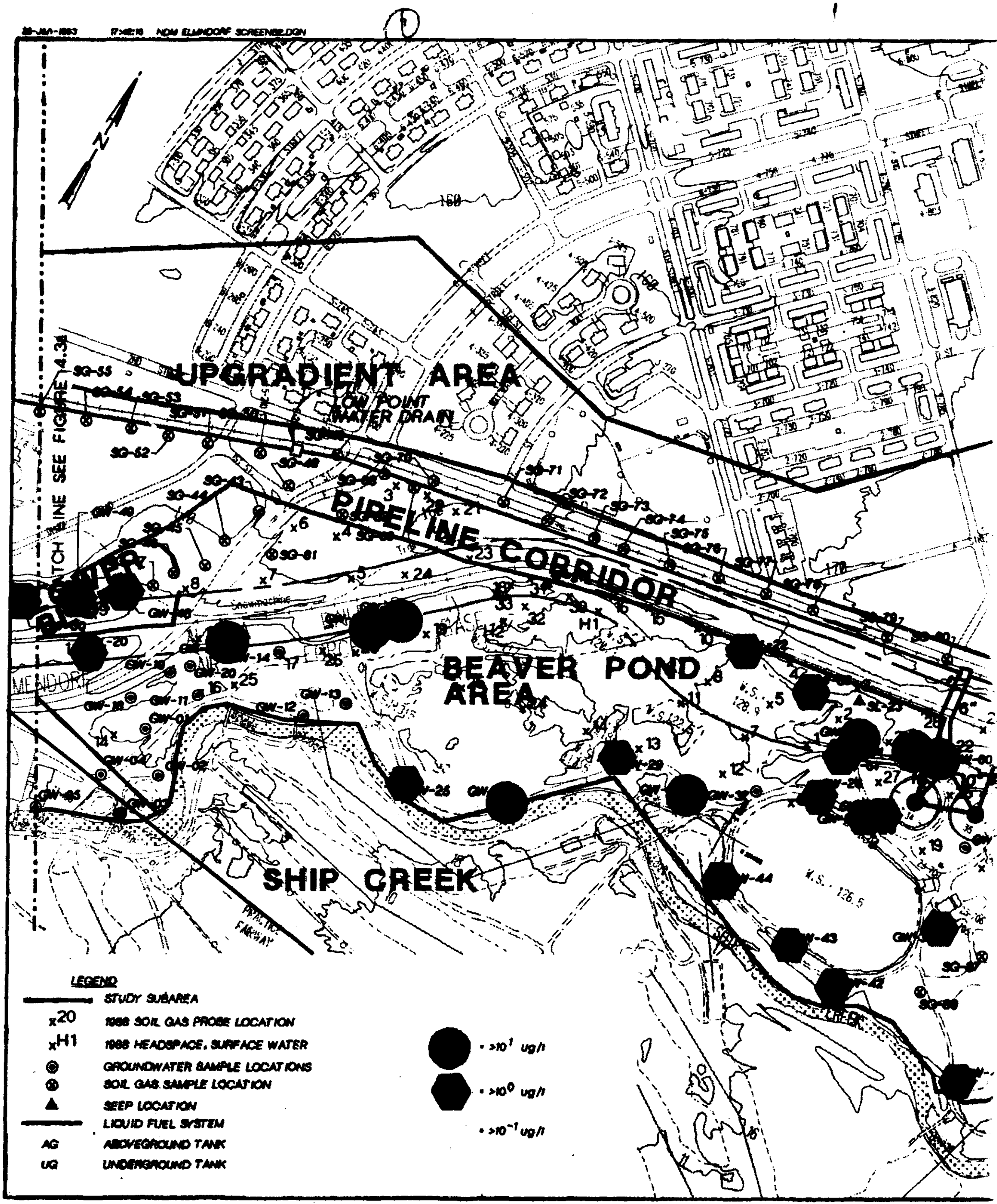

28-JAN-1993 17:48:16 NDM ELMNDORF SCREENSB.DGN
N
MATCH LINE SEE FIGURE 4.38
UPGRADIENT AREA
LOW POINT WATER DRAIN
PIPELINE CORRIDOR
BEAVER POND AREA
SHIP CREEK
SG-55
SG-54
SG-53
SG-52
SG-51
SG-50
SG-49
SG-48
SG-44
SG-43
SG-45
SG-46
SG-61
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SG-70
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SG-75
SG-76
SG-77
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SG-88
SL-23
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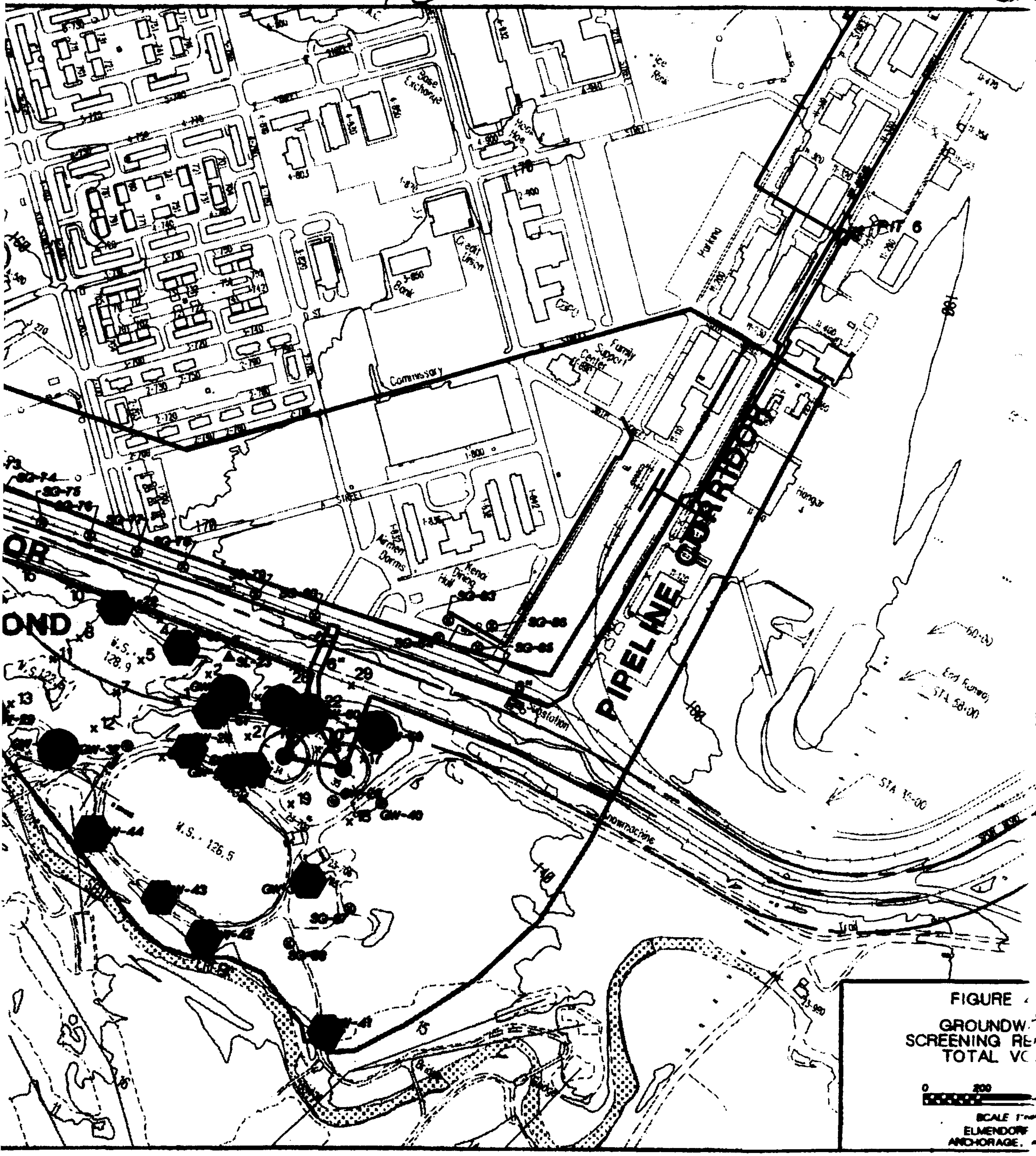
GW-04
GW-02
GW-03
GW-05
GW-12
GW-13
GW-26
GW-29
GW-32
GW-44
GW-43
GW-42
GW-30
H1
W.S. 128.9
W.S. 126.5
160
170
PRACTICE FAIRWAY
ELMENDORF
LEGEND
STUDY SUBAREA
x20 1988 SOIL GAS PROBE LOCATION
xH1 1988 HEADSPACE, SURFACE WATER
GROUNDWATER SAMPLE LOCATIONS
SOIL GAS SAMPLE LOCATION
SEEP LOCATION
LIQUID FUEL SYSTEM
AG ABOVEGROUND TANK
UG UNDERGROUND TANK
● >10¹ ug/l
⬢ >10⁰ ug/l
• >10⁻¹ ug/l



FIGURE

GROUNDW
SCREENING RE
TOTAL VC

SCALE 1"

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ANCHORAGE,

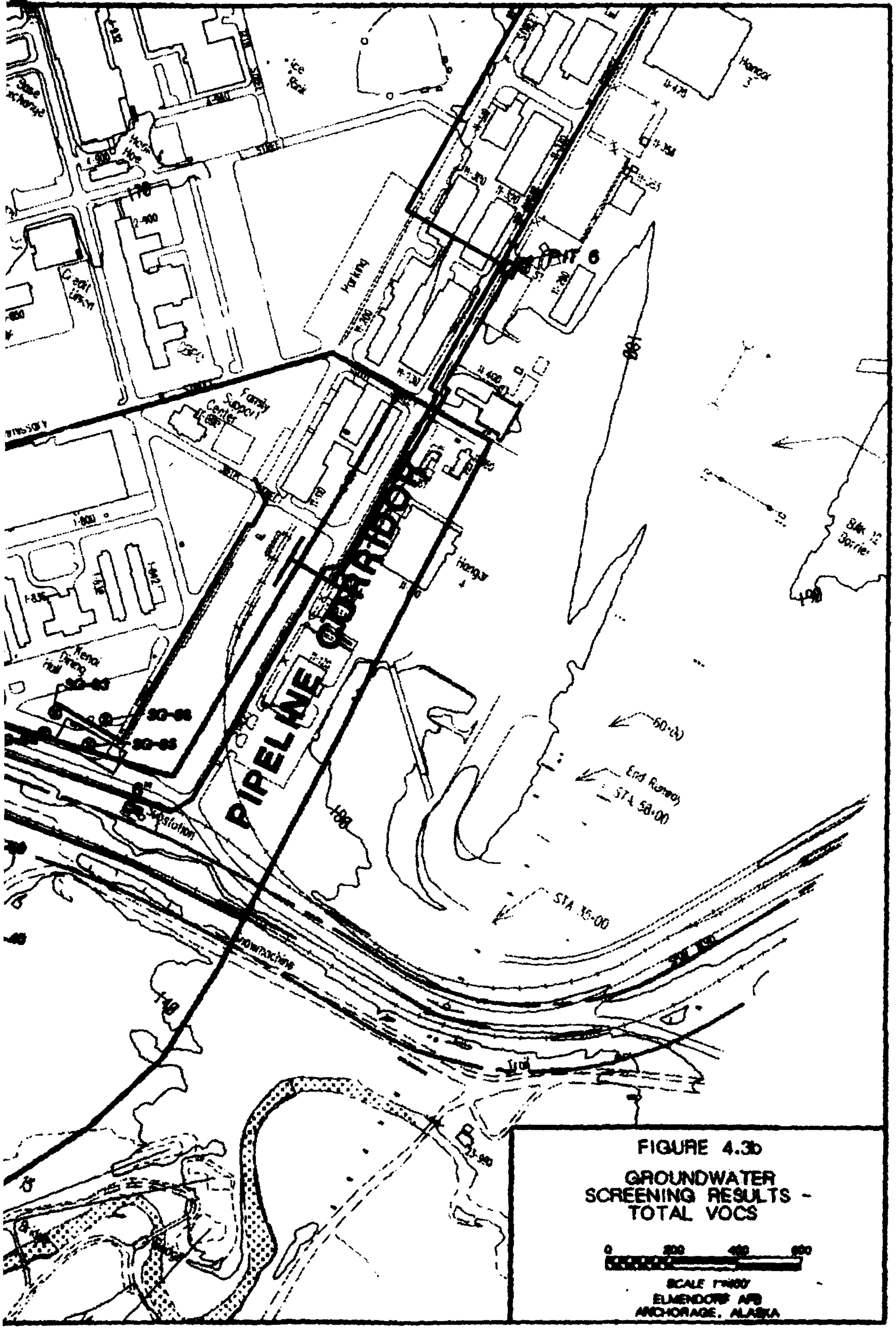

FIGURE 4.3b

GROUNDWATER SCREENING RESULTS - TOTAL VOCS

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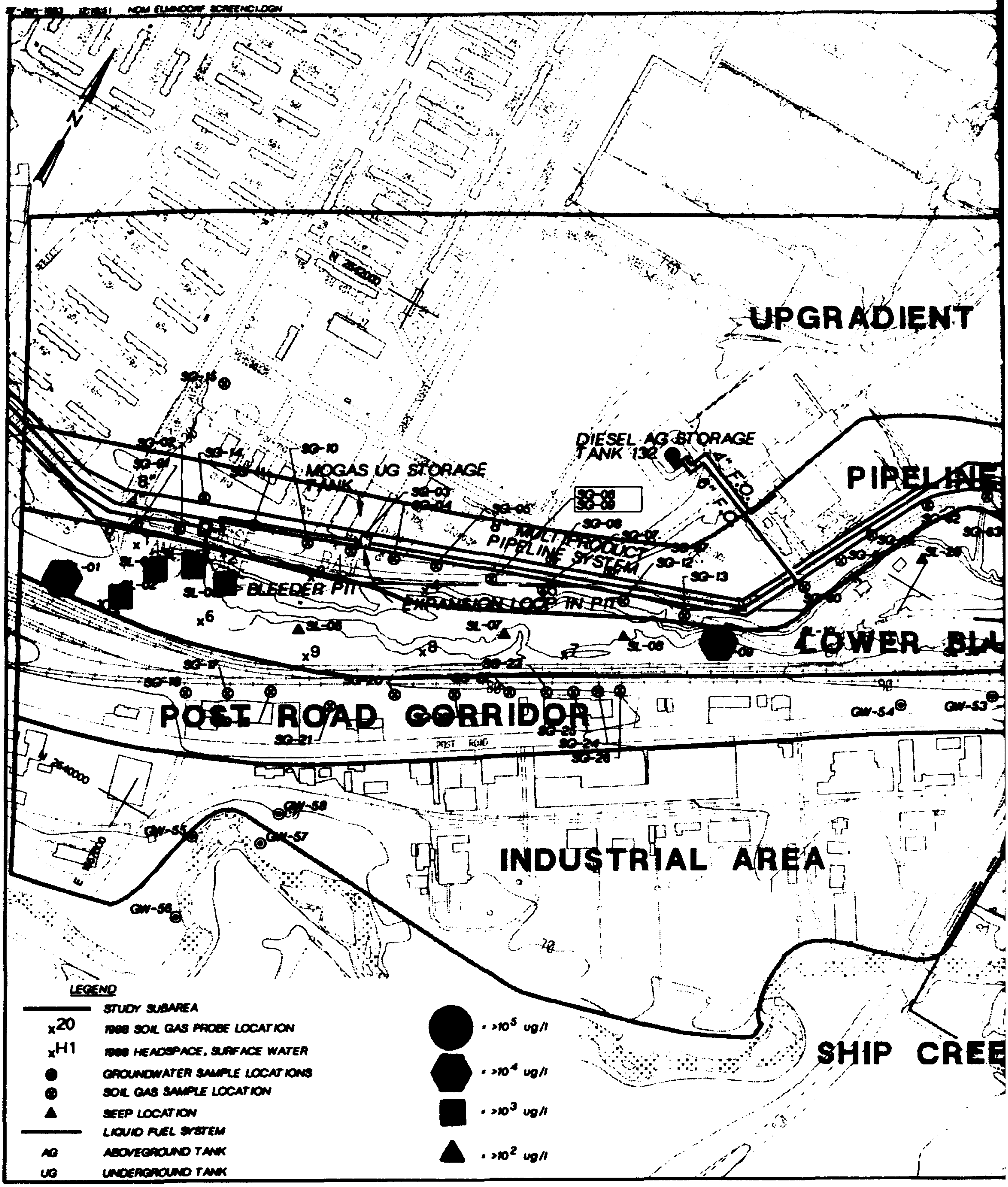

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N
UPGRADIENT
PIPELINE
LOWER BLU
POST ROAD CORRIDOR
POST ROAD
INDUSTRIAL AREA
SHIP CREE
DIESEL AG STORAGE TANK 132
4" F.O.
6" F.O.
MOGAS UG STORAGE TANK
8" MULTI-PRODUCT PIPELINE SYSTEM
8"
BLEEDER PIT
EXPANSION LOOP IN PIT
N 2640000
SG-01
SG-02
SG-03
SG-04
SG-05
SG-06
SG-07
SG-08
SG-09
SG-10
SG-11
SG-12
SG-13
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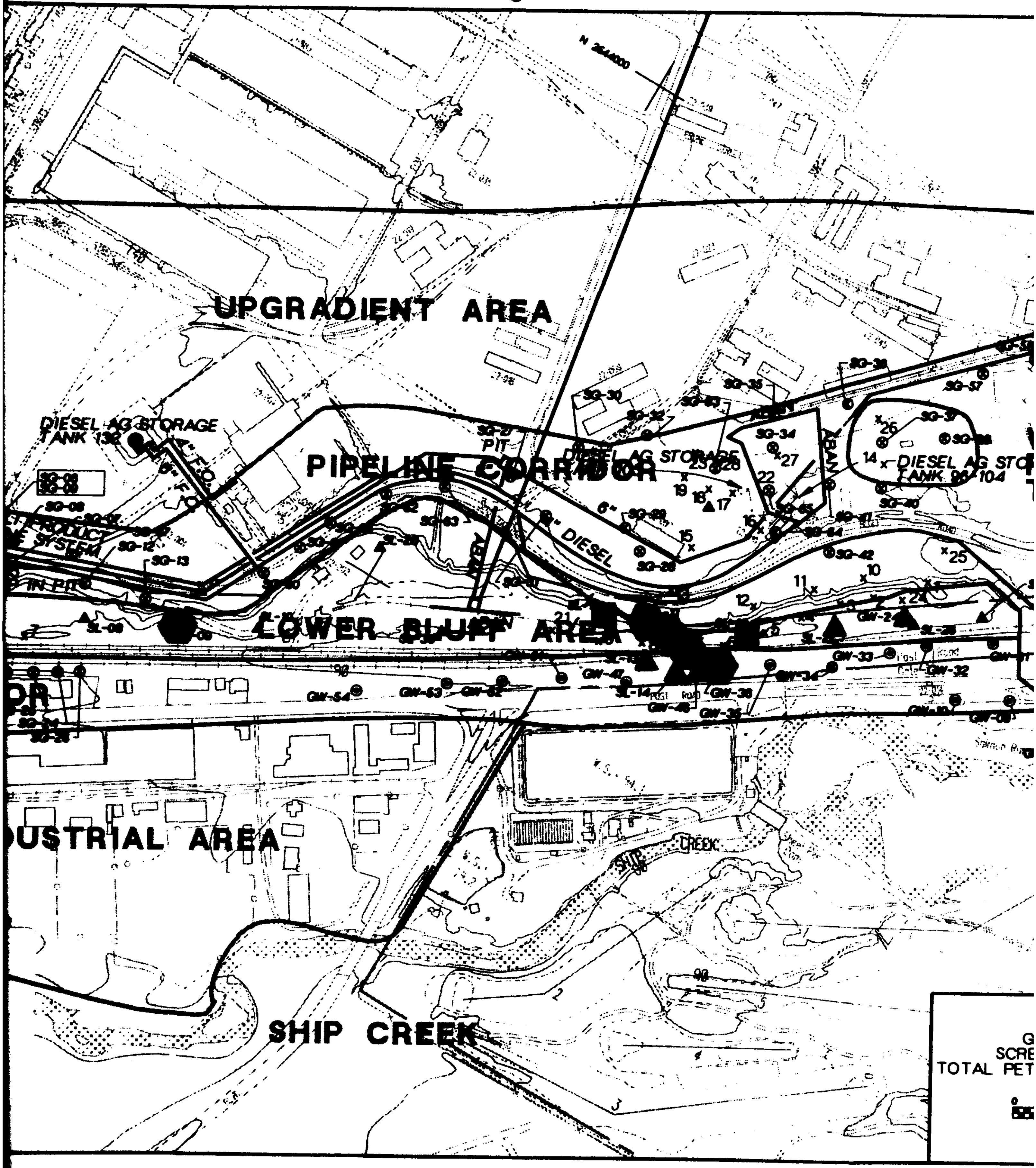
SL-02
SL-05
SL-06
SL-07
SL-08
SL-09
SL-26
x1
x6
x7
x8
x9
10
GW-53
GW-54
GW-55
GW-56
GW-57
GW-58
LEGEND
STUDY SUBAREA
x20 1988 SOIL GAS PROBE LOCATION
xH1 1988 HEADSPACE, SURFACE WATER
● GROUNDWATER SAMPLE LOCATIONS
⊗ SOIL GAS SAMPLE LOCATION
▲ SEEP LOCATION
LIQUID FUEL SYSTEM
AG ABOVEGROUND TANK
UG UNDERGROUND TANK
● >10^5 ug/l
⬢ >10^4 ug/l
■ >10^3 ug/l
▲ >10^2 ug/l

②



N 264000
UPGRADIENT AREA
PIPELINE CORRIDOR
LOWER BLUFF AREA
DUSTRIAL AREA
SHIP CREEK
SHIP CREEK
DIESEL AG STORAGE TANK 132
DIESEL AG STORAGE
DIESEL AG STO TANK 96
PIT
6" DIESEL
6" FO
PRODUCT SYSTEM
IN PIT
SG-08
SG-09
SG-12
SG-13
SG-27
SG-30
SG-32
SG-33
SG-34
SG-35
SG-36
SG-37
SG-38
SG-40
SG-41
SG-42
SG-57
SG-60
SG-62
SG-63
SG-64
SL-08
SL-14
GW-24
GW-31
GW-32
GW-33
GW-34
GW-36
GW-38
GW-40
GW-42
GW-46
GW-52
GW-53
GW-54
10
11
12
14
15
16
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18
19
21
22
23
24
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26
27
28
G
SCRE
TOTAL PET
0

② ③

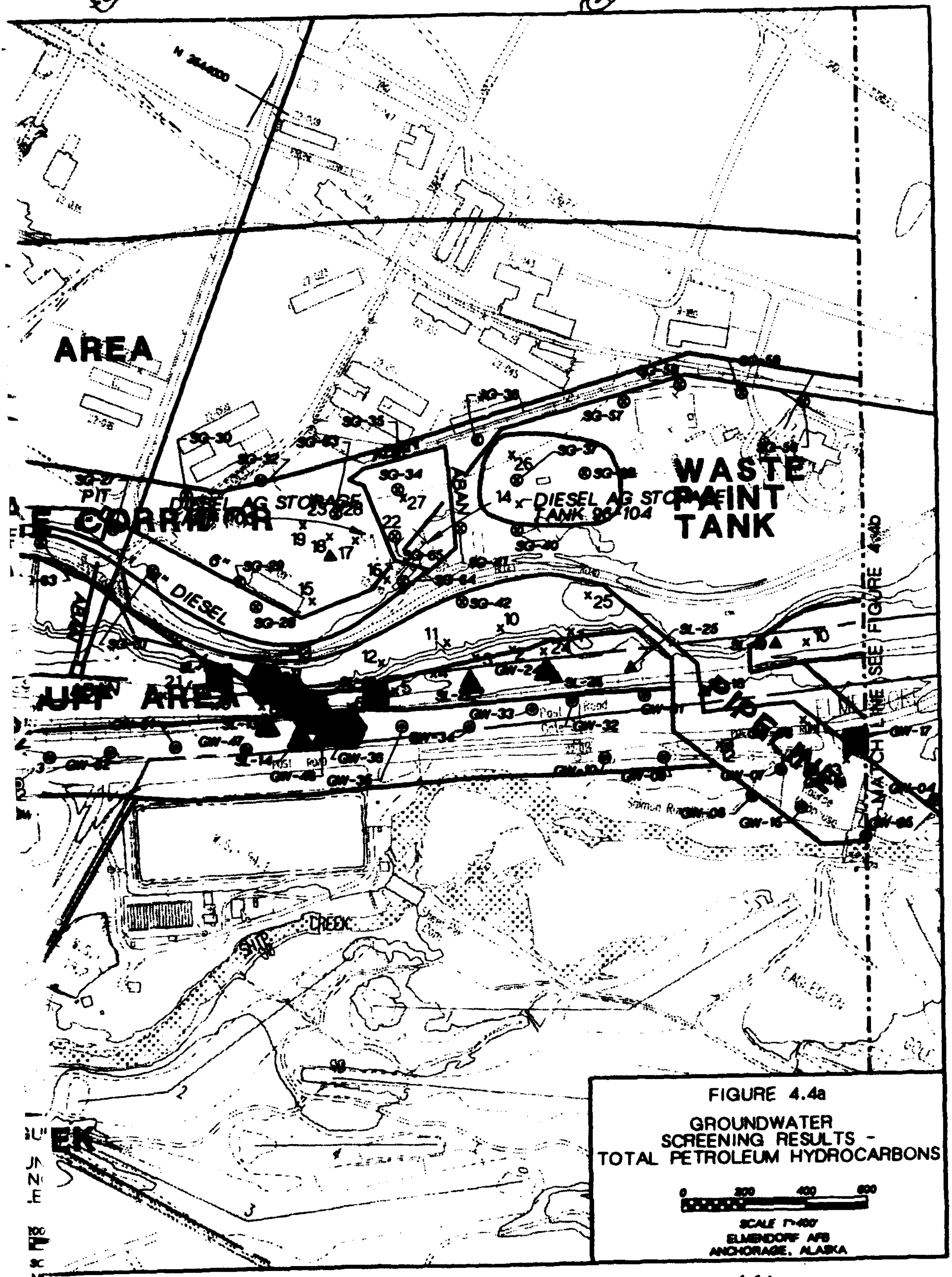


FIGURE 4.4a

GROUNDWATER
SCREENING RESULTS -
TOTAL PETROLEUM HYDROCARBONS

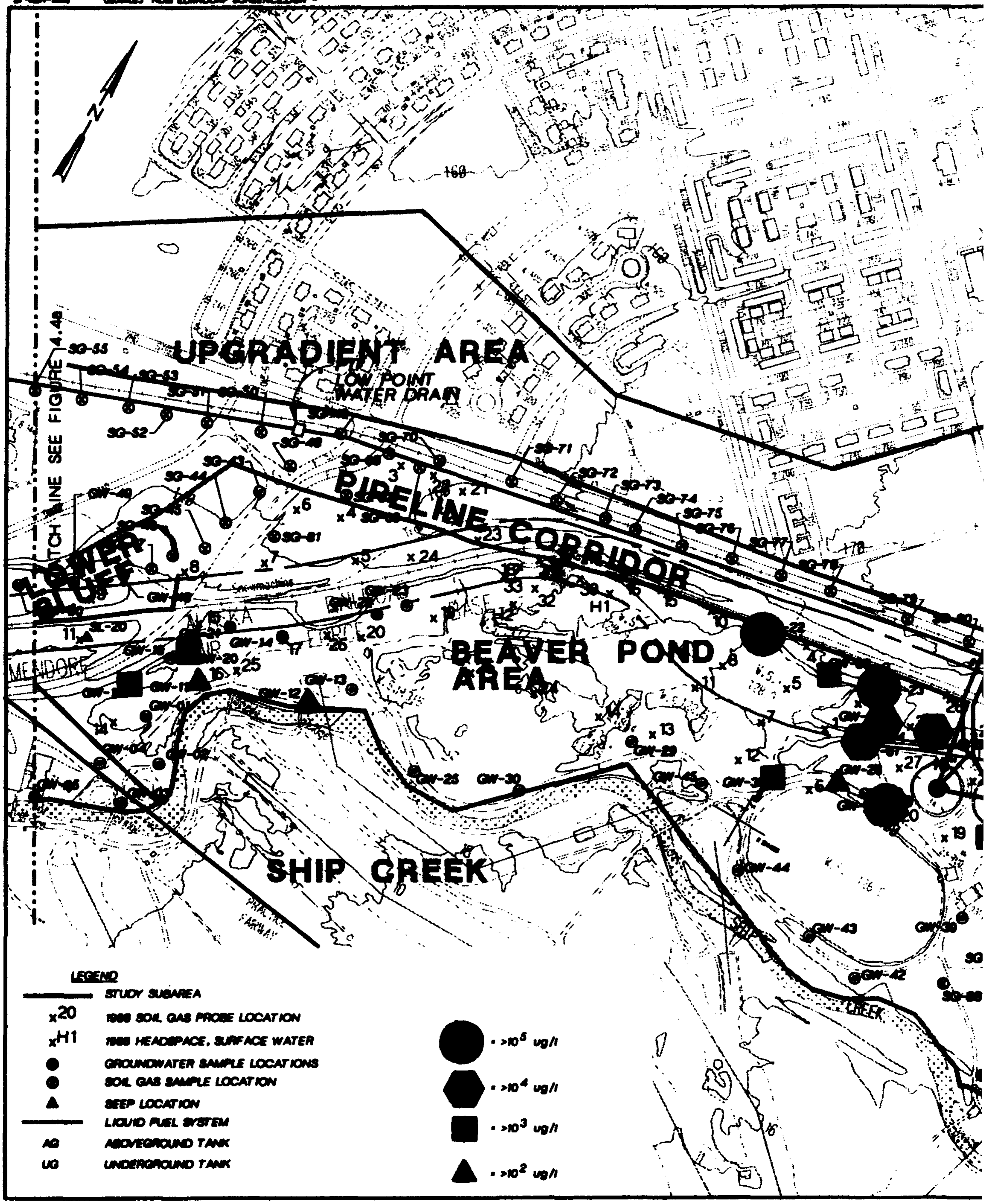
0 200 400 600

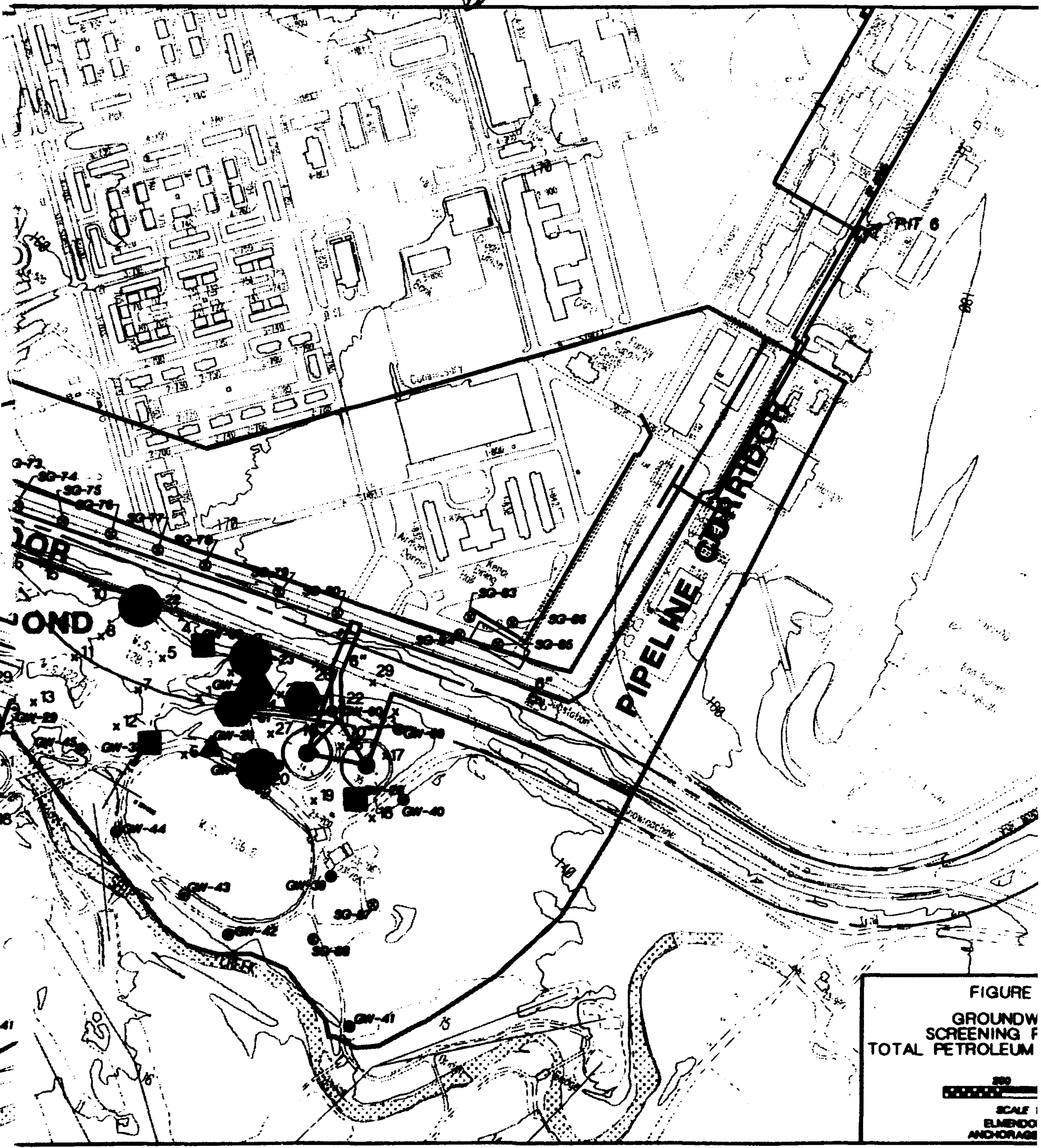
SCALE 1"=400'

ELMENDORF AFB
ANCHORAGE, ALASKA

1

27-Jan-1989 08:44:23 HCM ELMNDORF SCREENC2.DGN (1)





FIGURE

GROUNDW
SCREENING F
TOTAL PETROLEUM

SCALE
ELMENDO
ANCHORAGE

1 ②

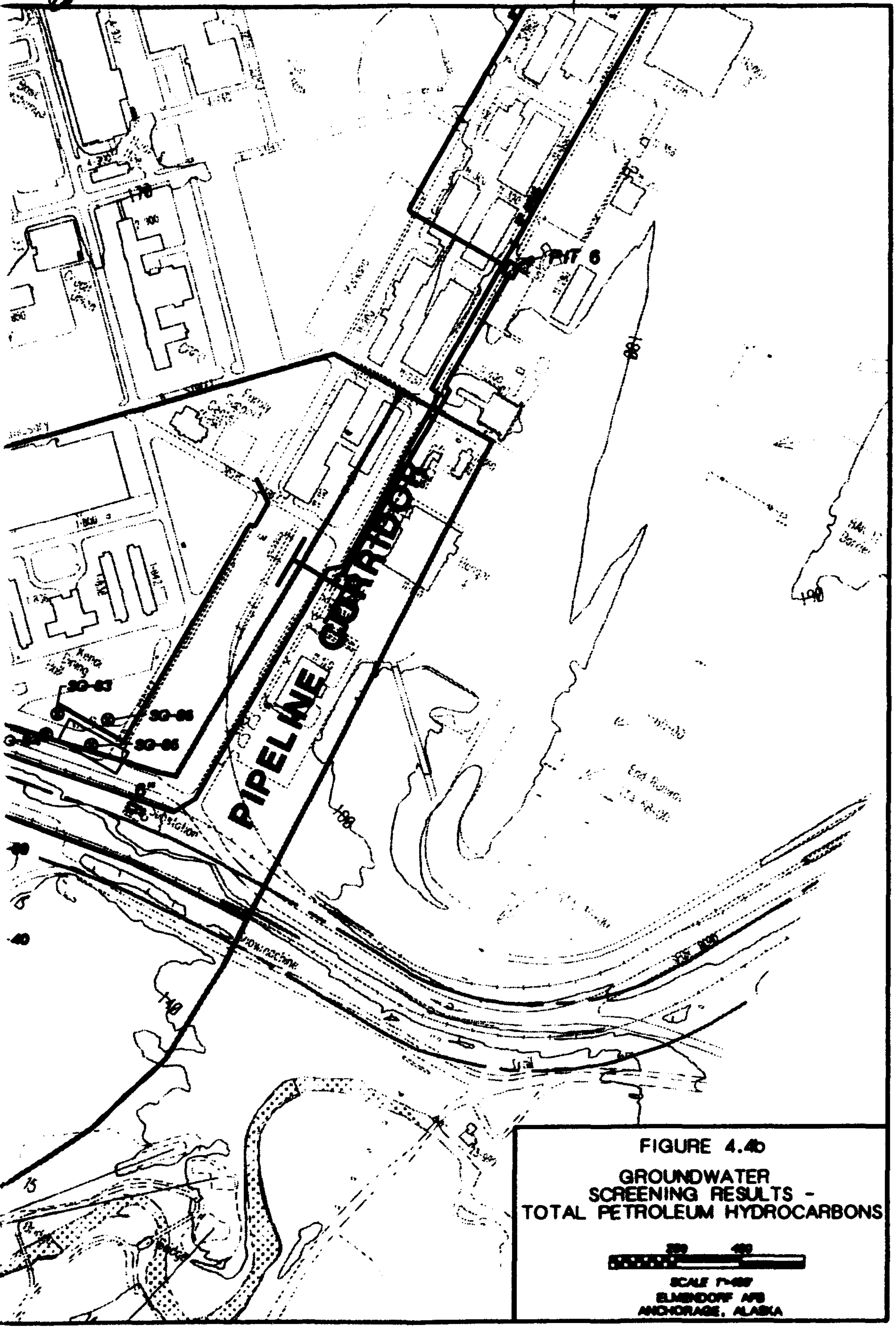


FIGURE 4.4b

GROUNDWATER SCREENING RESULTS - TOTAL PETROLEUM HYDROCARBONS

SCALE 1"=400'
ELMENDORF AFB
ANCHORAGE, ALASKA

4.1.2 Discussion

The soil gas screening results showed detections of 1,1,1-trichloroethane, cis-1,2-dichloroethene, trichloroethene, and tetrachloroethene at numerous locations in western OU 5 along the pipeline corridor and south of the railroad tracks along the Post Road corridor. The pattern of detections does not indicate a localized source area in OU 5 for VOCs. The widespread occurrence of VOCs in soil gas may be indicative of groundwater contaminants transported from upgradient sources.

Petroleum-range hydrocarbons were detected in soil gas at only five locations, and no BTEX compounds were detected. Most of the petroleum hydrocarbon hits were detected south of the railroad tracks along the Post Road corridor where groundwater is generally within 10 feet of the surface and may indicate fuel contamination in the groundwater.

Groundwater screening results indicated the presence of VOCs at several of the lower bluff area seeps on western OU 5, south of Post Road near the golf course clubhouse, and, in eastern OU 5, around the JP-4 storage tanks and along the northern bank of Ship Creek. The widespread occurrence and relatively low-level concentrations suggest that the VOCs are migrating in the groundwater from an unknown upgradient source.

Petroleum-range hydrocarbons were observed in reasonably tight clusters at groundwater seeps and in shallow groundwater below known source areas. Groups of hits were found below Sources ST37, ST38/SS42, SS53, and ST46.

Based on the soil gas and groundwater screening results, soil borings were placed along the pipeline corridor at Source ST37 (borings SB18 through SB21 and SB29), at the western end of Sources ST38/SS42 (borings SB22 and SB23), and along the pipeline corridor near Source SS53 (borings SB26, SB27, and SB28). Monitoring wells were installed to extend the coverage of the existing monitoring well network and to confirm the presence of contaminants observed in the groundwater screening survey. New wells in western OU 5 were placed between the bluff and Ship Creek along the Post Road corridor (wells MW12 through MW17) and along the north bank of Ship Creek in the golf course beaver pond area (wells MW09, MW10, MW30, and MW31).

4.2 Soil

4.2.1 Results

Soil samples were obtained from at least three depths for each soil boring in the upgradient area and the pipeline corridor to evaluate the presence of source area contamination in the vadose zone. The sampling intervals included surface soils (zero to 2 feet) at six locations, and for all borings, between surface and the water table at 10- and 25-foot depths, and at the water table. Samples were also collected at the top of the Bootlegger Cove Formation in borings SB19, SB21, SB23, and SB28 to evaluate the presence of DNAPLs. In the shallow groundwater areas along Post Road and the golf course beaver pond, soil samples were obtained from a single depth at the top of the water table.

All soil boring samples were analyzed for organic compounds by the quick-turnaround time CSL in Corvallis, Oregon. The CSL analyses included four Method 8010 compounds (1,1,1-TCA; trans-1,2-DCE; TCE; and PCE); Method 8015 total fuel hydrocarbon tests for gasoline, diesel, and JP-4 range organics; and four Method 8020 compounds (BTEX compounds). The CSL data are reported on an as-received (wet weight) basis. A summary of detection frequencies, ranges of values, and arithmetic and geometric means for the CSL data is presented in Table 4-3. Figure 4-5 shows the locations for detected organic constituents in soil.

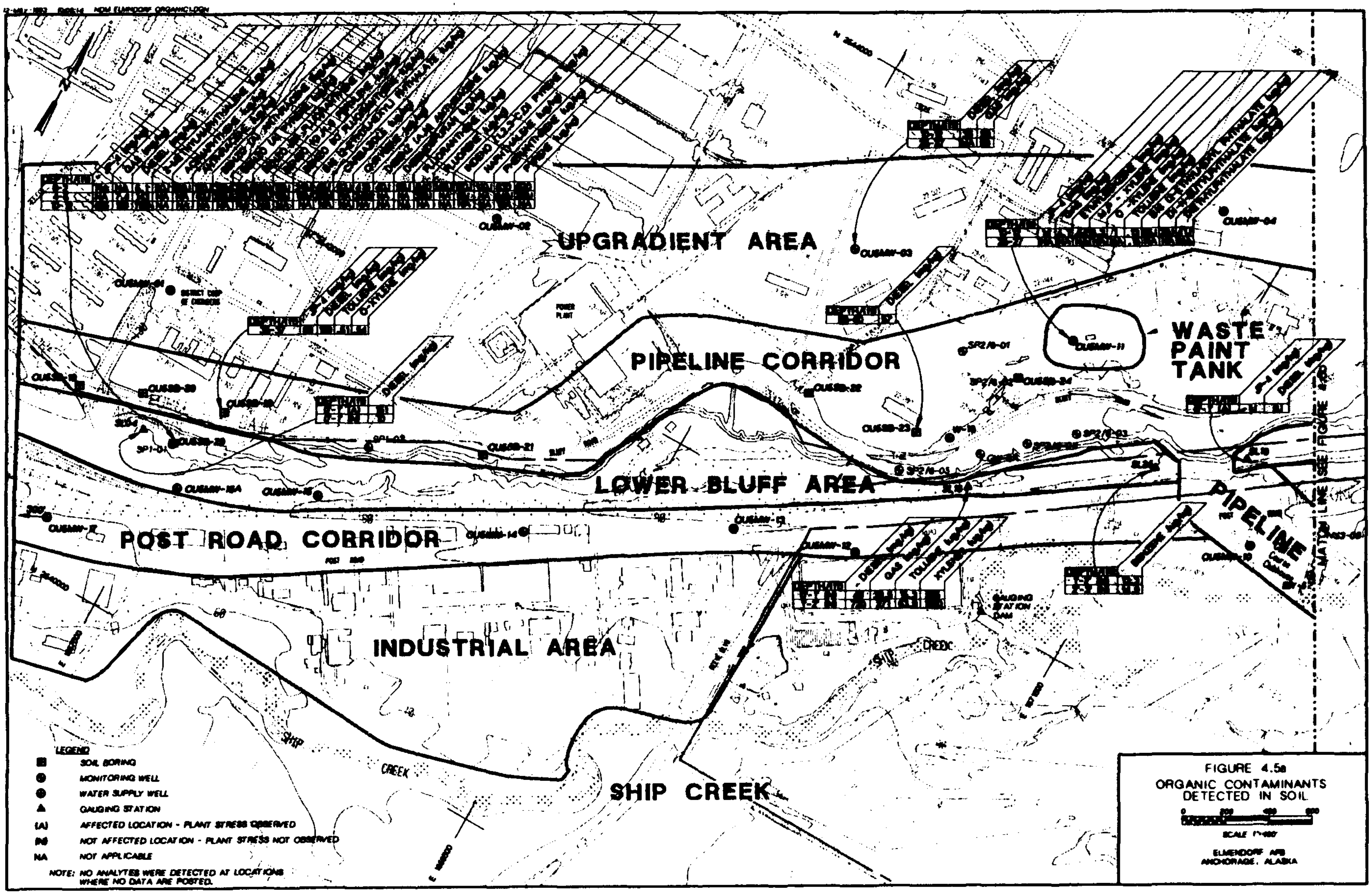
Approximately 10% of the soil boring samples were split and analyzed by the normal (30-day) turnaround time laboratory in Redding, California, for the Method 8010 (full list), Method 8015, Method 8020 (BTEX), and Method 8270 (semivolatile organic)

Table 4-3

Summary of Analytical Results for Detected Organic Constituents in Soil (Quick Turnaround Results)

Study Subarea	Depth	Detected Compound	Range of Detected Values (µg/kg)	Geometric Mean (µg/kg)	Arithmetic Mean (µg/kg)	No. of Detections/ No. of Samples	Percent of Samples
Upgradient	Deep	JP-4	80410 - NA	NA	NA	1/20	5
	Deep	TFH Diesel	38880 - NA	NA	NA	1/20	5
	Deep	TFH Gas	50000 - 50000	2.68×10^4	2.75×10^4	2/20	10
Pipeline Corridor	Deep	Benzene	20 - NA	NA	NA	1/34	3
	Deep	Ethylbenzene	220 - NA	NA	NA	1/34	3
	Deep	JP-4	89050 - 164590	2.74×10^4	3.10×10^4	2/34	6
	Deep	M,P-Xylene (Sum of Isomers)	660 - NA	NA	NA	1/34	3
	Deep	O-Xylene (1,2-Dimethyl benzene)	540 - NA	NA	NA	1/34	3
	Deep	TFH Diesel	56630 - 172180	2.86×10^4	3.42×10^4	3/34	9
	Deep	Toluene	390 - 510	2.96×10^1	5.00×10^1	2/34	6
Waste Paint Tank	Deep	Ethylbenzene	638 - NA	NA	NA	1/3	33
	Deep	M,P-Xylene (Sum of Isomers)	8298 - NA	NA	NA	1/3	33
	Deep	O-Xylene (1,2-Dimethyl benzene)	1077 - NA	NA	NA	1/3	33
	Deep	Toluene	132 - 166	8.18×10^1	1.08×10^2	2/3	67
Lower Bluff	Deep	JP-4	606980 - NA	NA	NA	1/4	25
	Deep	TFH Diesel	143110 - 1160000	1.01×10^5	3.38×10^5	2/4	50
	Deep	TFH Gas	7400 - 168000	1.51×10^4	5.02×10^4	2/5	40
Post Road Corridor	Deep	Toluene	68 - NA	NA	NA	1/7	14

Note: Results reported on "as received" (wet weight) basis.
NA = Not Applicable due to only one reported value.



NOTE: NO ANALYTES WERE DETECTED AT LOCATIONS WHERE NO DATA ARE POSTED.

FIGURE 4.5a
ORGANIC CONTAMINANTS DETECTED IN SOIL

ELMENDORF AFB
ANCHORAGE, ALASKA

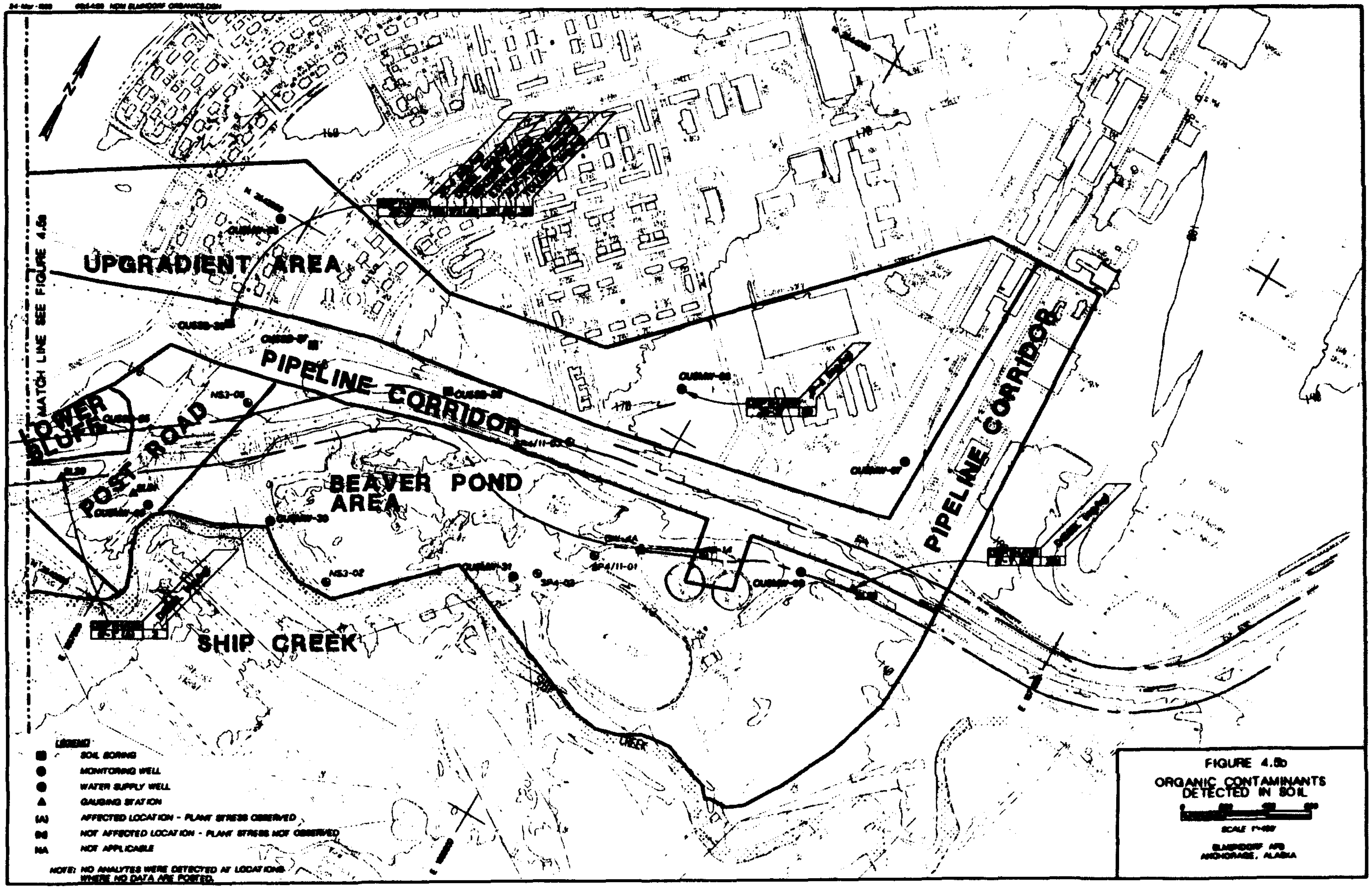


FIGURE 4.5b

ORGANIC CONTAMINANTS DETECTED IN SOIL

ELMENDORF AFB
ANCHORAGE, ALASKA

compounds. In addition, surface and root-zone soil samples collected as part of the terrestrial ecological survey for evaluating plant stress in OU 5 were analyzed for Method 8010 (full list), Method 8015, and Method 8020 (BTEX) compounds by a normal (30-day) turnaround time laboratory. The 30-day turnaround time results are reported on a dry-weight basis. A summary of these results is presented in Table 4-4 and the detected compounds are also shown on Figure 4-5.

Metals were evaluated first by comparing soil sample concentrations to background concentrations obtained during the basewide background sampling activities (CH2M HILL 1992a). A statistical summary of background metals in Elmendorf AFB soils is presented in Table 4-5. To evaluate metal results in soil samples from OU 5, each sample result was compared to the upper tolerance limit (UTL) in Table 4-5, which is defined as the 99th percentile value calculated at a 95% confidence interval. If the soil concentration is higher than the background comparison level, the possible reasons for this are discussed. Table 4-6 presents a summary of analytical results for metals in the soil samples from OU 5, including the number of results that exceeded background comparison levels. The sampling locations where metals exceeded background levels are presented on Figure 4-6. Only metals that are considered contaminants of concern for the human health risk assessments and ecological evaluations presented in subsequent sections of this report are shown on the figure.

Fly ash deposits have been observed on the lower bluff areas below Monitoring Well SP1-02, and were documented in the boring logs for pre-existing wells SP2/6-03, SP2/6-04, GW-6A, and SP2/6-05. Composite fly ash samples from two locations on the bluff below well SP1-02 were collected and analyzed for total TAL metals and metals in leachate using a modified EP (extraction procedure) Toxicity Test procedure with deionized water as the extractant. Results for the fly ash analyses are summarized in Table 4-7.

Background soil metal concentrations were also compared to levels in volcanic ash deposits at OU 5. On the evening of August 18, 1992, a volcanic eruption of Mount

Table 4-4

Summary of Analytical Results for Detected Organic Constituents in Soil (Normal Turnaround Results)

Study Subzone	Depth	Detected Compound	Range of Detected Values (µg/kg)	Geometric Mean (µg/kg)	Arithmetic Mean (µg/kg)	No. of Detections/ No. of Samples	Percent of Sample
Pipeline Corridor	Deep	4-Nitrophenol	100 - NA	NA	NA	1/5	20
	Deep	Diethyl phthalate	49 - NA	NA	NA	1/5	20
	Deep	Pyrene	44 - NA	NA	NA	1/5	20
Waste Paint Tank	Deep	Di-n-butyl phthalate	39 - NA	NA	NA	1/1	100
	Deep	Diethyl phthalate	41 - NA	NA	NA	1/1	100
	Deep	Ethylbenzene	51 - NA	NA	NA	1/1	100
	Deep	JP-4	14000 - NA	NA	NA	1/1	100
	Deep	TPH Gas	4100 - NA	NA	NA	1/1	100
	Deep	Toluene	7.8 - NA	NA	NA	1/1	100
	Deep	Xylenes, total	1800 - NA	NA	NA	1/1	100
	Deep	bis(2-Ethylhexyl) phthalate	86 - NA	NA	NA	1/1	100
Lower Bluff	Surface	Benzo(k)fluoranthene	43 - NA	NA	NA	1/1	100
	Surface	Ethylbenzene	200 - 202	7.98×10^1	4.03×10^1	2/11	18
	Surface	Fluoranthene	63 - NA	NA	NA	1/1	100
	Surface	JP-4	1000 - NA	NA	NA	1/10	10
	Surface	Phenanthrene	39 - NA	NA	NA	1/1	100
	Surface	Pyrene	67 - NA	NA	NA	1/1	100
	Surface	TPH Diesel	6100 - 83000	5.67×10^3	1.70×10^4	7/11	64
	Surface	TPH Gas	39500 - 310000	2.08×10^4	5.53×10^4	3/11	27
	Surface	Toluene	16.3 - NA	NA	NA	1/11	9
	Surface	Xylenes, Total	565 - 3940	2.10×10^2	6.91×10^2	3/11	27
	Surface	bis(2-Ethylhexyl) phthalate	49 - NA	NA	NA	1/1	100
	Root	Benzene	13.3 - 14.9	7.47×10^0	9.30×10^0	2/6	33
	Root	TPH Diesel	720000 - NA	NA	NA	1/6	17
	Root	TPH Gas	271000 - NA	NA	NA	1/6	17

Table 4-4

(Continued)

Study Subarea	Depth	Detected Compound	Range of Detected Values (µg/kg)	Geometric Mean (µg/kg)	Arithmetic Mean (µg/kg)	No. of Detections/ No. of Samples	Percent of Sample
	Root	Toluene	63.9 - NA	NA	NA	1/6	17
	Root	Xylenes, Total	1980 - NA	NA	NA	1/6	17
	Deep	2-Methylnaphthalene	48 - NA	NA	NA	1/1	100
	Deep	Anthracene	63 - NA	NA	NA	1/1	100
	Deep	Benzo(a)anthracene	200 - NA	NA	NA	1/1	100
	Deep	Benzo(a)pyrene	330 - NA	NA	NA	1/1	100
	Deep	Benzo(b)fluoranthene	160 - NA	NA	NA	1/1	100
	Deep	Benzo(g,h,i)perylene	100 - NA	NA	NA	1/1	100
	Deep	Benzo(k)fluoranthene	180 - NA	NA	NA	1/1	100
	Deep	Chrysene	240 - NA	NA	NA	1/1	100
	Deep	Fluoranthene	300 - NA	NA	NA	1/1	100
	Deep	Indeno(1,2,3-c,d)pyrene	98 - NA	NA	NA	1/1	100
	Deep	Phenanthrene	240 - NA	NA	NA	1/1	100
	Deep	Pyrene	280 - NA	NA	NA	1/1	100
	Deep	bis(2-ethylhexyl) phthalate	280 - NA	NA	NA	1/1	100
Post Road Corridor	Surface	TPH Diesel	2000 - NA	NA	NA	1/4	25
	Root	TPH Diesel	3000 - NA	NA	NA	1/4	25
Golf Course Beaver	Surface	TPH Diesel	29000 - NA	NA	NA	1/1	100
Pond	Deep	4-Methylphenol (p-cresol)	51 - NA	NA	NA	1/1	100

Note: Results reported on a dry weight basis.
NA = Not Applicable due to only one reported value.

Table 4-5

Background Metal Concentrations for Elmendorf AFB Soils

Metal	Depth Range	Concentrations (mg/kg soil)				Number of Cases	Number of Non-Detects	Upper Tolerance Limit^c (mg/kg)	Upper 99% Confidence Limit for the Mean (mg/kg)	Number of Points Exceeding the Upper Tolerance Limit
		Min	Mean^a	Max	Std Dev^b					
Aluminum	Surface^c	4,750	15,094	25,000	5,813	14	0	35,627	19,211	0
	Root zone^d	14,850	19,700	23,800	2,391	14	0	31,655	21,393	0
	Deep^e	9,830	12,878	16,600	1,606	21	0	18,013	13,764	0
Antimony	Surface	1.45	1.83	3.40	N/A	14	13	N/A	N/A	N/A
	Root zone	1.20	1.40	1.60	N/A	14	14	N/A	N/A	N/A
	Deep	1.10	1.29	3.10	N/A	21	20	N/A	N/A	N/A
Arsenic	Surface	3.90	7.20	13.10	2.54	14	0	16.18	9.00	0
	Root zone	4.70	6.87	9.60	1.28	14	0	11.40	7.78	0
	Deep	3.50	5.46	8.35	1.18	21	0	9.24	6.12	0
Barium	Surface	77.3	113.8	154.0	24.9	14	0	201.7	131.4	0
	Root zone	43.4	103.3	171.0	31.4	14	0	214.3	125.5	0
	Deep	37.1	54.5	82.5	12.7	21	0	95.0	61.5	0
Beryllium	Surface	0.12	0.37	0.62	0.15	14	3	0.91	0.47	0
	Root zone	0.29	0.41	0.55	0.08	14	0	0.70	0.46	0
	Deep	0.09	0.28	0.48	0.11	21	3	0.63	0.34	0
Cadmium	Surface	0.17	1.07	1.95	0.55	14	2	3.01	1.46	0
	Root zone	0.93	1.62	1.90	0.26	14	0	2.51	1.80	0
	Deep	0.96	1.63	2.70	0.44	21	0	3.03	1.87	0
Calcium	Surface	1,330	2,803	8,210	1,721	14	0	8,881	4,021	0
	Root zone	1,730	3,283	7,530	1,474	14	0	8,490	4,327	0
	Deep	2,980	5,312	10,800	1,503	20	0	10,169	6,165	1
Chromium	Surface	9.6	19.8	34.3	8.1	14	0	48.4	25.5	0
	Root zone	19.0	31.8	45.3	6.4	14	0	54.4	36.3	0
	Deep	18.5	31.6	80.9	13.9	21	0	76.1	39.3	1
Cobalt	Surface	1.3	7.1	12.6	3.9	14	2	20.7	9.81	0
	Root zone	7.2	12.3	14.3	2.2	14	0	20.2	13.8	0
	Deep	7.2	11.1	16.6	2.0	21	0	17.5	12.2	0

Table 4-5

(Continued)

Metal	Depth Range	Concentrations (mg/kg soil)				Number of Cases	Number of Non-Detects	Upper Tolerance Limit (mg/kg)	Upper 95% Confidence Limit for the Mean (mg/kg)	Number of Points Exceeding the Upper Tolerance Limit
		Min	Mean	Max	Std Dev					
Aluminum	Surface	4,750	15,094	25,000	5,813	14	0	25,627	19,211	0
Copper	Surface	7.8	14.8	24.8	4.9	14	0	32.2	18.3	0
	Root zone	14.0	20.8	28.3	4.0	14	0	34.7	23.6	0
	Deep	14.5	29.5	59.9	9.3	21	0	59.2	34.7	1
Iron	Surface	8,970	22,359	32,700	7,609	14	0	40,237	27,748	0
	Root zone	23,450	28,082	32,000	3,039	14	0	38,818	30,235	0
	Deep	18,500	24,581	38,000	4,262	21	0	38,210	26,932	0
Lead	Surface	4.30	6.93	11.10	1.80	14	0	13.3	8.2	0
	Root zone	4.10	5.65	7.00	0.89	14	0	8.78	6.28	0
	Deep	3.00	5.30	9.10	1.48	21	0	10.0	6.12	0
Magnesium	Surface	769	2,821	6610	2,133	14	0	10,356	4,332	0
	Root zone	2,160	6,371	10,100	1,929	14	0	15,183	7,737	0
	Deep	3,690	7,895	14,800	2,112	21	0	14,648	9,060	1
Manganese	Surface	67.8	319.9	738.0	197.0	14	0	1,015.7	459.4	0
	Root zone	193.5	489.4	742.5	136.2	14	0	970.5	585.8	0
	Deep	375.0	518.3	640.0	58.6	21	0	705.8	550.6	0
Mercury	Surface	0.050	0.090	0.150	0.029	14	0	0.19	0.11	0
	Root zone	0.040	0.075	0.220	0.044	14	0	0.23	0.11	0
	Deep	0.040	0.088	0.165	0.036	21	0	0.20	0.11	0
Nickel	Surface	1.3	13.0	31.7	10.1	14	2	48.5	20.1	0
	Root zone	11.0	29.6	44.5	8.8	14	0	50.6	35.8	0
	Deep	17.6	34.6	73.1	11.4	21	0	71.1	40.9	1
Potassium	Surface	244	406	685	144	14	0	935.7	508.5	0
	Root zone	236	466	630	119	14	0	887.1	550.3	0
	Deep	221	612	842	154	21	0	1,108.1	697.3	0
Selenium	Surface	0.055	0.295	0.510	0.113	14	1	0.69	0.37	0
	Root zone	0.045	0.161	0.290	0.089	14	3	0.47	0.22	0
	Deep	0.040	0.104	[illegible]	0.116	21	16	N/A	N/A	N/A

Table 4-5

(Continued)

Metal	Depth Range	Concentrations (mg/kg soil)				Number of Cases	Number of Non-Detects	Upper Tolerance Limit[b] (mg/kg)	Upper 95% Confidence Limit for the Mean (mg/kg)	Number of Points Exceeding the Upper Tolerance Limit
		Min	Mean[a]	Max	Std Dev[a]					
Aluminum	Surface[c]	4,750	15,094	25,000	5,813	14	0	35,627	19,211	0
Silver	Surface	0.23	0.63	1.60	0.39	14	4	2.00	0.91	0
	Root zone	0.16	0.51	1.20	0.32	14	5	1.62	0.73	0
	Deep	0.15	0.41	0.78	0.20	21	6	1.05	0.52	0
Sodium	Surface	242.0	327.8	381.0	44.5	11	0	477.8	364.9	0
	Root zone	178.5	251.2	317.0	40.5	11	0	406.1	285.0	0
	Deep	181.0	234.8	306.0	38.3	17	0	368.1	258.7	0
Thallium	Surface	0.105	0.133	0.280	N/A	14	13	N/A	N/A	N/A
	Root zone	0.085	0.101	0.115	N/A	14	14	N/A	N/A	N/A
	Deep	0.080	0.092	0.190	N/A	21	20	N/A	N/A	N/A
Vanadium	Surface	21.5	53.4	83.1	18.5	14	0	118.6	66.5	0
	Root zone	46.9	60.0	76.6	8.8	14	0	91.3	66.3	0
	Deep	33.2	44.3	59.9	6.7	21	0	65.8	48.0	0
Zinc	Surface	12.9	36.7	77.7	18.7	14	0	102.9	49.9	0
	Root zone	33.7	51.3	62.9	9.5	14	0	84.8	58.0	0
	Deep	34.1	51.7	63.0	7.5	21	0	73.7	55.9	0

[a] Assumes non-detect values are equal to one-half the detection limit.

[b] Upper tolerance limit for the 99th percentile with a 95% confidence level.

[c] Shallow soils correspond to 0 to 0.5 feet bgs.

[d] Root zone soils correspond to 0.5 to 3.0 feet bgs.

[e] Deep soils correspond to 3.0 ft bgs to the groundwater table.

Shaded values denote background comparison values.

Results reported on dry weight basis.

N/A = Not Applicable. Calculation of statistics is not applicable because of the number of non-detects.

Source: CH2M HILL 1992a

Table 4-6

Summary of Analytical Results for Metals in Soil

Study Subarea	Depth	Detected Compound	Range of Detected Values (mg/kg)	Geometric Mean (mg/kg)	Arithmetic Mean (mg/kg)	Background Comparison (mg/kg)	No. of Detections Above Background/No. of Samples	Percent of Samples
Upgradient	Deep	Aluminum	12600 - NA	NA	NA	18013	0/1	0
	Deep	Arsenic	4.8 - NA	NA	NA	9.24	0/1	0
	Deep	Barium	43.3 - NA	NA	NA	95	0/1	0
	Deep	Beryllium	0.35 - NA	NA	NA	0.63	0/1	0
	Deep	Cadmium	1.1 - NA	NA	NA	3.03	0/1	0
	Deep	Calcium	5970 - NA	NA	NA	10169	0/1	0
	Deep	Chromium, Total	21.7 - NA	NA	NA	76.1	0/1	0
	Deep	Cobalt	8.7 - NA	NA	NA	17.5	0/1	0
	Deep	Copper	21.1 - NA	NA	NA	59.2	0/1	0
	Deep	Iron	22300 - NA	NA	NA	38210	0/1	0
	Deep	Lead	4 - NA	NA	NA	10	0/1	0
	Deep	Magnesium	7610 - NA	NA	NA	14648	0/1	0
	Deep	Manganese	410 - NA	NA	NA	705.8	0/1	0
	Deep	Nickel	25.4 - NA	NA	NA	71.1	0/1	0
	Deep	Potassium	573 - NA	NA	NA	1105.1	0/1	0
	Deep	Silver	0.54 - NA	NA	NA	1.05	0/1	0
	Deep	Sodium	265 - NA	NA	NA	363.1	0/1	0
	Deep	Vanadium	43.4 - NA	NA	NA	65.8	0/1	0
	Deep	Zinc	47.1 - NA	NA	NA	75.7	0/1	0
Pipeline Corridor	Deep	Aluminum	9680 - 19100	1.30×10^{4}	1.34×10^{4}	18013	1/7	14
	Deep	Antimony	2.8 - NA	NA	NA	3.1	0/7	0
	Deep	Arsenic	3.5 - 8.1	5.44×10^{0}	5.69×10^{0}	9.24	0/7	0
	Deep	Barium	33.8 - 96.3	4.98×10^{1}	5.36×10^{1}	95	1/7	14
	Deep	Beryllium	0.17 - 0.54	2.43×10^{-1}	3.04×10^{-1}	0.63	0/7	0
	Deep	Cadmium	1.1 - 1.8	1.32×10^{0}	1.34×10^{0}	3.03	0/7	0
	Deep	Calcium	3230 - 13500	5.89×10^{3}	6.54×10^{3}	10169	1/7	14
	Deep	Chromium, Total	18.3 - 37.4	2.59×10^{1}	2.68×10^{1}	76.1	0/7	0

Table 4-6

(Continued)

Study Subarea	Depth	Detected Compound	Range of Detected Values (mg/kg)	Geometric Mean (mg/kg)	Arithmetic Mean (mg/kg)	Background Comparison (mg/kg)	No. of Detections Above Background/No. of Samples	Percent of Samples
Pipeline Corridor (cont.)	Deep	Cobalt	8.2 - 15.9	1.03×10^1	1.06×10^1	17.5	0/7	0
	Deep	Copper	22.3 - 48.4	2.89×10^1	2.99×10^1	59.2	0/7	0
	Deep	Iron	20800 - 34100	2.52×10^4	2.57×10^4	38210	0/7	0
	Deep	Lead	3.1 - 7.8	4.65×10^0	4.89×10^0	10	0/7	0
	Deep	Magnesium	6890 - 11700	8.40×10^3	8.56×10^3	14648	0/7	0
	Deep	Manganese	381 - 658	4.75×10^2	4.83×10^2	705.8	0/7	0
	Deep	Mercury	0.03 - 0.06	3.53×10^{-2}	3.79×10^{-2}	0.2	0/7	0
	Deep	Nickel	23.6 - 47.8	3.20×10^1	3.30×10^1	71.1	0/7	0
	Deep	Potassium	360 - 1440	5.61×10^2	6.28×10^2	1105.1	1/7	14
	Deep	Selenium	0.16 - 0.24	7.69×10^{-2}	9.50×10^{-2}	0.4	0/7	0
	Deep	Silver	0.48 - 0.59	3.34×10^{-1}	3.65×10^{-1}	1.05	0/7	0
	Deep	Sodium	193 - 386	2.36×10^2	2.42×10^2	363.1	1/7	14
	Deep	Vanadium	33.1 - 58.9	4.48×10^1	4.58×10^1	65.8	0/7	0
	Deep	Zinc	43.3 - 81.3	5.41×10^1	5.54×10^1	75.7	1/7	14
Lower Bluff	Surface	Aluminum	4380 - 18400	1.23×10^4	1.31×10^4	35627	0/11	0
	Surface	Arsenic	4 - 28.2	7.91×10^0	9.37×10^0	16.18	1/11	9
	Surface	Barium	61.4 - 3650	1.65×10^2	5.27×10^2	201.7	3/11	27
	Surface	Beryllium	0.57 - 1.3	2.73×10^{-1}	3.66×10^{-1}	0.91	1/11	9
	Surface	Cadmium	0.66 - 1.6	1.08×10^0	1.16×10^0	3.01	0/11	0
	Surface	Calcium	5260 - 35300	8.24×10^3	1.00×10^4	8881	3/11	27
	Surface	Chromium, Total	14.3 - 36.6	2.51×10^1	2.60×10^1	48.4	0/11	0
	Surface	Cobalt	3.5 - 12.5	7.91×10^0	8.54×10^0	20.7	0/11	0
	Surface	Copper	14 - 35.6	2.32×10^1	2.42×10^1	32.2	2/11	18
	Surface	Iron	13000 - 37800	2.48×10^4	2.56×10^4	49237	0/11	0
	Surface	Lead	10.2 - 32.5	1.98×10^1	2.14×10^1	13.3	9/11	82
	Surface	Magnesium	2300 - 9080	6.06×10^3	6.50×10^3	10356	0/11	0
	Surface	Manganese	434 - 199000	1.70×10^3	1.99×10^4	1015.7	5/11	45

Table 4-6

(Continued)

Study Subarea	Depth	Detected Compound	Range of Detected Values (mg/kg)	Geometric Mean (mg/kg)	Arithmetic Mean (mg/kg)	Background Comparison (mg/kg)	No. of Detections Above Background/No. of Samples	Percent of Samples
Lower Bluff (cont.)	Surface	Mercury	0.04 - 0.12	6.16×10^{-2}	6.59×10^{-2}	0.19	0/11	0
	Surface	Nickel	15.9 - 34.2	2.79×10^{1}	2.86×10^{1}	48.5	0/11	0
	Surface	Potassium	419 - 743	5.93×10^{2}	6.00×10^{2}	915.7	0/11	0
	Surface	Selenium	0.17 - 1.1	1.11×10^{-1}	1.90×10^{-1}	0.69	1/11	9
	Surface	Silver	0.49 - 22	9.57×10^{-1}	2.72×10^{0}	2	1/11	9
	Surface	Sodium	251 - 1430	4.21×10^{2}	5.06×10^{2}	497.8	3/11	27
	Surface	Thallium	0.21 - NA	NA	NA	0.28	0/10	0
	Surface	Vanadium	20.5 - 83.3	4.72×10^{1}	5.01×10^{1}	118.6	[illegible]	0
	Surface	Zinc	39.6 - 63.5	5.10×10^{1}	5.15×10^{1}	102.9	0/11	0
	Root	Aluminum	8670 - 19700	1.33×10^{4}	1.37×10^{4}	31655	0/6	0
	Root	Arsenic	2.7 - 8.7	6.26×10^{0}	6.70×10^{0}	11.4	0/6	0
	Root	Barium	36.5 - 1430	3.25×10^{2}	6.19×10^{2}	214.3	4/6	67
	Root	Beryllium	0.71 - 1.1	3.55×10^{-1}	4.53×10^{-1}	0.7	2/6	33
	Root	Cadmium	0.45 - 1.6	8.26×10^{-1}	9.66×10^{-1}	2.53	0/6	0
	Root	Calcium	7240 - 18300	9.16×10^{3}	9.73×10^{3}	8490	3/6	50
	Root	Chromium, Total	11.8 - 54.3	2.20×10^{1}	2.60×10^{1}	54.4	0/6	0
	Root	Cobalt	3.3 - 13.9	7.49×10^{0}	8.28×10^{0}	20.2	0/6	0
	Root	Copper	17.8 - 32	2.41×10^{1}	2.45×10^{1}	34.7	0/6	0
	Root	Iron	6550 - 34600	1.56×10^{4}	1.85×10^{4}	38818	0/6	0
	Root	Lead	4.7 - 19.8	9.97×10^{0}	1.10×10^{1}	8.78	4/6	67
	Root	Magnesium	1660 - 9810	4.87×10^{3}	5.93×10^{3}	13183	0/6	0
	Root	Manganese	473 - 7860	1.33×10^{3}	2.24×10^{3}	970.5	3/6	50
	Root	Mercury	0.05 - NA	NA	NA	0.23	0/6	0
	Root	Nickel	12.1 - 47.6	2.45×10^{1}	2.72×10^{1}	60.6	0/6	0
	Root	Potassium	306 - 854	6.12×10^{2}	6.46×10^{2}	887.1	0/6	0
	Root	Selenium	0.3 - NA	NA	NA	0.47	0/6	0
	Root	Silver	0.65 - 1.5	8.04×10^{-1}	8.71×10^{-1}	1.62	0/6	0
	Root	Sodium	277 - 929	5.51×10^{2}	6.02×10^{2}	406.1	4/6	67

Table 4-6

(Continued)

Study Subarea	Depth	Detected Compound	Range of Detected Values (mg/kg)	Geometric Mean (mg/kg)	Arithmetic Mean (mg/kg)	Background Comparison (mg/kg)	No. of Detections Above Background/No. of Samples	Percent of Samples
Lower Bluff (cont.)	Root	Thallium	0.31 - 0.59	3.11×10^{-1}	3.52×10^{-1}	0.115	4/6	67
	Root	Vanadium	51 - 81.1	6.42×10^{1}	6.50×10^{1}	91.3	0/6	0
	Root	Zinc	29.8 - 69.7	4.73×10^{1}	4.94×10^{1}	84.8	0/6	0
	Deep	Aluminum	11800 - 14800	1.32×10^{4}	1.33×10^{4}	18013	0/2	0
	Deep	Arsenic	4.2 - 6.4	5.18×10^{0}	5.30×10^{0}	9.24	0/2	0
	Deep	Barium	154 - 504	2.79×10^{2}	3.29×10^{2}	95	2/2	100
	Deep	Beryllium	0.23 - 0.35	2.84×10^{-1}	2.90×10^{-1}	0.63	0/2	0
	Deep	Cadmium	1.4 - 1.6	1.50×10^{0}	1.50×10^{0}	3.03	0/2	0
	Deep	Calcium	4830 - 7420	5.99×10^{3}	6.13×10^{3}	10169	0/2	0
	Deep	Chromium, Total	27.8 - NA	NA	NA	76.1	0/2	0
	Deep	Cobalt	9.5 - 11.3	1.04×10^{1}	1.04×10^{1}	17.5	0/2	0
	Deep	Copper	28.9 - 30.9	2.99×10^{1}	2.99×10^{1}	59.2	0/2	0
	Deep	Iron	24300 - 24500	2.44×10^{4}	2.44×10^{4}	38210	0/2	0
	Deep	Lead	31.2 - 206	8.02×10^{1}	1.19×10^{2}	10	2/2	100
	Deep	Magnesium	7590 - 8590	8.07×10^{3}	8.09×10^{3}	14648	0/2	0
	Deep	Manganese	486 - 590	5.35×10^{2}	5.38×10^{2}	705.8	0/2	0
	Deep	Mercury	0.06 - NA	NA	NA	0.2	0/2	0
	Deep	Nickel	34.3 - 35	3.46×10^{1}	3.47×10^{1}	71.1	0/2	0
	Deep	Potassium	510 - 983	7.08×10^{2}	7.47×10^{2}	1105.1	0/2	0
	Deep	Sodium	237 - 419	3.15×10^{2}	3.28×10^{2}	363.1	1/2	50
	Deep	Vanadium	42.6 - 63.5	5.20×10^{1}	5.31×10^{1}	65.8	0/2	0
	Deep	Zinc	55.8 - 74.1	6.43×10^{1}	6.50×10^{1}	75.7	0/2	0
Post Road Corridor	Surface	Aluminum	13600 - 17600	1.61×10^{4}	1.62×10^{4}	35627	0/4	0
	Surface	Arsenic	4.3 - 8	6.45×10^{0}	6.63×10^{0}	16.18	0/4	0
	Surface	Barium	81.7 - 101	8.85×10^{1}	8.88×10^{1}	201.7	0/4	0
	Surface	Beryllium	0.57 - NA	NA	NA	0.91	0/4	0
	Surface	Cadmium	1.4 - 3.1	1.77×10^{0}	1.88×10^{0}	3.01	1/4	25
	Surface	Calcium	5260 - 12500	7.89×10^{3}	8.31×10^{3}	8881	1/4	25

Table 4-6

(Continued)

Study Element	Depth	Detected Compound	Range of Detected Values (mg/kg)	Geometric Mean (mg/kg)	Arithmetic Mean (mg/kg)	Background Comparison (mg/kg)	No. of Detections Above Background/No. of Samples	Percent of Samples
Post Road Corridor (cont.)	Surface	Chromium, Total	29.9 - 39	3.42×10^1	3.43×10^1	48.4	0/4	0
	Surface	Cobalt	9.7 - 11.7	1.06×10^1	1.07×10^1	20.7	0/4	0
	Surface	Copper	25.1 - 37.3	2.80×10^1	2.84×10^1	32.2	1/4	25
	Surface	Iron	22500 - 28900	2.69×10^4	2.70×10^4	49237	0/4	0
	Surface	Lead	9.5 - 87.2	1.79×10^1	2.98×10^1	13.3	1/4	25
	Surface	Magnesium	6850 - 8960	7.94×10^3	7.98×10^3	10356	0/4	0
	Surface	Manganese	402 - 765	5.78×10^2	5.93×10^2	1015.7	0/4	0
	Surface	Mercury	0.09 - 0.1	8.35×10^{-2}	8.50×10^{-2}	0.19	0/4	0
	Surface	Nickel	29.7 - 36.3	3.25×10^1	3.26×10^1	48.5	0/4	0
	Surface	Potassium	451 - 908	6.61×10^2	6.83×10^2	915.7	0/4	0
	Surface	Silver	0.75 - NA	NA	NA	2	0/4	0
	Surface	Sodium	308 - 909	4.65×10^2	5.09×10^2	497.8	1/4	25
	Surface	Thallium	0.19 - 0.31	2.53×10^{-1}	2.58×10^{-1}	0.28	1/4	25
	Surface	Vanadium	48.3 - 62.3	5.60×10^1	5.63×10^1	118.6	0/4	0
	Surface	Zinc	66.8 - 159	8.96×10^1	9.56×10^1	102.9	1/4	25
	Root	Aluminum	16000 - 18300	1.67×10^4	1.67×10^4	31655	0/4	0
	Root	Arsenic	2.8 - 6.4	4.64×10^0	4.85×10^0	11.4	0/4	0
	Root	Barium	50.8 - 98.7	7.19×10^1	7.54×10^1	214.3	0/4	0
	Root	Cadmium	1.5 - 1.8	1.65×10^0	1.65×10^0	2.53	0/4	0
	Root	Calcium	5780 - 8100	6.86×10^3	6.92×10^3	8490	0/4	0
	Root	Chromium, Total	30.8 - 64.3	4.47×10^1	4.66×10^1	54.4	1/4	25
	Root	Cobalt	9.6 - 12.3	1.09×10^1	1.09×10^1	20.2	0/4	0
	Root	Copper	18.6 - 29	2.37×10^1	2.40×10^1	34.7	0/4	0
	Root	Iron	22200 - 30100	2.72×10^4	2.74×10^4	38818	0/4	0
	Root	Lead	4.5 - 22.3	1.08×10^1	1.26×10^1	8.78	3/4	75
	Root	Magnesium	6770 - 9210	8.10×10^3	8.16×10^3	13183	0/4	0
	Root	Manganese	307 - 811	4.85×10^2	5.15×10^2	970.5	0/4	0

Table 4-6

(Continued)

Study Subarea	Depth	Detected Compound	Range of Detected Values (mg/kg)	Geometric Mean (mg/kg)	Arithmetic Mean (mg/kg)	Background Comparison (mg/kg)	No. of Detections Above Background/No. of Samples	Percent of Samples
Post Road Corridor (cont.)	Root	Mercury	0.03 - 0.11	6.10×10^{-2}	6.75×10^{-2}	0.23	0/4	0
	Root	Nickel	31.1 - 54.9	4.06×10^{1}	4.18×10^{1}	60.6	0/4	0
	Root	Potassium	540 - 865	7.09×10^{2}	7.22×10^{2}	887.1	0/4	0
	Root	Silver	0.85 - NA	NA	NA	1.62	0/4	0
	Root	Sodium	320 - 429	3.76×10^{2}	3.79×10^{2}	406.1	2/4	50
	Root	Thallium	0.16 - 0.59	2.30×10^{-1}	2.89×10^{-1}	0.115	3/4	75
	Root	Vanadium	52.6 - 63.1	5.70×10^{1}	5.72×10^{1}	91.3	0/4	0
	Root	Zinc	55.7 - 86.4	6.52×10^{1}	6.63×10^{1}	84.8	1/4	25
Golf Course Beaver Pond	Surface	Aluminum	13300 - NA	NA	NA	35627	0/1	0
	Surface	Arsenic	6.9 - NA	NA	NA	16.18	0/1	0
	Surface	Barium	152 - NA	NA	NA	201.7	0/1	0
	Surface	Beryllium	0.74 - NA	NA	NA	0.91	0/1	0
	Surface	Cadmium	1.5 - NA	NA	NA	3.01	0/1	0
	Surface	Calcium	15100 - NA	NA	NA	8881	1/1	100
	Surface	Chromium, Total	27.2 - NA	NA	NA	48.4	0/1	0
	Surface	Cobalt	8.6 - NA	NA	NA	20.7	0/1	0
	Surface	Copper	38 - NA	NA	NA	32.2	1/1	100
	Surface	Iron	21300 - NA	NA	NA	49237	0/1	0
	Surface	Lead	35.2 - NA	NA	NA	13.3	1/1	100
	Surface	Magnesium	6140 - NA	NA	NA	10356	0/1	0
	Surface	Manganese	384 - NA	NA	NA	1015.7	0/1	0
	Surface	Mercury	0.3 - NA	NA	NA	0.19	1/1	100
	Surface	Nickel	28.9 - NA	NA	NA	48.5	0/1	0
	Surface	Potassium	763 - NA	NA	NA	915.7	0/1	0
	Surface	Sodium	494 - NA	NA	NA	497.8	0/1	0
	Surface	Vanadium	46.6 - NA	NA	NA	118.6	0/1	0
	Surface	Zinc	98.5 - NA	NA	NA	102.9	0/1	0
	Root	Aluminum	9380 - 10400	9.88×10^{3}	9.89×10^{3}	31655	0/2	0

Table 4-6

(Continued)

Study Subarea	Depth	Detected Compound	Range of Detected Values (mg/kg)	Geometric Mean (mg/kg)	Arithmetic Mean (mg/kg)	Background Comparison (mg/kg)	No. of Detections Above Background/No. of Samples	Percent of Samples
Golf Course Beaver Pond (cont.)	Root	Arsenic	3.3 - 4.5	3.85×10^0	3.90×10^0	11.4	0/2	0
	Root	Barium	44.6 - 124	7.44×10^1	8.43×10^1	214.3	0/2	0
	Root	Cadmium	0.75 - 1.3	9.87×10^{-1}	1.03×10^0	2.53	0/2	0
	Root	Calcium	7080 - 20400	1.20×10^4	1.37×10^4	8490	1/2	50
	Root	Chromium, Total	23.8 - 31.6	2.74×10^1	2.77×10^1	54.4	0/2	0
	Root	Cobalt	6.2 - 6.5	6.35×10^0	6.35×10^0	20.2	0/2	0
	Root	Copper	19.5 - 31	2.46×10^1	2.53×10^1	34.7	0/2	0
	Root	Iron	16300 - NA	NA	NA	38818	0/2	0
	Root	Lead	5.4 - 16.8	9.52×10^0	1.11×10^1	8.78	1/2	50
	Root	Magnesium	5020 - 5410	5.21×10^3	5.22×10^3	13183	0/2	0
	Root	Manganese	358 - 533	4.37×10^2	4.46×10^2	970.5	0/2	0
	Root	Mercury	0.11 - 0.31	1.85×10^{-1}	2.10×10^{-1}	0.23	1/2	50
	Root	Nickel	21.3 - 23.1	2.22×10^1	2.22×10^1	60.6	0/2	0
	Root	Potassium	339 - 493	4.09×10^2	4.16×10^2	887.1	0/2	0
	Root	Selenium	1.2 - 3.1	1.93×10^0	2.15×10^0	0.47	2/2	100
	Root	Sodium	419 - 753	5.62×10^2	5.86×10^2	406.1	2/2	100
	Root	Thallium	0.51 - NA	NA	NA	0.115	1/2	50
	Root	Vanadium	34.3 - 34.7	3.45×10^1	3.45×10^1	91.3	0/2	0
	Root	Zinc	47 - 74	5.90×10^1	6.05×10^1	84.8	0/2	0

Note: Results reported on a dry weight basis.
NA = Not Applicable due to only one reported value.

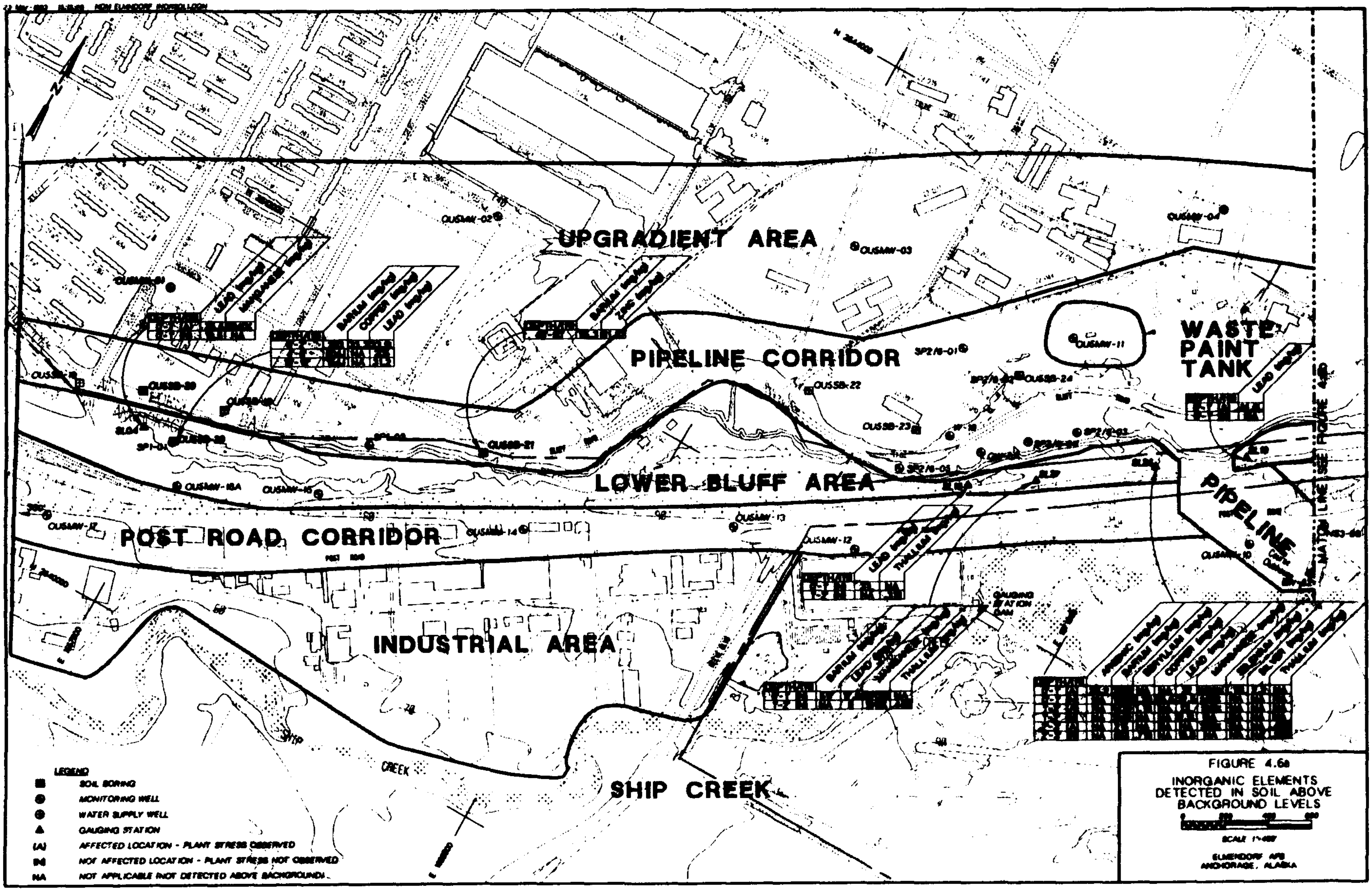


FIGURE 4.6a

INORGANIC ELEMENTS DETECTED IN SOIL ABOVE BACKGROUND LEVELS

ELMENDORF AFB
ANCHORAGE, ALASKA

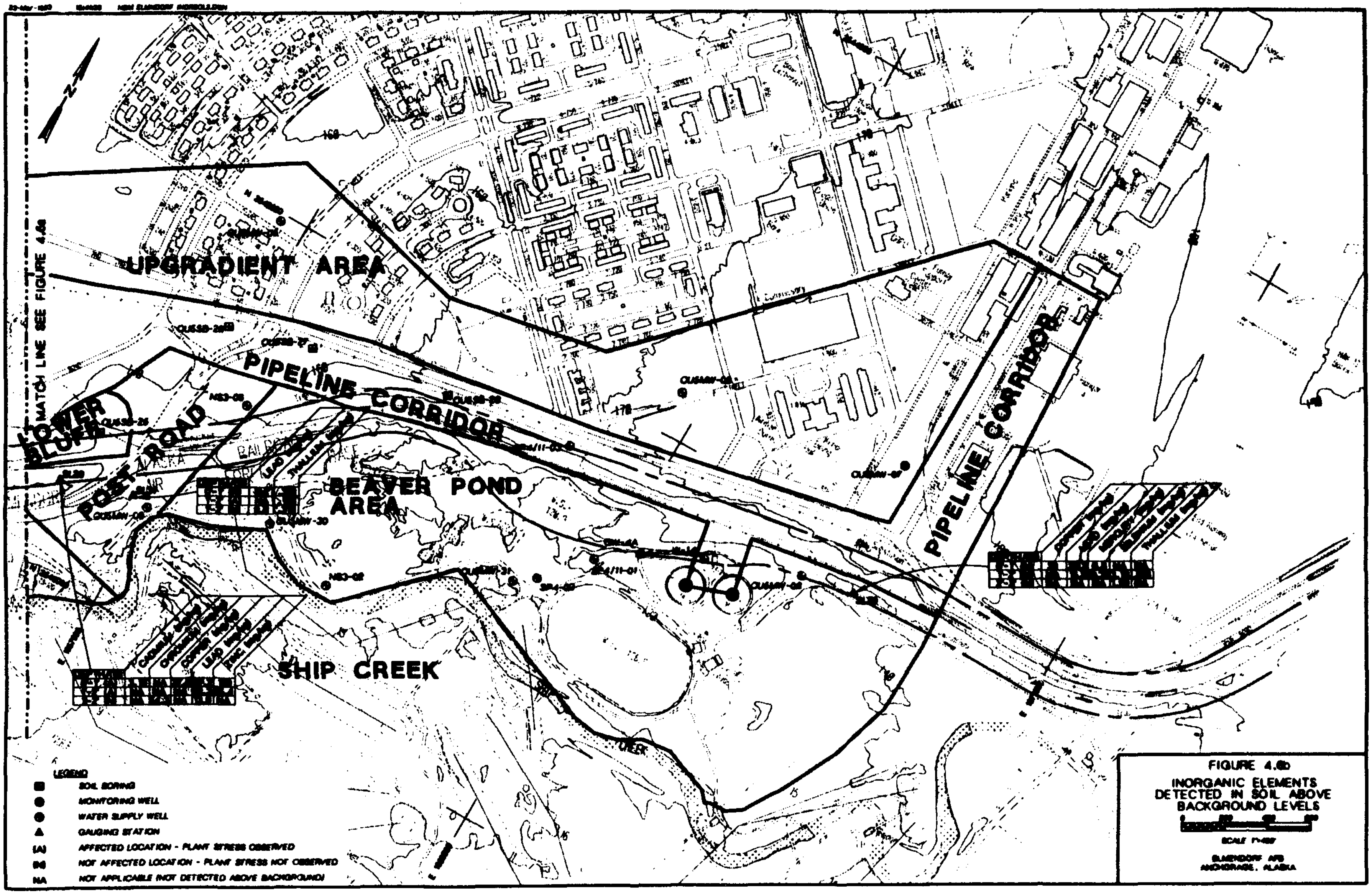


FIGURE 4.6b

INORGANIC ELEMENTS DETECTED IN SOIL ABOVE BACKGROUND LEVELS

Table 4-7

Total Metals in Fly Ash and Fly Ash Leachate Samples

	Media Sample Location					
	Fly Ash		Background Soil		Fly Ash Leachate	
Metal	FA01-02 (mg/kg)	FA02-02 (mg/kg)	Root Zone UTL (mg/kg)	Does Fly Ash Exceed Background?	FA01-02 (mg/L)	FA02-02 (mg/L)
Aluminum	15,500	6,770 - 6,900	31,655	No	0.4472	0.3122
Antimony	<3.6	3.6	1.6	No	<0.0121	<0.0121
Arsenic	6.5	3.5 - 4.0	11.40	No	0.0019	0.0052
Barium	1,170	1,300 - 1,600	214.3	Yes	0.1003	0.2022
Beryllium	0.60	0.32 - 0.58	0.70	No	<0.0005	<0.0005
Cadmium	1.3	0.68 - 1.1	2.53	No	<0.0012	<0.0012
Calcium	6,520	5,090 - 5,610	8,490	No	3.7727	7.1394
Chromium	25.5	9.8 - 12.0	54.4	No	<0.0037	<0.0037
Cobalt	12.9	9.8 - 10.4	20.2	No	<0.0058	<0.0058
Copper	26.7J	19.9J - 23.0J	34.7	No	0.0024	0.0043
Iron	21,400	5,360 - 6,660	38,818	No	0.5686	0.2377
Lead	6.7	10.1 - 13.5	8.78[a]	Yes[a]	<0.0006	0.0023
Magnesium	5,800	1,280 - 1,530	13,183	No	1.4391	2.4688
Manganese	376	63.4 - 91.4	970.5	No	0.0150	0.0083
Mercury	0.05	<0.04 - 0.05	0.23	No	<0.0001	<0.0001
Nickel	32.1	20.4 - 22.2	60.6	No	<0.0077	<0.0077
Potassium	891	838 - 876	887.1[a]	Yes[a]	3.8588	9.7592
Selenium	<0.15	<0.15	0.47	No	<0.0005	<0.0005
Silver	<0.63	<0.62	1.62	No	<0.0021	<0.0021
Sodium	427	526 - 531	406.1	Yes	2.7255	1.7045
Thallium	<0.21	0.21	0.115[a]	Yes[a]	<0.0007	<0.0007
Vanadium	74.5	71.1 - 79.9	91.3	No	0.0123	0.0281
Zinc	45.2J	22.1J - 27.4J	84.8	No	0.0177	0.0390

[a] Although fly ash value exceeded background UTL for root zone (0.5 to 3.0 feet), it would not have exceeded background value for surface soil (zero to 0.5 foot). The fly ash was collected at 1.5- to 2-foot depths.

Spurr deposited a 1/8-inch (approximate) thick layer of ash over the Anchorage area. A sample of the ash deposited at OU 5 was collected and analyzed for metals. Only calcium (9210 mg/kg) and sodium (1690 mg/kg) in the ash were found to exceed background concentrations in Elmendorf AFB soils. These elements are not contaminants of concern at OU 5, and it is therefore not expected that the ash event influenced the analytical results or interpretation of metals in OU 5 soils.

4.2.2 Discussion

4.2.2.1 Upgradient Area

Seven borings were placed in the upgradient area of OU 5 (SB01 through SB07) and all of these borings were completed as monitoring wells. Only two of the seven borings showed any detectable organic contamination in the soil.

Petroleum hydrocarbons were detected in soil boring SB03. This boring is approximately 600 feet northwest of Sources ST38/SS42 and approximately 200 feet east of an abandoned diesel product pipeline that runs parallel to Maple Street. Diesel-range organics were reported at 38 mg/kg in SB03 at 10 feet, and gasoline-range organics were detected at 50 mg/kg at depths of 10 feet and 25 feet below ground surface. Groundwater is approximately 31.5 feet deep at this location.

In boring SB06, JP-4-range organics were reported at 35 feet below ground surface at the groundwater table. These results indicate that vadose zone samples taken in the upgradient area are free of organic contamination, with the exception of SB03, which has detectable fuel hydrocarbons above the water table.

One soil sample from the upgradient area was collected for metal analysis at SB01, 25 feet below ground surface. None of the metal concentrations exceeded the comparison levels in the background data.

4.2.2.2 Pipeline Corridor

Ten borings were placed in the pipeline corridor area: SB18 through SB24, and SB26, SB27, and SB28. The purpose of these borings was to evaluate the extent of vadose zone contamination at the suspected source areas. Samples were also taken at the top of the Bootlegger Cove Formation in borings SB19, SB21, SB23, and SB28 to evaluate the presence of DNAPLs.

Petroleum hydrocarbons were detected in three of the ten soil borings within the pipeline corridor area. In soil boring SB18 at Source ST37, JP-4 was detected at 89 mg/kg, diesel was detected at 159 mg/kg, and BTEX compounds were detected at 1 mg/kg at a depth of 35 feet, corresponding to the top of the water table. Petroleum hydrocarbons were not detected above the 35-foot depth, suggesting that those constituents have either been flushed from the vadose zone soils or are migrating with the groundwater. The three other borings drilled around Source ST37 did not detect organic contaminants in the vadose zone or at the top of the Bootlegger Cove Formation.

The second soil boring in the pipeline corridor area where petroleum hydrocarbons were detected is SB23, adjacent to the JP-4 pipeline at Source ST38 and approximately 50 feet east of the Small Arms Firing Range (Building 22-007). Diesel was detected at 57 mg/kg in the sample taken at the top of the Bootlegger Cove Formation, 58 feet below ground surface. The water table in this vicinity is approximately 40 feet below ground surface. Diesel fuel is not a "sinker" and would not be expected to be found in high concentrations on top of the Bootlegger Cove Formation, but may be present as a dissolved contaminant in the saturated soil layer. Two other borings at source areas ST38/SS42 were free of detectable contamination, including boring SB22, which was a site where raised levels of halogenated VOCs were detected during the soil gas screening survey.

A third boring where petroleum hydrocarbons were detected is SB26. This boring is located approximately 15 feet from a low point water drain pit on the JP-4 pipeline where a leak was detected in 1982 (refer to Section 1.2.3.5 for discussion). It is likely that this pipeline leak was responsible for the petroleum seeps observed along Post Road that comprise Source SS53. Near the groundwater table at a depth of 25 feet, JP-4 and diesel-range organics were detected at 165 and 172 mg/kg, respectively. All of the BTEX compounds were also detected at concentrations less than 1 mg/kg. A shallower sample taken at 10 feet did not show any detectable organic contaminants. If the source of contamination is the low point water drain pit, then these observations suggest that the leaking product migrated downward to the water table and did not create a large secondary source area of contaminated vadose zone soils. Two other borings located along the pipeline near Source SS53 did not yield any detectable contamination in the vadose zone or at the top of the Bootlegger Cove Formation.

Metals concentrations in borings SB20 and SB21 were either less than the background comparison values or flagged as estimates because of QC considerations.

In summary, petroleum hydrocarbons were detected in the pipeline corridor only in three samples taken from the saturated soil layer. Vadose zone contamination was not observed at the source areas. It is likely that vadose zone contamination from past pipeline leaks was localized and left a relatively small footprint as fuel products percolated rapidly downward through the sandy soils. Given the age of the leaks (15 to 35 years) and the relatively porous subsurface soils, it is also likely that vadose zone contamination has already been attenuated by natural processes such as flushing or biodegradation. Therefore, it does not appear that soil around the pipeline leaks and surface spill areas is acting as a significant secondary source for groundwater contamination. DNAPL contaminants such as TCE were not detected in any of the four samples taken at the top of the Bootlegger Cove Formation.

4.2.2.3 Waste Paint Tank Area

The waste paint tank is about 400 feet northeast of Source SS42. Soil samples were collected at 10-, 25-, and 35-foot depths in SB11, immediately east of the tank. Petroleum hydrocarbons were reported at depths of 10 feet and 25 feet below ground surface in SB11. The depth to groundwater is approximately 36 feet at this location. At 10 feet, JP-4 was detected at 14 mg/kg, and gasoline was detected at 7.1 mg/kg. Xylenes were also reported at 10 feet, at a total concentration of 9.4 mg/kg, higher than expected for the low levels of fuel. The total BTEX concentration at the 10-foot depth was 10.2 mg/kg. At 25 feet below ground surface in SB11, the BTEX concentration decreased to 0.17 mg/kg and JP-4 and gasoline-range organics were not detected. Because the BTEX contamination (particularly xylenes) is high at the 10-foot depth relative to fuel concentrations, it is suspected that it may originate from solvents from the waste paint tank. Additional sampling around the tank and at various depths would be required to confirm whether the tank has leaked waste paint products to the surrounding soil.

No soil samples from the waste paint tank area were submitted for metal analysis.

4.2.2.4 Lower Bluff Area

Petroleum hydrocarbons and PAHs were observed in soil samples collected from SB29 in the lower bluff area. This boring location is on the hillside below Source ST37 and is next to a groundwater seep (SL05)and monitoring well SP1-01. This location appears to have grass cuttings and other ground maintenance debris dumped here on a regular basis. It is speculated that this could be a site where individuals have changed the oil in their vehicles, and discarded small quantities of it, although no interviews were performed to confirm this. Numerous PAHs were detected at a total concentration of 5050 μg/kg at the surface (zero to 2 feet), and decreased to 2240 mg/kg in the 4- to 6-foot interval. PAHs were not analyzed in samples collected at depths lower than 6 feet.

Unlike the PAHs reported in soil boring SB29, diesel concentrations increased with depth. Diesel was detected at 6.1 mg/kg at the surface, and at 1160 mg/kg at 10 to 12 feet. JP-4 and gasoline were detected at the 10- to 12-foot interval, at 600 mg/kg and 160 mg/kg, respectively.

In addition to the soil contaminants in SB29, petroleum hydrocarbons were found at nine separate surface soil locations, unrelated to the soil borings. Soil samples were collected from these locations (designated with the prefix SL) as part of the ecological assessment to evaluate the impact, if any, of contaminants on terrestrial plants. The highest values of petroleum hydrocarbons were observed at locations SL04 and SL16. Gasoline (670 mg/kg), JP-4 (280 mg/kg), and diesel (115 mg/kg) were reported in surface soils at SL04 in an area of stressed vegetation. Gasoline (271 mg/kg), JP-4 (525 mg/kg), and diesel (400 mg/kg) were detected at SL16 in an area where vegetation appeared to be normal. Benzene was reported in samples collected from SL25 at the 1- to 2-foot and 2- to 3-foot intervals (0.013 mg/kg and 0.015 mg/kg, respectively). Diesel, JP-4, and gasoline were detected at levels below 100 ppm at SL04 and SL16 in areas where vegetation appeared normal. These constituents were also observed at SL19 and SL20, but at concentrations less than 10 mg/kg.

Metal concentrations in the lower bluff area soils that exceeded background comparison levels include arsenic, barium, calcium, lead, manganese, nickel, silver, and sodium. Most of these were observed at surface soil sampling location SL25 at the zero to 1-foot depth, immediately north of the ARRC railroad tracks in an area of stressed vegetation.

Nickel was reported at 10 times the background comparison level in SL27, approximately 500 feet west of SL25 in an area where vegetation appeared normal. Lead was detected at approximately 20 times background comparison concentrations in soil boring SB29 at the 4- to 6-foot interval. Barium, calcium, manganese, lead, and/or sodium were detected at concentrations significantly higher than background comparison levels at sample locations SL04 (zero to 1-foot interval), SL16 (zero to 1-foot interval), SL25 (1- to 2-foot and 2- to 3-foot intervals), SL27 (zero to 1-foot and 1-to 2-foot intervals), and SB29 (zero to 2-foot and 4- to 6-foot intervals).

Fly ash deposits were sampled on the bluff below Monitoring Well SP1-02 at depths between 2 and 4 feet. The total metals results for fly ash and leachate are shown in Table 4-7. Comparison of the fly ash metals to total metals in background soils (Table 4-5) shows that barium is present in the fly ash at greater than five times the background levels. Lead, potassium, sodium, and thallium only slightly exceeded the background comparisons. Aluminum, iron, manganese, and vanadium are not above soil background levels in the fly ash. Arsenic, barium, vanadium, and zinc in the fly ash may be leaching out at levels that represent the detected concentrations in the groundwater (see Section 4.3.2.4).

4.2.2.5 Post Road Corridor

One petroleum hydrocarbon (toluene) on soil was reported at 0.068 mg/kg in SB13, on the north side of Post Road and west of the Post Road and Reeve Boulevard intersection. The toluene was detected at a depth interval of 2.5 to 4.5 feet. Soil boring SB13 was converted to monitoring well MW13 during the field investigation. Groundwater at MW13 was measured at 1.4 feet below ground surface, suggesting that fluctuating levels of contaminated groundwater may have affected soil in the smear zone.

Some metal concentrations reported on surface soil samples collected from the Post Road corridor were significantly higher than the background comparison values. Calcium, lead, sodium, and zinc at two to eight times higher than background comparison levels were reported at surface sampling location SL20, at the zero to 1-foot interval. Lead was also detected at twice the background comparison level in the 1- to 2-foot interval at SL20. Location SL20 is a grassy area between Post Road and the ARRC tracks, in the golf course seep area (Source SS53). Stressed vegetation was observed at SL20 during the terrestrial survey.

Other metals were only slightly above the background comparison levels, were near the detection limit, or were flagged as estimates because of QC considerations.

4.3 Groundwater

4.3.1 Results

Groundwater data were collected during one round of sampling from new and previously installed wells in OU 5. All samples were analyzed for BTEX compounds; gasoline-, diesel-, and JP-4-range hydrocarbons; and semivolatile organic compounds. Halogenated VOCs were also analyzed in samples from the new wells installed during the investigation; these wells are located in areas upgradient and downgradient of the OU 5 pipeline corridor source areas. All groundwater samples were analyzed with a 30-day turnaround time at the Redding, California, laboratory. Table 4-8 lists a statistical summary of organic constituents detected in OU 5 groundwater samples. Figure 4-7 provides physical locations for organic constituents detected in the subareas.

Target analyte list (TAL) metals were analyzed for dissolved and total metals from six shallow aquifer monitoring wells (MW01, MW02, SP1-01, SP1-02, MW15, and MW16A) near a fly ash disposal location on the bluff below well SP1-02, at the western end of OU 5. Wells MW01 and MW02 are located hydraulically upgradient of the fly ash deposits, and the groundwater results for these wells were used as background for the other four wells that are located in or downgradient of the fly ash. Results for dissolved and total metals are summarized in Tables 4-9 and 4-10, respectively. Only the results from the December 1992 sampling event are presented and discussed. Wells SP1-01 and SP1-02 were also sampled in August 1992. However, the total metals concentration was higher in August than in December, and for some metals, the difference was tenfold. It is believed that the suspended solids observed in the samples from the August sampling caused high metals results that were not representative of the groundwater. During the December sampling, a submersible pump was used and resulted in low turbidity in the samples. Consequently, the

Table 4-8

Summary of Analtycial Results for Detected Organic Constituents in Groundwater (Upper Aquifer)

Study Subarea	Detected Compound	Range of Detected Values (µg/l)	Geometric Mean (µg/l)	Arithmetic Mean (µg/l)	No. of Detections/ No. of Samples	Percent of Samples
Upgradient	1,1,1-Trichloroethane	9.4 - NA	NA	NA	1/7	14
	1,1,2,2-Tetrachloroethane	8 - NA	NA	NA	1/7	14
	Ethylbenzene	0.67 - NA	NA	NA	1/7	14
	JP-4	760 - NA	NA	NA	1/7	14
	TFH Diesel	120 - NA	NA	NA	1/7	14
	TFH Gas	92 - NA	NA	NA	1/7	14
	Toluene	0.62 - 1.4	3.64×10^{-1}	4.67×10^{-1}	1/7	14
	Trichloroethylene (TCE)	5.2 - 52	2.16×10^{0}	1.03×10^{1}	2/7	29
	Xylenes, Total	2.7 - NA	NA	NA	1/7	14
	bis(2-ethylhexyl) phthalate	2 - NA	NA	NA	1/7	14
	tert-butyl methyl ether	0.56 - NA	NA	NA	1/7	14
Pipeline Corridor	Di-n-butyl phthalate	1 - NA	NA	NA	2/12	17
	Diethyl phthalate	1 - NA	NA	NA	1/12	8
	N-nitrosodiphenylamine	5 - NA	NA	NA	1/12	8
	TFH Diesel	100 - NA	NA	NA	3/12	25
	Trichloroethylene (TCE)	33 - NA	NA	NA	3/3	100
	bis(2-ethylhexyl) phthalate	1 - NA	NA	NA	2/12	17
Waste Paint Tank	Di-n-butyl phthalate	1 - NA	NA	NA	1/1	100
	Toluene	0.56 - NA	NA	NA	1/1	100
	bis(2-ethylhexyl) phthalate	20 - NA	NA	NA	1/1	100
Lower Bluff	1,1-Dichloroethane	1.3 - NA	NA	NA	1/3	33
	2-Methylnaphthalene	9 - NA	NA	NA	1/3	33
	Benzene	3.9 - 8.5	2.02×10^{0}	4.22×10^{0}	1/3	33
	Chloroethane	1.3 - NA	NA	NA	1/3	33
	Ethylbenzene	16 - NA	NA	NA	1/3	33

Table 4-8

(Continued)

Study Subarea	Detected Compound	Range of Detected Values (µg/l)	Geometric Mean (µg/l)	Arithmetic Mean (µg/l)	No. of Detections/ No. of Samples	Percent of Samples
	JP-4	200 - NA	NA	NA	1/3	33
	N-nitrosodiphenylamine	1 - NA	NA	NA	1/3	33
	Naphthalene	13 - NA	NA	NA	3/3	100
	TFH Diesel	290 - NA	NA	NA	1/3	33
	TFH Gas	54 - 700	2.03×10^2	3.25×10^2	1/3	33
	Xylenes, Total	0.57 - 39	5.76×10^0	1.61×10^1	1/3	33
Post Road Corridor	Benzene	0.6 - NA	NA	NA	1/6	17
	Diethyl phthalate	1 - NA	NA	NA	1/6	17
	JP-4	730 - NA	NA	NA	1/6	17
	TFH Diesel	180 - NA	NA	NA	2/6	33
	TFH Gas	250 - NA	NA	NA	3/6	50
	bis(2-ethylhexyl) phthalate	1 - NA	NA	NA	1/6	17
Golf Course Beaver	Benzene	0.84 - NA	NA	NA	2/7	29
Pond	Diethyl phthalate	15 - NA	NA	NA	1/7	14
	JP-4	370 - NA	NA	NA	1/7	14
	TFH Gas	260 - NA	NA	NA	1/7	14
	Trichloroethylene (TCE)	2.5 - NA	NA	NA	1/4	25

NA = Not Applicable due to only one reported value.

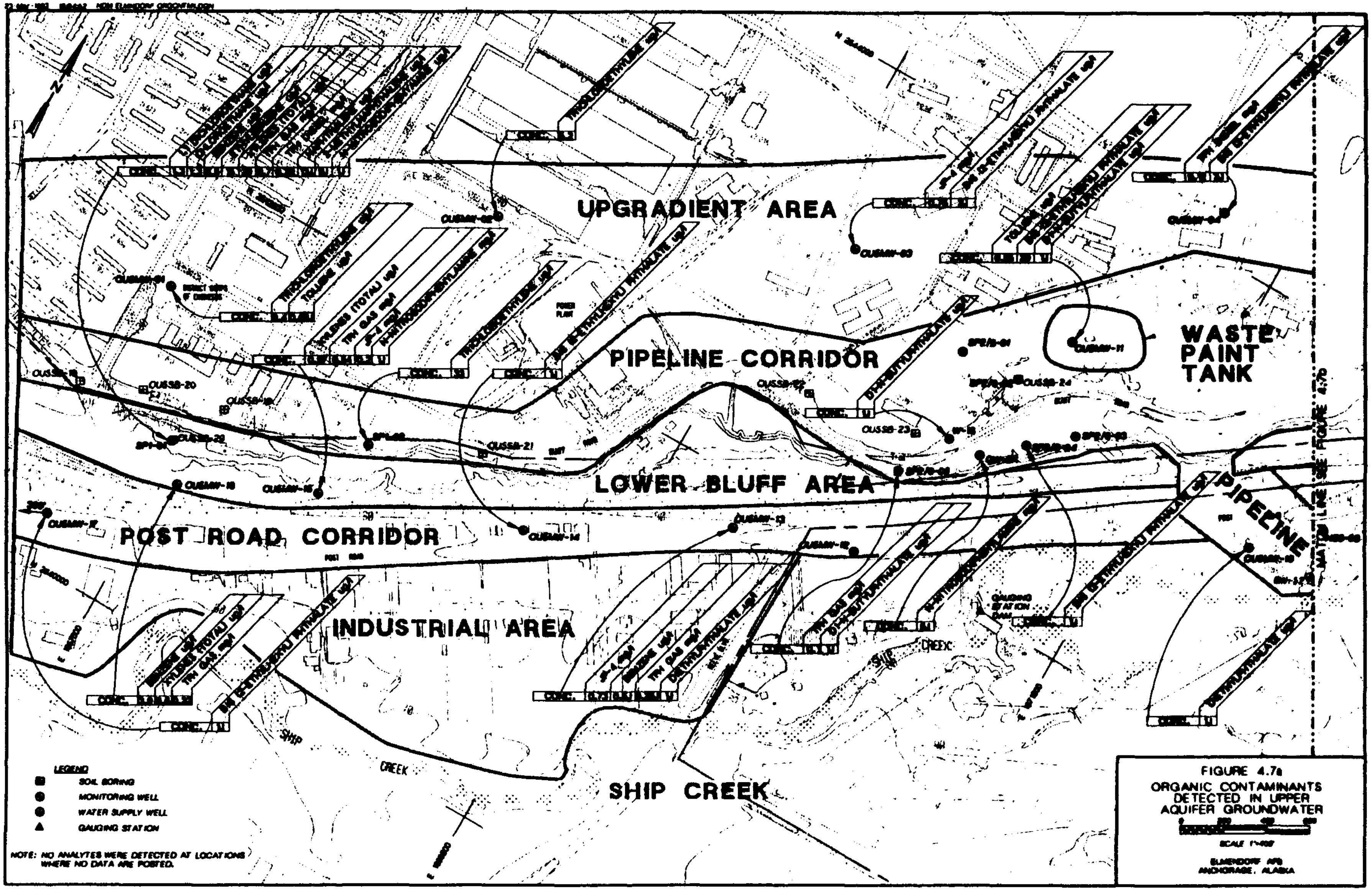


FIGURE 4.7a
ORGANIC CONTAMINANTS DETECTED IN UPPER AQUIFER GROUNDWATER

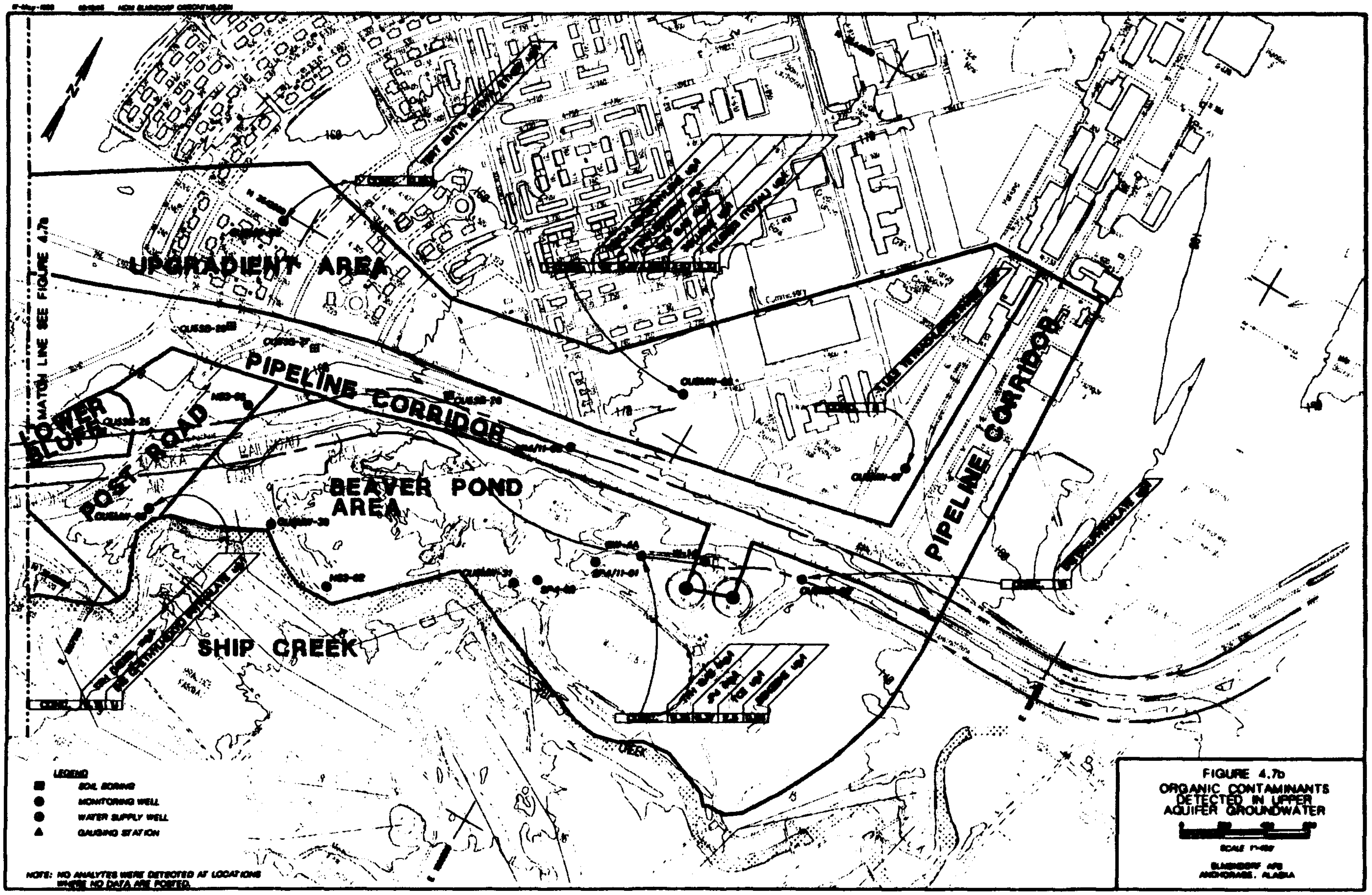


FIGURE 4.7b
ORGANIC CONTAMINANTS DETECTED IN UPPER AQUIFER GROUNDWATER

Table 4-9

Summary of Analytical Results for Dissolved Metals in Groundwater (Upper Aquifer)

Study Subarea	Detected Compound	Range of Detected Values (mg/l)	Geometric Mean (mg/l)	Arithmetic Mean (mg/l)	Background Comparison (mg/l)	No. of Detections Above Background/ No. of Samples	Percent of Samples
Upgradient	**Barium, soluble**	0.0146 - 0.0152	1.49 x 10^{-2}	1.49 x 10^{-2}	0.0152	0/2	0
	Calcium, soluble	83.3 - 87.2	8.52 x 10^{1}	8.53 x 10^{1}	89	0/2	0
	Copper, soluble	0.0011 - 0.0029	1.79 x 10^{-3}	2.00 x 10^{-3}	0.0063	0/2	0
	Magnesium, soluble	14.4 - 23.4	1.84 x 10^{1}	1.89 x 10^{1}	23.8	0/2	0
	Manganese, soluble	0.0039 - 0.317	3.52 x 10^{-2}	1.60 x 10^{-1}	0.323	0/2	0
	Potassium, soluble	1.52 - 1.79	1.65 x 10^{0}	1.66 x 10^{0}	2.04	0/2	0
	Selenium, soluble	0.0019 - NA	NA	NA	0.0019	0/2	0
	Sodium, soluble	7.9 - 11.4	9.49 x 10^{0}	9.65 x 10^{0}	11.5	0/2	0
	Vanadium, soluble	0.0019 - 0.0023	2.09 x 10^{-3}	2.10 x 10^{-3}	0.003	0/2	0
Pipeline Corridor	**Barium, soluble**	0.0189 - NA	NA	NA	0.0151	1/1	100
	Calcium, soluble	84.8 - NA	NA	NA	89	0/1	0
	Copper, soluble	0.0023 - NA	NA	NA	0.0063	0/1	0
	Iron, soluble	0.0783 - NA	NA	NA	0.00142	1/1	100
	Magnesium, soluble	18.3 - NA	NA	NA	23.8	0/1	0
	Manganese, soluble	1.38 - NA	NA	NA	0.323	1/1	100
	Potassium, soluble	1.35 - NA	NA	NA	2.04	0/1	0
	Sodium, soluble	7.12 - NA	NA	NA	11.5	0/1	0

Table 4-9

(Continued)

Study Subarea	Detected Compound	Range of Detected Values (mg/l)	Geometric Mean (mg/l)	Arithmetic Mean (mg/l)	Background Comparison (mg/l)	No. of Detections Above Background/ No. of Samples	Percent of Samples
	Vanadium, soluble	0.0023 - NA	NA	NA	0.003	0/1	0
Lower Bluff	Aluminum, soluble	0.0439 - 0.0678	3.59 x 10^2	4.24 x 10^2	0.031	2/3	67
	Arsenic, soluble	0.0009 - 0.0032	2.05 x 10^3	2.37 x 10^3	0.007	0/3	0
	Barium, soluble	0.0165 - 0.103	4.71 x 10^2	6.04 x 10^2	0.0151	3/3	100
	Calcium, soluble	77.8 - 94.7	8.68 x 10^1	8.71 x 10^1	89	1/3	33
	Copper, soluble	0.0023 - NA	NA	NA	0.0063	0/3	0
	Iron, soluble	5.23 - 12.6	8.83 x 10^1	5.95 x 10^0	0.00142	2/3	67
	Magnesium, soluble	14.3 - 18.8	1.70 x 10^1	1.71 x 10^1	23.8	0/3	0
	Manganese, soluble	0.0941 - 4.28	8.69 x 10^1	2.00 x 10^0	0.323	2/3	67
	Potassium, soluble	1.13 - 2.07	1.66 x 10^0	1.72 x 10^0	2.04	1/3	33
	Selenium, soluble	0.0022 - 0.0025	1.45 x 10^0	1.75 x 10^3	0.0019	2/3	67
	Sodium, soluble	6.79 - 9.57	7.70 x 10^0	7.79 x 10^0	11.5	0/3	0
	Thallium, soluble	0.0007 - NA	NA	NA	0.0007	0/3	0
	Vanadium, soluble	0.003 - 0.005	3.95 x 10^3	4.03 x 10^3	0.003	2/3	67

NA = Not Applicable due to only one reported value.

Table 4-10

Summary of Analytical Results for Total Metals in Groundwater (Upper Aquifer)

Study Subarea	Detected Compound	Range of Detected Values (mg/l)	Geometric Mean (mg/l)	Arithmetic Mean (mg/l)	Background Comparison (mg/l)	No. of Detections Above Background/ No. of Samples	Percent of Samples
Upgradient	Aluminum	0.0581 - NA	NA	NA	0.0581	0 / 2	0
	Antimony	0.0144 - NA	NA	NA	0.0144	0 / 2	0
	Arsenic	0.0018 - NA	NA	NA	0.0018	0 / 2	0
	Barium	0.0152 - 0.0163	1.57 x 10^{-2}	1.58 x 10^{-2}	0.0163	0 / 2	0
	Calcium	84.4 - 90.1	8.72 x 10^{1}	8.73 x 10^{1}	90.1	0 / 2	0
	Copper	0.0027 - 0.0037	3.16 x 10^{-3}	3.20 x 10^{-3}	0.0037	0 / 2	0
	Iron	0.0415 - 0.184	8.74 x 10^{-2}	1.13 x 10^{-1}	0.184	0 / 2	0
	Lead	0.0009 - NA	NA	NA	0.0009	0 / 2	0
	Magnesium	14.6 - 24.1	1.88 x 10^{1}	1.94 x 10^{1}	24.1	0 / 2	0
	Manganese	0.0271 - 0.329	9.44 x 10^{-2}	1.78 x 10^{-1}	0.329	0 / 2	0
	Potassium	1.43 - 1.8	1.60 x 10^{0}	1.62 x 10^{0}	1.8	0 / 2	0
	Sodium	7.82 - 11.5	9.48 x 10^{0}	9.66 x 10^{0}	11.5	0 / 2	0
	Thallium	0.0012 - NA	NA	NA	0.0012	0 / 2	0
	Vanadium	0.0019 - 0.003	2.39 x 10^{-3}	2.45 x 10^{-3}	0.003	0 / 2	0
Pipeline Corridor	Aluminum	1.09 - NA	NA	NA	0.0581	1 / 1	100
	Arsenic	0.0017 - NA	NA	NA	0.0018	0 / 1	0
	Barium	0.0259 - NA	NA	NA	0.0163	1 / 1	100

Table 4-10

(Continued)

Study Subarea	Detected Compound	Range of Detected Values (mg/l)	Geometric Mean (mg/l)	Arithmetic Mean (mg/l)	Background Comparison (mg/l)	No. of Detections Above Background/ No. of Samples	Percent of Samples
Pipeline Corridor (cont.)	Calcium	87.5 - NA	NA	NA	90.1	0 / 1	0
	Copper	0.0059 - NA	NA	NA	0.0037	1 / 1	100
	Iron	1.84 - NA	NA	NA	0.184	1 / 1	100
	Lead	0.0007 - NA	NA	NA	0.0009	0 / 1	0
	Magnesium	19 - NA	NA	NA	24.1	0 / 1	0
	Manganese	1.45 - NA	NA	NA	0.329	1 / 1	100
	Nickel	0.0115 - NA	NA	NA	0.0077	1 / 1	100
	Potassium	1.33 - NA	NA	NA	1.8	0 / 1	0
	Sodium	6.98 - NA	NA	NA	11.5	0 / 1	0
	Vanadium	0.0061 - NA	NA	NA	0.003	1 / 1	100
Lower Bluff	Aluminum	0.392 - 7.84	3.63×10^{-1}	2.75×10^{0}	0.0581	2 / 3	67
	Arsenic	0.0008 - 0.0054	2.12×10^{-3}	2.80×10^{-3}	0.0018	2 / 3	67
	Barium	0.0168 - 0.116	5.98×10^{-2}	8.09×10^{-2}	0.0163	3 / 3	100
	Calcium	77.6 - 93.7	8.57×10^{1}	8.60×10^{1}	90.1	1 / 3	33
	Chromium, total	0.0125 - NA	NA	NA	0.0037	1 / 3	33
	Copper	0.0017 - 0.0099	3.48×10^{-3}	4.70×10^{-4}	0.0037	1 / 3	33
	Iron	0.057 - 19.3	1.89×10^{0}	8.51×10^{0}	0.184	2 / 3	67
	Magnesium	14.4 - 20.2	1.80×10^{1}	1.82×10^{1}	24.1	0 / 3	0

Table 4-10

(Continued)

Study Subarea	Detected Compound	Range of Detected Values (mg/l)	Geometric Mean (mg/l)	Arithmetic Mean (mg/l)	Background Comparison (mg/l)	No. of Detections Above Background/ No. of Samples	Percent of Samples
Lower Bluff (cont.)	Manganese	0.099 - 4.44	9.48 x 10^{1}	2.16 x 10^{0}	0.329	2 / 3	67
	Nickel	0.0208 - NA	NA	NA	0.0077	1 / 3	33
	Potassium	1.09 - 2.15	1.71 x 10^{0}	1.79 x 10^{0}	1.8	2 / 3	67
	Sodium	6.9 - 10	7.83 x 10^{0}	7.96 x 10^{0}	11.5	0 / 3	0
	Vanadium	0.0034 - 0.0187	7.60 x 10^{3}	9.67 x 10^{3}	0.003	3 / 3	100
	Zinc	0.0328 - 0.0341	1.76 x 10^{2}	2.39 x 10^{2}	0.0144	2 / 3	67

NA = Not Applicable due to only one reported value.

December results for wells SP1-01 and SP1-02 are considered more representative of the total metals in the groundwater. All of the sampling results from both the August and December sampling events are presented in Appendix K.

The only lower aquifer well in the OU 5 study area tested for TAL metals was the IGM well (WS01). Four wells (IGM, Inlet Company [WS02], Base Well 52 [BW52], and Base Well 02 [BW02]) were tested for calcium, iron, magnesium, potassium, and sodium to allow a geotechnical comparison of upper and lower aquifer waters. Sampling results are summarized in Table 4-11.

The following data were reviewed to determine background levels for inorganics in the lower aquifer:

- Elmendorf supply wells—BESG data found in the *Basewide Background Sampling Report* (CH2M HILL 1992a), and data collected by Black & Veatch (1990);
- MOA supply wells—data obtained from Mitch Lile, Ship Creek Water Treatment Plant, Anchorage Water and Wastewater Utility, MOA;
- Fort Richardson wells (COE 1991); and
- Regional groundwater well data obtained from USGS computer database and reported in the *Basewide Background Sampling Report* (CH2M HILL 1992a).

The background data were reviewed to determine if the analytical detection limits were suitable for comparison with the data collected during the OU 5 investigation and if wells were located near potential sources of contamination. BESG data were not useable for background comparison because of higher detection limits than the OU 5 data (for example, the BESG data had a detection limit of 10 $\mu g/L$ for arsenic, but the value detected in WS01 was 4.1 $\mu g/L$). The USGS data were from wells near the Merrill Field Sanitary Landfill and

Table 4-11

Summary of Analytical Results for Total Metals in Water Supply Wells (Lower Aquifer)

Study Subarea	Detected Compound	Range of Detected Values (mg/l)	Geometric Mean (mg/l)	Arithmetic Mean (mg/l)	Background Comparison (mg/l)	No. of Detections Above Background/ No. of Samples	Percent of Samples
Supply Wells	Arsenic	0.0041 - NA	NA	NA	0.01	0/1	0
	Barium	0.0142 - NA	NA	NA	0.126	0/1	0
	Calcium	10.3 - 27	1.55×10^1	1.69×10^1	76.9	0/4	0
	Copper	0.002 - NA	NA	NA	0.014	0/1	0
	Iron	0.0555 - 0.183	9.37×10^{-2}	1.05×10^{-1}	3.1	0/4	0
	Magnesium	5.63 - 8.65	6.77×10^0	6.85×10^0	7.4	1/4	25
	Manganese	0.0354 - NA	NA	NA	0.11	0/1	0
	Potassium	0.83 - 1.99	1.48×10^0	1.55×10^0	1.9	1/4	25
	Selenium	0.00071 - NA	NA	NA	0.001	0/1	0
	Sodium	6.17 - 41.9	1.98×10^1	2.57×10^1	18.6	2/4	50
	Zinc	0.0281 - NA	NA	NA	0.043	0/1	0

NA = Not Applicable due to only one reported value.

were eliminated from the consideration as background because of the potential for contamination from the landfill.

Figure 4-8 shows the location of the MOA wells and Fort Richardson wells selected for the background comparison, in addition to the four OU 5 wells sampled during the RI. Only wells near Ship Creek were chosen as background comparison wells so that the data would more closely reflect the hydrogeology of the OU 5 study area. Table 4-12 shows the data for the wells from the Black & Veatch investigation, the MOA, and the COE. Black & Veatch sampled only BW2 and BW52, which are located in OU 5.

There is some degree of uncertainty in the data presented in Table 4-12 because it was collected by several investigators at different times and analyzed in different laboratories. It appears, however, that standard EPA methods and QA/QC checks were made. Because of the different sources of the data, the background comparison values were not calculated statistically, as was done for the background soil metals. Instead, the maximum concentration detected in the wells was selected for the background comparison.

The field parameters temperature, pH, and specific conductance were measured at each well that was sampled. Although these data are of general interest, they are most applicable to the geochemical evaluation of the confined and unconfined aquifers, and will be discussed in that section.

4.3.2 Discussion

4.3.2.1 Upgradient

The monitoring wells located in the upgradient subarea are MW01, MW02, MW03, MW04, MW05, MW06, and MW07. All of these shallow aquifer wells were installed as part of this investigation.

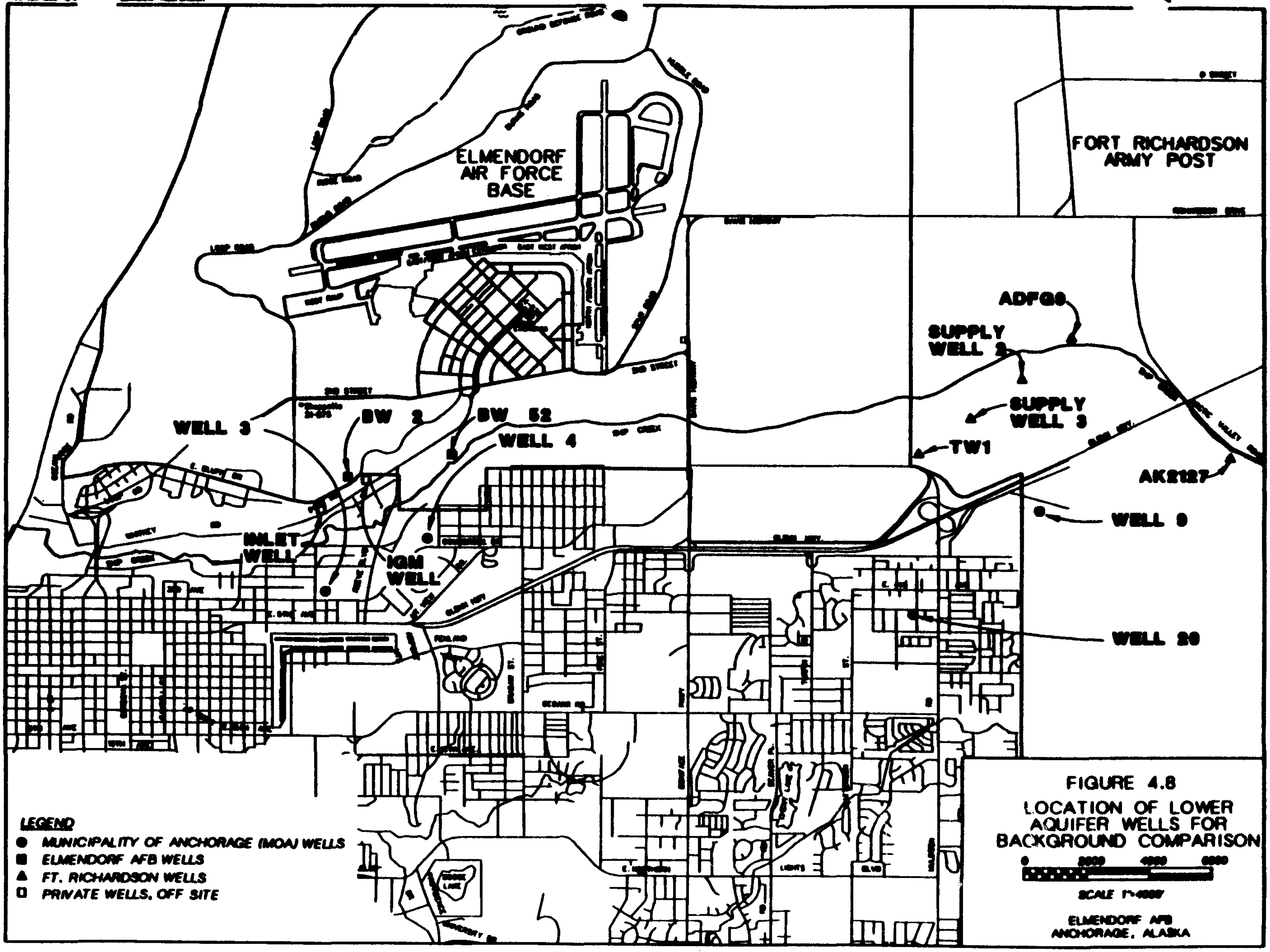


FIGURE 4.8
LOCATION OF LOWER AQUIFER WELLS FOR BACKGROUND COMPARISON

Table 4-12

Background Comparison of Total Metals and Anions in Groundwater for Lower Aquifer Wells near Ship Creek

	Range of Concentrations (mg/L)											
	Elmendorf AFB Wells[a]		Municipality of Anchorage Wells[b]				Fort Richardson Wells[c]					Background Comparison Value[d] mg/L
Metals	BW3	BWS2	Well 3	Well 4	Well 9	Well 20	TW1	Supply Well 2	Supply Well 3	ADFG 9	AK-2127	
Aluminum	NR	NR	NA	NA	NA	NA	0.36	<0.045-0.1	<0.045	<0.045	<0.045	0.36
Antimony	NR	NR	NA	NA	NA	NA	<0.01	<0.001-<0.010	<0.010	<0.010	<0.010	MDL
Arsenic	0.005	NR	0.008-0.010	<0.001	<0.001	0.002-0.003	0.0029	0.001-<0.002	0.0026	0.0021	<0.002	0.010
Barium	0.013	NR	0.125-0.126	0.004	0.006	0.084-0.093	<0.010	0.005-<0.010	0.013	<0.010	0.015	0.126
Beryllium	NR	NR	NA	NA	NA	NA	<0.001	<0.001-<0.007	<0.001	<0.001	<0.001	MDL
Cadmium	NR	NR	<0.0001-0.0001	<0.0001	<0.0001	<0.0001	<0.0005	<0.0005-<0.002	<0.0005	<0.0005	<0.0005	0.0001
Calcium	10	2.6	39.7-53	34.3-34.4	47.6-49.5	64.8-76.9	37	35-36	32	28	27	76.9
Chloride	2.4	1.4	11.6-16.2	1.1-3.6	5.2-14.6	7.1-7.7	3.25	1.5-2.6	2.15	2.85	2.05	16.2
Chromium	NR	NR	<0.001	<0.001	<0.001-0.001	<0.001	0.0026	<0.002-0.003	0.0048	<0.002	0.0041	0.0048
Cobalt	NR	NR	NA	NA	NA	NA	<0.005	<0.003-<0.005	<0.005	<0.005	<0.005	MDL
Copper	0.009	NR	<0.001-0.002	<0.001	<0.001-0.002	0.002-0.014	<0.005	0.0083-0.012	<0.005	<0.005	<0.005	0.014
Iron	NR	NR	0.040-0.050	<0.03-0.08	0.04	0.08-0.14	2.1	0.14-3.1	0.13	0.054	0.12	3.1
Lead	NR	NR	<0.001	<0.001	<0.001	<0.001	0.0022	0.0037-0.016	<0.002	0.047	<0.002	0.047
Magnesium	5.7	6.7	NA	NA	NA	NA	7.4	1.7-6.3	5	5.1	6.3	7.4
Manganese	0.019	NR	0.1-0.11	<0.02	<0.02	0.08-0.09	0.025	<0.002-0.008	<0.002	<0.002	0.016	0.11

Table 4-12

(Continued)

Metals	Range of Concentrations (mg/L)											Background Comparison Value[d] mg/L
	Elmendorf AFB Wells[a]		Municipality of Anchorage Wells[b]				Fort Richardson Wells[c]					
	BW2	BW52	Well 3	Well 4	Well 9	Well 20	TW1	Supply Well 2	Supply Well 3	ADFG 9	AK-2127	
Mercury	NR	NR	>0.0003	<0.0003	<0.0003	<0.0003	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	MDL
Nickel	NR	NR	NA	NA	NA	NA	<0.005	<0.005-<0.010	<0.005	<0.005	<0.005	MDL
Nitrate	NR	NR	<0.1	0.2	0.5-0.9	0.1-0.2	NA	NA	NA	NA	NA	0.9
Potassium	NR	NR	NA	NA	NA	NA	0.82	0.51-1.9	0.53	0.45	0.67	1.9
Selenium	NR	NR	<0.002	<0.002	<0.002	<0.002	<0.005	0.001-<0.005	<0.005	<0.005	<0.005	0.001
Silver	NR	NR	<0.0002	<0.0002-0.0004	<0.0002	<0.0002	<0.0005	<0.0005-0.010	<0.0005	<0.0005	<0.0005	0.0004
Sodium	40	6.4-6.7	17.38-18.6	3.29-3.6	3.8-4.62	4.86-5	3.2	3.1-4.5	3.4	3.2	5	18.6
Sulfate	16	12	17.38-29	12-15	23-32	16-24	15	14-16	18	17	14	32
Thallium	NR	NR	NA	NA	NA	NA	<0.001	<0.001	<0.001	<0.001	<0.001	MDL
Vanadium	NR	NR	NA	NA	NA	NA	<0.005	<0.002-<0.005)	<0.005	<0.005	<0.005	MDL
Zinc	NR	NR	<0.005	<0.005	<0.005-0.006	0.022-0.026	0.014	0.012-0.043	0.013	0.037	0.015	0.043

[a] Data from one sampling event in 1987 by Black & Veatch (1990). One sample for Well 2. Two duplicate samples for Well 52, range reported.

[b] Data obtained from Mitch Lile, Ship Creek Water Treatment Plant, Anchorage Water and Wastewater Utility, Municipality of Anchorage. Two sampling events, March 1991 and September 1991, for each well range reported.

[c] Data from one sampling event, September 1990 by COE (1991). Results for duplicate samples are reported.

[d] Value selected for background comparison is the maximum concentration detected at the Municipality of Anchorage wells or Fort Richardson wells.

NR = Analyte tested for and not detected, detection limit not reported.
NA = Analyte not analyzed.
MDL = Minimum detection limit.

Halogenated VOCs were detected in four of the seven upgradient wells. TCE was detected in wells MW01, MW02, and MW06 ranging from 5.2 to 52 $\mu g/L$. 1,1,2,2-Tetrachloroethane was detected in MW07 at a concentration of 8 $\mu g/L$. Because there are no known sources of these compounds in OU 5, it is likely that these compounds are migrating with the groundwater from upgradient locations. Low levels of both TCE and 1,1,2,2-tetrachloroethane were detected in previous investigations in well 1, which is upgradient of MW06 and MW07.

BTEX compounds (except benzene) were detected in at least one upgradient well at very low levels, with only one concentration (toluene in MW06) exceeding 1 $\mu g/L$. No PAHs were detected in any upgradient well samples. Gasoline-, diesel-, and JP-4-range hydrocarbons were detected in several wells within the upgradient subarea in concentrations of less than 1 mg/L. As with the halogenated VOCs, the low frequency of detection and low concentrations suggest migration from some source(s) upgradient of OU 5.

Very low concentrations of bis(2-ethylhexyl)phthalate were detected in monitoring wells MW03 and MW04. Because there is no known source of this compound in the upgradient subarea, it is likely that these concentrations are the result of migration from sources upgradient of OU 5 or of laboratory contamination.

4.3.2.2 Pipeline Corridor

The pipeline corridor wells include SP1-02, GW-6A, W-16, SP2/6-01 through SP2/6-05, SP4/11-03, W14, NS3-03, and MW10.

The second highest halogenated VOC concentration detected in OU 5 was reported for well SP1-02. This value of 33 $\mu g/L$ TCE was the only reported halogenated VOC within the pipeline corridor. Because SP1-02 is downgradient of well MW02 (where this compound was also detected), it is possible that these concentrations indicate a pattern of TCE transport in groundwater through the western part of OU 5.

Only one well in the pipeline corridor, SP2/6-05, contained any detectable fuel hydrocarbons. A concentration of 0.1 mg/L of gasoline-range organics was measured in this well, located downgradient of Sources ST38/SS42. Previous investigations detected TPH in well SP2/6-05 at 5.8 mg/L and TPH concentrations ranging from 1.0 to 64 mg/L in nearby wells SP2/6-03, SP2/6-04, and GW-6A The absence of any hydrocarbons in groundwater in an area of known historical fuel leaks suggests that the impacts of past leaks on groundwater have been attenuated by natural processes.

4.3.2.3 Waste Paint Tank

A monitoring well (MW11) was installed near a waste paint tank to investigate potential impacts from the tank contents. The organic compounds detected in well MW11 were toluene at less than 1 μg/L, bis(2-ethylhexyl)phthalate at 20 μg/L, and di-n-butylphthalate at 1 μg/L. The toluene concentration is similar to levels detected in upgradient wells. Elevated xylenes detected in soil at a 10-foot depth were not observed in the groundwater sample. The low levels of toluene and phthalates do not indicate that contents of the tank have affected groundwater quality.

4.3.2.4 Lower Bluff

Two new monitoring wells (MW15 and MW16A) were installed in the Lower Bluff subarea during this investigation to augment the one existing well (SP1-01). Despite the small number of wells, a more extensive list of organic compounds was detected in this subarea than any other.

Halogenated VOC compounds 1,1-dichloroethane (1.3 μg/L) and chloroethene (1.3 μg/L) were detected in well SP1-01. No halogenated VOCs were detected in wells MW15 and MW16A, located downgradient of SP1-01. These two compounds may be a degradation product of TCE detected in upgradient wells. Well SP1-01 marks the farthest downgradient point within OU 5 at which a halogenated VOC was detected in groundwater.

In contrast to the diminishing trend relative to upgradient and pipeline corridor wells exhibited by halogenated VOCs, the BTEX compounds were detected with greater frequency and in higher concentrations in lower bluff wells than any other area of OU 5. With the exception of toluene, all BTEX compounds were detected at least once in the three wells with concentrations ranging from less than 1 to 39 μg/L. Well SP1-01 had the highest BTEX contamination. No well completed upgradient of SP1-01 contains the level of BTEX or variety of compounds found in this well.

At least one fuel hydrocarbon (diesel, gasoline, or JP-4) was detected in each well of the lower bluff subarea wells. As with the BTEX compounds, the greater concentration is present in SP1-01, although all detected levels are less than 2 mg/l. Two PAHs known to be associated with diesel fuel, naphthalene and 2-methylnapthalene, were also found in groundwater at SP1-01. Petroleum hydrocarbons and PAHs were also present in shallow soil samples in boring SB29, located approximately 15 feet from well SP1-01. This may indicate that this location is a localized source where petroleum products such as waste automotive oil have been discarded.

The semivolatile organic compound n-nitrosodiphenylamine was detected in both SP1-01 and MW15 at a concentration of 1 μg/L. The lack of a known source of this compound and the very low concentration make it difficult to determine whether these data reflect groundwater concentrations or are the result of laboratory contamination.

Groundwater samples for total and dissolved metals were collected from wells MW01, MW02, SP1-01, SP1-02, MW15, and MW16A to assess potential impacts of fly ash disposed of along the edge of the bluff in this area. According to the well construction log, Monitoring Well SP1-02 was installed through the fly ash. Therefore, wells SP1-01, MW15, and MW16A are considered downgradient of the fly ash deposits. Upgradient (background) water quality was assessed by sampling wells MW01 and MW02.

Fourteen metals were found in higher concentrations in well SP1-02 or downgradient wells than in the upgradient wells. A comparison of the groundwater results is presented in Table 4-13. Comparing maximum concentrations detected, the following trends can be identified:

- Aluminum, barium, iron, manganese, and vanadium were detected in the lower bluff subarea at greater than five times the upgradient levels. The concentrations of the five metals also increased across the site in a downgradient direction.
- Arsenic, chromium, copper, lead, nickel, selenium, and zinc were detected in the lower bluff subarea at between two and five times the upgradient levels. The maximum concentrations of arsenic and lead in the pipeline corridor well (SP1-02) were slightly less than in the maximum concentrations in the upgradient subarea. The maximum concentration of selenium on the site was in the pipeline corridor well. The remaining four metals increased over the site in a downgradient direction.
- Calcium and potassium were slightly higher in the lower bluff subarea and slightly less in the pipeline corridor subarea, compared to the maximum upgradient concentrations.

Comparing fly ash leachate results (Table 4-7) to the shallow aquifer groundwater results, it appears that arsenic, barium, vanadium, and zinc may be leaching out at levels that represent the detected concentrations in the groundwater. Naturally occurring levels of aluminum, iron, and manganese in OU 5 soils are most likely responsible for the observed raised levels in the lower bluff area groundwater.

4.3.2.5 Post Road Corridor

Six wells are included in the Post Road corridor: NS3-06, MW09, MW12, MW13, MW14, and MW17. On the western site of OU 5, wells MW14 and MW17 were both free of contamination, with the exception of trace levels of bis(2-ethylhexyl)phthalate at 1 μg/L (estimated) at each well. This compound is typically observed as a common laboratory contaminant, and is not considered significant at the low levels detected. In the

Table 4-13

Comparison of Downgradient to Upgradient Total Metals for the Upper Aquifer

	Upgradient Maximum Concentration		Pipeline Corridor (Fly Ash Area) Maximum Concentration		Lower Bluff Maximum Concentration		
Metal	mg/L	Location	mg/L	Location	mg/L	Location	Comment
Aluminum	0.0581	MW02	1.090	SP1-02	7.84	SP1-01	c, e
Arsenic	0.0018	MW02	0.0017	SP1-02	0.0054	SP1-01	b
Barium	0.0163	MW02	0.0259	SP1-02	0.116	MW16	c, e
Calcium	90.1	MW01	87.5	SP1-02	93.7	MW16	a
Chromium	<0.0037	MW01, MW02	<0.0037	SP1-02	0.0125	SP1-01	b, e
Copper	0.0037	MW01	0.0059	SP1-02	0.0099	SP1-01	b, e
Iron	0.184	MW02	1.84	SP1-02	19.3	SP1-01	c, e
Lead	0.0009	MW01	0.0007	SP1-02	0.0032	SP1-01	b
Manganese	0.329	MW01	1.45	SP1-02	4.44	SP1-01	c, e
Nickel	<0.0077	MW01, MW02	0.00115	SP1-02	0.0208	SP1-01	b, e
Potassium	1.80	MW01	1.33	SP1-02	2.150	SP1-01	a
Selenium	0.00064	MW01, MW02	0.002	SP1-02	0.001	MW15	b, d
Vanadium	0.0030	MW02	0.0061	SP1-02	0.0187	SP1-01	c, e
Zinc	<0.0144	MW02	<0.0131	SP1-02	0.0341	SP1-01	b, e

a = A downgradient value is less than two times the upgradient metal's concentration.
b = A downgradient value is between two and five times the upgradient metal's concentration.
c = A downgradient value is greater than five times the upgradient metal's concentration.
d = The pipeline corridor sample has the highest metal concentration.
e = The metal concentration increases progressively from the upgradient to the lower bluff subarea.

Note: A metal is shown only if its concentration in a downgradient sample exceeded the value for an upgradient sample. Only data from the December 1992 sampling event is compared. The lower bluff subarea is downgradient of the pipeline corridor subarea. Well SP1-02 in the pipeline corridor subarea is located in the fly ash deposit.

middle of OU 5, at wells MW09 and MW13, low levels of petroleum hydrocarbons were detected as well as trace levels of phthalates.

No halogenated VOCs were detected in groundwater in the Post Road corridor. Because no known source of these compounds exists in OU 5, the halogenated VOCs are useful in tracing groundwater flow through OU 5. The disappearance of these compounds in the Post Road corridor suggests that either the groundwater containing halogenated VOCs is being discharged in seeps along the lower bluff area or the halogenated VOC concentrations are reduced below detection due to mixing with groundwater in the Ship Creek alluvium.

Monitoring Well MW13 was the only location where any of the four compounds included in the BTEX group were detected in the Post Road corridor. A single estimated value of 0.6 μg/L benzene was detected at this well. Low levels of fuel hydrocarbons were also detected at wells MW09 and MW13. Diesel-range organics were detected at MW09, and both JP-4 and gasoline-range organics were detected at MW13. All concentrations were less than 1 mg/L. Both of these wells are downgradient of reported fuel hydrocarbon spills at Sources ST38/SS42 and SS53, and these concentrations may represent the remnants of the fuel that migrated to the water table.

Each of the Post Road corridor well samples contained a phthalate compound except MW12 and NS3-03. No concentrations exceeded 2 μg/L. As at other locations, it is difficult to determine whether these data reflect groundwater concentrations or are the result of laboratory contamination.

4.3.2.6 Golf Course Beaver Pond

Two monitoring wells (MW30 and MW31) were installed in this subarea in addition to existing wells NS3-02, SP4-02, SP4/11-01, and GW-4A. No contaminants were detected in groundwater samples collected at any of the wells in this subarea. Although this is contrary to expectations, since low levels of fuel hydrocarbons (TPH less than 3.5 mg/L) and volatile organics (TCE and other compounds less than 3 μg/L) were detected in previous investigations, it is in an area of groundwater discharge and it is possible that the readily mobile contaminants have been flushed from the area. Given the hydrologic conditions in this subarea, analytical results for surface water and sediments may provide a better indication of environmental impacts of fuel spills than the groundwater.

4.3.2.7 Lower (Confined) Aquifer

Lower aquifer groundwater samples were collected from Elmendorf AFB Supply Wells 2 and 52, and offsite water supply wells for two businesses along Post Road, IGM and the Inlet Co. No organic contaminants were detected in any of these wells. A summary of the results for total metal analyses is presented in Table 4-11. Only total magnesium, potassium, and sodium were slightly higher in OU 5 RI data than in the background wells (Table 4-12). Arsenic has a risk-based concentration of approximately 5 μg/L for an excess lifetime cancer risk of 1 in 10,000 (EPA Region 10, 1991), but a higher federal (40 CFR 141) and state (18 AAC 80) drinking water standard of 50 μg/L. Arsenic appears in low levels in 6 of the 9 background wells outside of the OU 5 study area, indicating that the levels found in the IGM well during the OU 5 investigation and in BW2 by Black & Veatch (1990) can be attributed to naturally occurring background levels and not to OU 5 sources.

4.3.2.8 Geochemical Evaluation

Major cation and anion data and field parameter measurements were used to compare the geochemical characteristics of confined and unconfined groundwater within OU 5. The unconfined groundwater data were collected at several OU 5 monitoring wells. The confined groundwater characteristics were evaluated using data collected at three water supply wells located in or near OU 5.

The cations used for the comparison were dissolved concentrations for the unconfined aquifer and total concentrations for the confined aquifer. Because the confined aquifer wells are water supply wells that produce water of very low turbidity, it was assumed that using the total concentrations will not introduce significant error into the comparison.

The cations used in this comparison were calcium, sodium, magnesium, and potassium. The anions include bicarbonate, carbonate, chloride, and sulfate. The anion nitrate was not included in the comparison because concentrations of this ion were very low at all wells.

Field parameter results are listed for all wells and surface water locations in Appendix M. These data show that water from both aquifers is relatively low in total dissolved solids as indicated by the specific conductance data. With the exception of wells MW17 and SP2/6-03 (the specific conductance readings for these two wells appear anomalous), the unconfined aquifer data ranged from 280 to 550 micro-mhos per centimeter (μmho/cm). The two confined wells monitored for field parameters were both less than 200 μmho/cm. However, the pH for the two confined wells was 8 or greater while the pH for the unconfined aquifer wells was considerably lower, ranging from 6.3 to 7.38. Temperatures measured at confined aquifer wells were between 5 and 6 degrees Celsius, while the unconfined aquifer wells ranged from 6.2 to 11.7 degrees Celsius. The unconfined temperatures reflect the greater influence of atmospheric temperatures on the shallow groundwater.

A Piper plot was constructed using the major ion data from the two aquifers to illustrate the relative percentage of each ion in the two groundwaters. The plot presented in Figure 4-9 illustrates the following general characteristics of both groundwaters:

- The dominant anion in all samples is bicarbonate. Low concentrations of chloride, nitrate (measured in unconfined aquifer wells only), and carbonate (found in confined aquifer wells only) and moderate levels of sulfate were also detected.

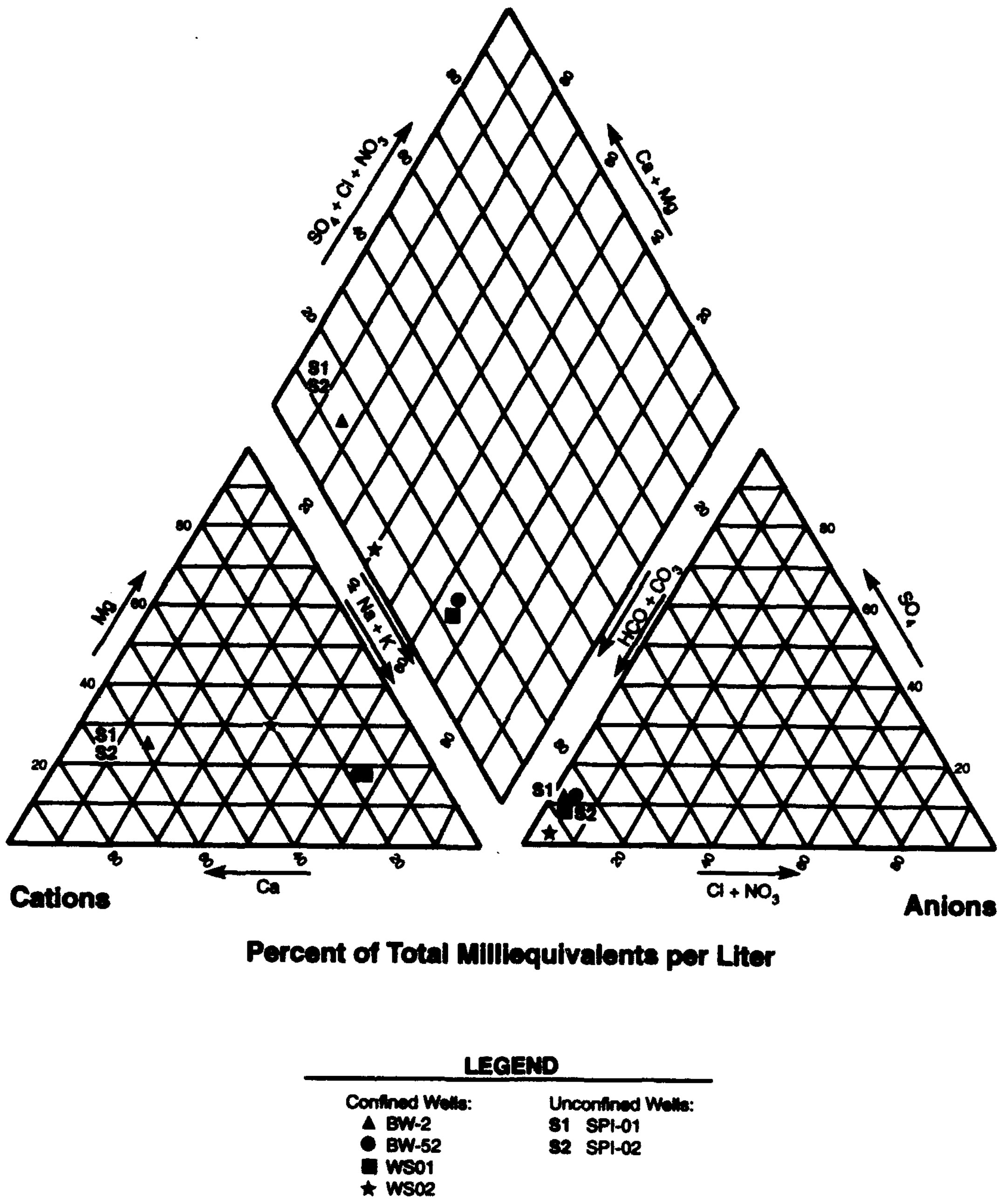


Figure 4.9. Piper Plot Comparing Confined & Unconfined Groundwater Results, Elmendorf AFB, Anchorage, Alaska

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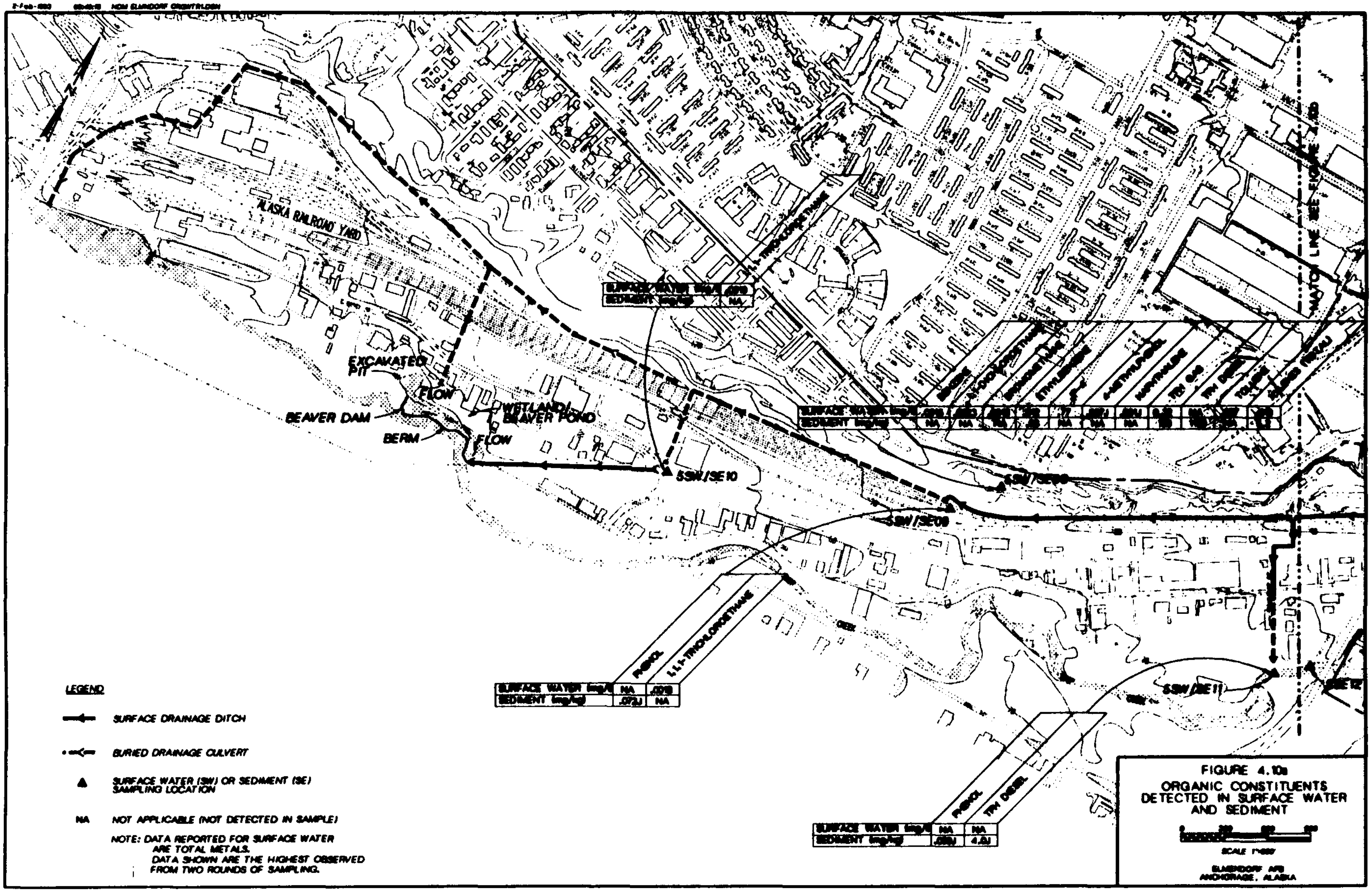
- The dominant cation in the two unconfined aquifer samples and the sample from supply well BW2 is calcium. Approximately equal quantities of calcium, magnesium, and sodium were found in the sample from supply well WS02, and sodium is the dominant cation in samples from wells WS01 and BW52.

It is common for calcium and magnesium to be the most prevalent cations in groundwater (in silicate rock) that is near the area of recharge. The relatively high concentrations of sodium in the three confined aquifer wells (WS01, WS02, and BW52) are not consistent with this expectation. The reason for this apparent increase in sodium is not known. The distance between the recharge area and Elmendorf AFB is similar for both the confined and unconfined aquifers, and no minerals have been identified in the confined aquifer that would increase the sodium concentration relative to the unconfined aquifer values. Salt-water intrusion, another potential explanation for elevated sodium, is not occurring at these wells because chloride and specific conductance levels are consistent with unconfined aquifer valves. It is possible that the elevated sodium concentrations are the result of water softeners, which typically exchange sodium for calcium and magnesium to reduce hardness. It is possible that the samples were collected from wells with water softener units installed.

4.4 Surface Water and Sediments

4.4.1 Results

Surface water and sediment samples were collected from Ship Creek, the golf course beaver pond, and ponds and drainage ditches that capture OU 5 runoff. Figure 4-10 shows the surface water and sediment sampling locations. In accordance with the sampling schedule specified in the work plan (CH2M HILL 1992b), surface water and sediments were sampled in the spring and late summer in Ship Creek and the golf course beaver pond. The other ponds and drainage ditches were sampled once; locations SW/SE06, 07, 08, and 09 in the spring, and SW/SE10, 11, 12, and 13 in the late summer. Tables 4-14 through 4-18 present statistical summaries of organic and inorganic constituents in surface water and sediments.



	BENZENE	1,1-DICHLOROETHANE	BROMODICHLOROMETHANE	ETHYLBENZENE	[illegible]	4-METHYLPHENOL	NAPHTHALENE	TPH GAS	TPH DIESEL	TOLUENE	XYLENES (TOTAL)
SURFACE WATER (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	.77	[illegible]	[illegible]	0.8	NA	[illegible]	[illegible]
SEDIMENT (mg/kg)	NA	NA	NA	[illegible]	NA	NA	NA	[illegible]	[illegible]	NA	[illegible]

	1,1,1-TRICHLOROETHANE
SURFACE WATER (mg/l)	.019
SEDIMENT (mg/kg)	NA

	PHENOL	1,1,1-TRICHLOROETHANE
SURFACE WATER (mg/l)	NA	.019
SEDIMENT (mg/kg)	.072J	NA

	PHENOL	TPH DIESEL
SURFACE WATER (mg/l)	NA	NA
SEDIMENT (mg/kg)	.088J	4.0J

LEGEND

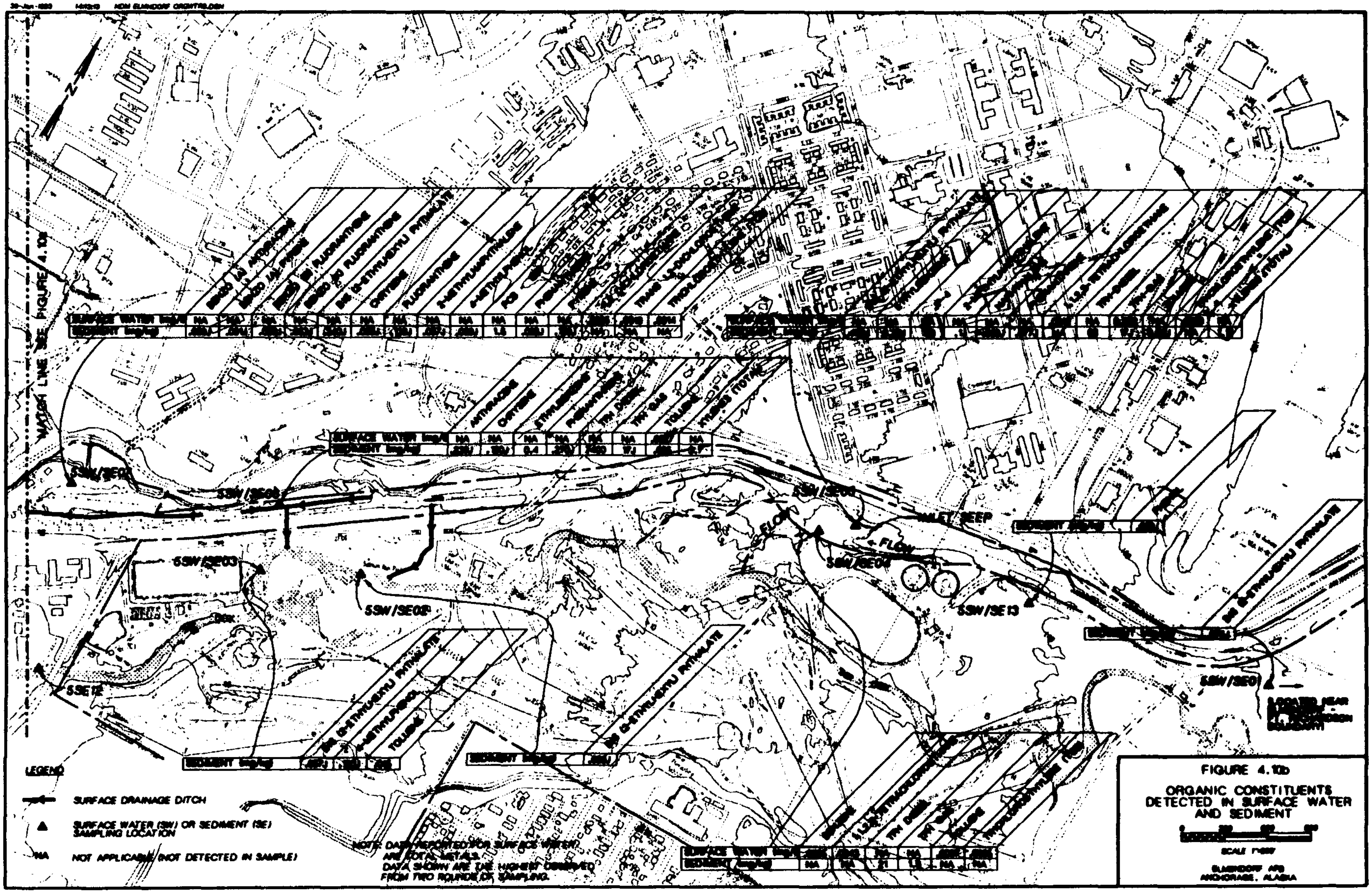
━◀━	SURFACE DRAINAGE DITCH
╍◀╍	BURIED DRAINAGE CULVERT
▲	SURFACE WATER (SW) OR SEDIMENT (SE) SAMPLING LOCATION
NA	NOT APPLICABLE (NOT DETECTED IN SAMPLE)

NOTE: DATA REPORTED FOR SURFACE WATER ARE TOTAL METALS.
DATA SHOWN ARE THE HIGHEST OBSERVED FROM TWO ROUNDS OF SAMPLING.

FIGURE 4.10a

ORGANIC CONSTITUENTS DETECTED IN SURFACE WATER AND SEDIMENT

ELMENDORF AFB
ANCHORAGE, ALASKA



NOTE: DATA REPORTED FOR SURFACE WATER ARE TOTAL METALS. DATA SHOWN ARE THE HIGHEST OBSERVED FROM TWO ROUNDS OF SAMPLING.

FIGURE 4.10b

ORGANIC CONSTITUENTS DETECTED IN SURFACE WATER AND SEDIMENT

ELMENDORF AFB
ANCHORAGE, ALASKA

Table 4-14

Summary of Analytical Results for Detected Organic Constituents in Surface Water

Study Subarea	Detected Compound	Range of Detected Values (μg/l)	Geometric Mean (μg/l)	Arithmetic Mean (μg/l)	No. of Detections/No. of Samples	Percent of Samples
Lower Bluff Ponds & Drainage	1,1,1-Trichloroethane	1.8 - 1.9	8.44×10^{-1}	1.04×10^{0}	2/5	40
	1,1-Dichloroethane	2.3 - NA	NA	NA	1/5	20
	1,2-Dichloroethane	2.6 - NA	NA	NA	1/5	20
	4-Methylphenol (p-cresol)	7 - NA	NA	NA	1/4	25
	Benzene	1.5 - NA	NA	NA	1/5	20
	Bromomethane	1.3 - NA	NA	NA	1/5	20
	Ethylbenzene	12 - NA	NA	NA	1/5	20
	JP-4	770 - NA	NA	NA	1/5	20
	Naphthalene	1 - NA	NA	NA	1/4	25
	TFH Gas	400 - NA	NA	NA	1/3	33
	Toluene	2.7 - 27	8.37×10^{-1}	6.05×10^{0}	2/5	40
	Trichloroethylene (TCE)	1.4 - NA	NA	NA	1/5	20
	Xylenes, total	19 - NA	NA	NA	1/5	20
	trans-1,2-Dichloroethene	1.9 - NA	NA	NA	1/3	33

Table 4-14

(Continued)

Study Subarea	Detected Compound	Range of Detected Values ($\mu g/l$)	Geometric Mean ($\mu g/l$)	Arithmetic Mean ($\mu g/l$)	No. of Detections/No. of Samples	Percent of Samples
Golf Course Beaver Pond	1,1,2,2-Tetrachloroethane	1.2 - 4.3	9.16×10^{-1}	1.40×10^{0}	2/5	40
	Benzene	0.6 - NA	NA	NA	1/5	20
	Toluene	0.7 - NA	NA	NA	1/4	25
	Trichloroethylene (TCE)	2.4 - 6.6	1.63×10^{0}	2.58×10^{0}	3/5	60

NA = Not Applicable due to only one reported value.

Table 4-15

Summary of Analytical Results for Dissolved Metals in Surface Water

Study Subarea	Detected Compound	Range of Detected Values (mg/l)	Geometric Mean (mg/l)	Arithmetic Mean (mg/l)	No. of Detections/ No. of Samples	Percent of Samples
Lower Bluff Ponds & Drainage	Arsenic, soluble	0.0014 - 0.0016	8.37×10^{-4}	1.04×10^{-3}	3/5	60
	Barium, soluble	0.0155 - 0.16	3.72×10^{-2}	5.48×10^{-2}	5/5	100
	Beryllium, soluble	0.00061 - 0.00062	4.75×10^{-4}	4.86×10^{-4}	2/5	40
	Cadmium, soluble	0.0014 - NA	NA	NA	1/5	20
	Calcium, soluble	79.2 - 91.1	8.34×10^{1}	8.35×10^{1}	5/5	100
	Iron, soluble	0.309 - 2.4	2.50×10^{-1}	5.43×10^{-1}	2/5	40
	Magnesium, soluble	10.7 - 25	1.68×10^{1}	1.77×10^{1}	5/5	100
	Manganese, soluble	0.0215 - 2.85	4.84×10^{-1}	1.25×10^{0}	5/5	100
	Nickel, soluble	0.0097 - NA	NA	NA	1/5	20
	Potassium, soluble	0.983 - 1.84	1.43×10^{0}	1.46×10^{0}	5/5	100
	Sodium, soluble	5.2 - 13.2	8.28×10^{0}	8.67×10^{0}	5/5	100
	Vanadium, Soluble	0.0015 - 0.0059	2.25×10^{-3}	2.73×10^{-3}	4/5	80
	Zinc, soluble	0.0031 - 0.0136	2.54×10^{-3}	4.44×10^{-3}	3/5	60
Golf Course Beaver Pond	Arsenic, soluble	0.0007 - 0.0008	4.74×10^{-4}	5.10×10^{-4}	2/5	40
	Barium, soluble	0.0157 - 0.053	2.37×10^{-2}	2.63×10^{-2}	5/5	100
	Beryllium, soluble	0.00061 - NA	NA	NA	1/5	20
	Cadmium, soluble	0.0017 - NA	NA	NA	1/5	20
	Calcium, soluble	57.2 - 68.6	6.28×10^{1}	6.29×10^{1}	5/5	100
	Copper, soluble	0.0047 - 0.0219	1.70×10^{-3}	5.63×10^{-3}	2/5	40
	Iron, soluble	0.245 - NA	NA	NA	1/5	20
	Lead, soluble	0.0007 - NA	NA	NA	1/5	20
	Magnesium, soluble	10.5 - 11.4	1.11×10^{1}	1.11×10^{1}	5/5	100
	Manganese, soluble	0.042 - 1.39	3.67×10^{-1}	6.10×10^{-1}	5/5	100
	Nickel, soluble	0.0111 - NA	NA	NA	1/5	20

Table 4-15

(Continued)

Study Location	Detected Compound	Range of Detected Values (mg/l)	Geometric Mean (mg/l)	Arithmetic Mean (mg/l)	No. of Detections/ No. of Samples	Percent of Samples
	Potassium, soluble	0.735 - 3.58	9.29×10^{-1}	1.26×10^{0}	3/5	60
	Sodium, soluble	3.75 - 7.39	4.66×10^{0}	4.81×10^{0}	5/5	100
	Thallium, soluble	0.0008 - NA	NA	NA	1/5	20
	Vanadium, soluble	0.0021 - 0.0027	1.49×10^{-3}	1.70×10^{-3}	3/5	60
	Zinc, soluble	0.0016 - 0.0589	1.02×10^{-2}	2.24×10^{-2}	4/5	80
Ship Creek	Aluminum, soluble	0.0618 - NA	NA	NA	1/7	14
	Antimony, soluble	0.015 - NA	NA	NA	1/7	14
	Arsenic, soluble	0.0009 - NA	NA	NA	1/7	14
	Barium, soluble	0.004 - 0.0721	8.25×10^{-3}	1.56×10^{-2}	7/7	100
	Beryllium, soluble	0.00061 - NA	NA	NA	1/7	14
	Calcium, soluble	12.6 - 95.7	2.25×10^{1}	2.94×10^{1}	7/7	100
	Copper, soluble	0.0017 - 0.0098	1.58×10^{-3}	2.99×10^{-3}	4/7	57
	Iron, soluble	0.014 - 0.161	1.96×10^{-2}	3.93×10^{-2}	5/7	71
	Lead, soluble	0.0017 - NA	NA	NA	1/7	14
	Magnesium, soluble	2.01 - 13.3	3.38×10^{0}	4.27×10^{0}	7/7	100
	Manganese, soluble	0.001 - 0.312	1.47×10^{-2}	6.01×10^{-2}	7/7	100
	Potassium, soluble	0.323 - 1.3	4.17×10^{-1}	4.93×10^{-1}	5/7	71
	Selenium, soluble	0.00054 - 0.00056	2.85×10^{-4}	3.14×10^{-4}	2/7	29
	Sodium, soluble	1.55 - 7.21	2.38×10^{0}	2.78×10^{0}	7/7	100
	Vanadium, soluble	0.0013 - 0.0026	1.18×10^{-3}	1.30×10^{-3}	2/7	29
	Zinc, soluble	0.0042 - 0.0133	3.09×10^{-3}	4.43×10^{-3}	2/7	29

NA = Not Applicable due to only one reported value.

Table 4-16

Summary of Analytical Results for Total Metals in Surface Water

Study Area	Detected Compound	Range of Detected Values (mg/l)	Geometric Mean (mg/l)	Arithmetic Mean (mg/l)	No. of Detections/ No. of Samples	Percent of Samples
Lower Bluff Ponds & Drainage	Aluminum	0.0256 - 1.19	7.52×10^{-2}	3.15×10^{-1}	3/5	60
	Arsenic	0.0007 - 0.0035	1.23×10^{-3}	1.73×10^{-3}	4/5	80
	Barium	0.017 - 0.2	5.36×10^{-2}	8.23×10^{-2}	5/5	100
	Beryllium	0.00061 - NA	NA	NA	1/5	20
	Cadmium	0.0014 - NA	NA	NA	1/5	20
	Calcium	83.1 - 92.3	8.67×10^{1}	8.68×10^{1}	5/5	100
	Copper	0.0015 - 0.0072	1.08×10^{-3}	2.05×10^{-3}	2/5	40
	Iron	0.0362 - 6.27	6.38×10^{-1}	2.13×10^{0}	5/5	100
	Lead	0.0026 - 0.0148	9.72×10^{-4}	3.65×10^{-3}	2/5	40
	Magnesium	10.9 - 25.8	1.73×10^{1}	1.83×10^{1}	5/5	100
	Manganese	0.0208 - 3.85	5.80×10^{-1}	1.73×10^{0}	5/5	100
	Nickel	0.0082 - NA	NA	NA	1/5	20
	Potassium	0.847 - 4.97	1.79×10^{0}	2.15×10^{0}	5/5	100
	Sodium	5.28 - 14.9	8.68×10^{0}	9.19×10^{0}	5/5	100
	Vanadium	0.0018 - NA	3.60×10^{-3}	4.48×10^{-3}	5/5	100
	Zinc	0.0039 - NA	NA	NA	3/5	60
Golf Course Beaver Pond	Aluminum	0.249 - NA	NA	NA	1/5	20
	Arsenic	0.0012 - 0.0014	5.91×10^{-4}	7.30×10^{-4}	2/5	40
	Barium	0.0169 - 0.045	2.42×10^{-2}	2.59×10^{-2}	5/5	100
	Calcium	56.7 - 69.6	6.32×10^{1}	6.34×10^{1}	5/5	100
	Copper	0.002 - NA	NA	NA	1/5	20
	Iron	0.0392 - 2.72	5.08×10^{-1}	1.06×10^{0}	5/5	100
	Lead	0.0047 - NA	NA	NA	1/5	20
	Magnesium	10.7 - 11.7	1.12×10^{1}	1.12×10^{1}	5/5	100
	Manganese	0.0127 - 1.5	3.36×10^{-1}	7.19×10^{-1}	5/5	100
	Potassium	0.727 - 3.37	8.36×10^{-1}	1.16×10^{0}	3/5	60

Table 4-16

(Continued)

Study Subarea	Detected Compound	Range of Detected Values (mg/l)	Geometric Mean (mg/l)	Arithmetic Mean (mg/l)	No. of Detections/ No. of Samples	Percent of Samples
	Sodium	3.86 - 5.82	4.32×10^{0}	4.37×10^{0}	5/5	100
	Vanadium	0.0014 - 0.0021	1.40×10^{-3}	1.48×10^{-3}	3/5	60
	Zinc	0.0045 - 0.0214	4.64×10^{-3}	7.48×10^{-3}	4/5	80
Ship Creek	**Aluminum**	0.315 - 0.569	1.04×10^{-1}	2.05×10^{-1}	3/7	43
	Arsenic	0.0007 - 0.0021	5.62×10^{-4}	7.25×10^{-4}	2/6	33
	Barium	0.0085 - 0.0678	1.36×10^{-2}	1.88×10^{-2}	7/7	100
	Beryllium	0.00061 - NA	NA	NA	1/7	14
	Calcium	12.9 - 95.7	2.49×10^{1}	3.14×10^{1}	7/7	100
	Copper	0.001 - 0.0025	8.72×10^{-4}	1.06×10^{-3}	4/7	57
	Iron	0.0489 - 0.863	2.17×10^{-1}	3.40×10^{-1}	7/7	100
	Lead	0.0007 - NA	NA	NA	1/7	14
	Magnesium	2.15 - 13.3	3.77×10^{0}	4.59×10^{0}	7/7	100
	Manganese	0.0034 - 0.254	4.39×10^{-2}	8.61×10^{-2}	7/7	100
	Potassium	0.323 - 1.44	3.82×10^{-1}	4.89×10^{-1}	4/7	57
	Sodium	1.53 - 7.14	2.41×10^{0}	2.77×10^{0}	7/7	100
	Vanadium	0.002 - 0.0028	1.47×10^{-3}	1.68×10^{-3}	3/7	43
	Zinc	0.0026 - NA	NA	NA	1/7	14

NA = Not Applicable due to only one reported value.

Table 4-17

Summary of Analytical Results for Detected Organic Constituents in Sediment

Study Subarea	Detected Compound	Range of Detected Values (ug/kg)	Geometric Mean (ug/kg)	Arithmetic Mean (ug/kg)	No. of Detections/ No. of Samples	Percent of Samples
Lower Bluff Ponds & Drainage	2-Methylnaphthalene	57 - NA	NA	NA	1/5	20
	4-Methylphenol (p-cresol)	89 - NA	NA	NA	1/5	20
	Anthracene	230 - NA	NA	NA	1/5	20
	Benzo(a)anthracene	59 - NA	NA	NA	1/5	20
	Benzo(a)pyrene	91 - NA	NA	NA	1/5	20
	Benzo(b)fluoranthene	58 - NA	NA	NA	1/5	20
	Benzo(k)fluoranthene	63 - NA	NA	NA	1/5	20
	Chrysene	85 - 120	2.93×10^{2}	1.09×10^{3}	2/5	40
	Ethylbenzene	400 - 930	2.49×10^{1}	2.68×10^{2}	2/5	40
	Fluoranthene	130 - NA	NA	NA	1/5	20
	PCB-1260 (Arochlor 1260)	1600 - NA	NA	NA	1/1	100
	Phenanthrene	92 - 270	3.50×10^{2}	1.12×10^{3}	2/5	40
	Pyrene	150 - NA	NA	NA	1/5	20
	TFH Diesel	1100000 - 7400000	3.20×10^{4}	1.70×10^{6}	2/5	40
	TFH Gas	110000 - 700000	3.95×10^{4}	2.70×10^{5}	2/3	67
	Toluene	26 - NA	NA	NA	1/5	20
	Xylenes, total	3700 - 6200	8.80×10^{1}	1.98×10^{3}	2/5	40
	bis(2-ethylhexyl) phthalate	240 - NA	NA	NA	1/5	20
Golf Course Beaver Pond	2-methylnaphthalene	100 - NA	NA	NA	1/5	20
	Ethylbenzene	260 - NA	NA	NA	1/5	20
	JP-4	100000 - NA	NA	NA	1/5	20
	Naphthalene	69 - NA	NA	NA	1/5	20
	Phenanthrene	77 - NA	NA	NA	1/5	20

Table 4-17

(Continued)

[illegible]	Detected Compound	Range of Detected Values (µg/kg)	Geometric Mean (µg/kg)	Arithmetic Mean (µg/kg)	No. of Detections/ No. of Samples	Percent of Samples
	TFH Diesel	21000 - 63000	1.13 x 10^4	2.55 x 10^4	3/5	60
	TFH Gas	1500 - 29000	5.21 x 10^3	1.03 x 10^4	2/4	50
	Toluene	520 - NA	NA	NA	1/5	20
	Xylenes, total	1100 - NA	NA	NA	1/5	20
	bis(2-ethylhexyl) phthalate	450 - NA	NA	NA	1/5	20
Ship Creek	4-methylphenol (p-cresol)	160 - NA	NA	NA	1/8	13
	TFH Diesel	1000 - NA	NA	NA	1/8	13
	Toluene	15 - NA	NA	NA	1/8	13
	bis(2-ethylhexyl) phthalate	57 - 76	1.10 x 10^2	1.31 x 10^2	4/8	50

NA = Not Applicable due to only one reported value.

Table 4-18

Summary of Analytical Results for Metals in Sediment

Study Subunit	Detected Compound	Range of Detected Values (mg/kg)	Geometric Mean (mg/kg)	Arithmetic Mean (mg/kg)	No. of Detections/ No. of Samples	Percent of Samples
Lower Bluff Ponds & Drainage	**Aluminum**	6910 - 18400	1.31×10^4	1.38×10^4	5/5	100
	Arsenic	4.2 - 23.1	6.55×10^0	8.46×10^0	5/5	100
	Barium	39.6 - 1250	1.47×10^2	3.41×10^2	5/5	100
	Beryllium	0.39 - 0.59	5.14×10^{-1}	5.20×10^{-1}	5/5	100
	Cadmium	0.78 - 1.9	1.43×10^0	1.50×10^0	5/5	100
	Calcium	5140 - 13700	7.22×10^3	7.72×10^3	5/5	100
	Chromium, total	7.7 - 31.6	2.02×10^1	2.24×10^1	5/5	100
	Cobalt	8.9 - 12.1	1.04×10^1	1.05×10^1	5/5	100
	Copper	21.1 - 30.6	2.45×10^1	2.47×10^1	5/5	100
	Iron	9190 - 54100	2.39×10^4	2.77×10^4	5/5	100
	Lead	4.9 - 39.5	1.21×10^1	1.67×10^1	5/5	100
	Magnesium	2140 - 8890	5.16×10^3	5.90×10^3	5/5	100
	Manganese	478 - 9580	1.17×10^3	2.49×10^3	5/5	100
	Mercury	0.06 - 0.1	4.74×10^{-2}	6.00×10^{-2}	3/5	60
	Nickel	19.8 - 36.6	2.71×10^1	2.80×10^1	5/5	100
	Potassium	367 - 676	4.98×10^2	5.14×10^2	5/5	100
	Silver	0.85 - 1.3	4.60×10^{-1}	5.90×10^{-1}	2/5	40
	Sodium	258 - 452	3.46×10^2	3.54×10^2	5/5	100
	Thallium	0.26 - NA	NA	NA	1/5	20
	Vanadium	47.9 - 62.3	5.48×10^1	5.50×10^1	5/5	100
	Zinc	36.8 - 100	6.23×10^1	6.58×10^1	5/5	100
Golf Course Beaver Pond	**Aluminum**	6930 - 14800	1.06×10^4	1.10×10^4	5/5	100
	Arsenic	4.3 - 38.1	7.78×10^0	1.18×10^1	5/5	100
	Barium	40.8 - 1180	1.60×10^2	3.61×10^2	5/5	100
	Beryllium	0.46 - 0.63	3.20×10^{-1}	3.94×10^{-1}	3/5	60
	Cadmium	1 - 1.7	1.45×10^0	1.48×10^0	5/5	100

Table 4-18

(Continued)

Study Subarea	Detected Compound	Range of Detected Values (mg/kg)	Geometric Mean (mg/kg)	Arithmetic Mean (mg/kg)	No. of Detections/No. of Samples	Percent of Samples
	Calcium	4730 - 12000	6.67×10^3	7.04×10^3	5/5	100
	Chromium, total	12.7 - 34	2.36×10^1	2.49×10^1	5/5	100
	Cobalt	9.8 - 23.7	1.23×10^1	1.31×10^1	5/5	100
	Copper	22.8 - 37.4	2.79×10^1	2.83×10^1	5/5	100
	Iron	8860 - 69300	2.59×10^4	3.17×10^4	5/5	100
	Lead	7.6 - 25.5	1.57×10^1	1.79×10^1	5/5	100
	Magnesium	2730 - 9070	6.18×10^3	6.72×10^3	5/5	100
	Manganese	197 - 37900	1.55×10^3	8.29×10^3	5/5	100
	Mercury	0.05 - 0.2	6.49×10^{-2}	8.10×10^{-2}	3/5	60
	Nickel	26.5 - 71.5	3.90×10^1	4.15×10^1	5/5	100
	Potassium	344 - 717	5.10×10^2	5.30×10^2	5/5	100
	Silver	0.64 - 5.6	9.80×10^{-1}	1.64×10^0	4/5	80
	Sodium	318 - 459	2.97×10^2	3.13×10^2	3/5	60
	Vanadium	38.4 - 57.5	4.77×10^1	4.84×10^1	5/5	100
	Zinc	35.6 - 108	6.29×10^1	6.69×10^1	5/5	100
Ship Creek	Aluminum	10900 - 18000	1.45×10^4	1.47×10^4	8/8	100
	Arsenic	4.7 - 8	5.94×10^0	6.03×10^0	8/8	100
	Barium	52.6 - 445	8.62×10^1	1.16×10^2	8/8	100
	Beryllium	0.38 - 0.73	4.19×10^{-1}	4.62×10^{-1}	6/8	75
	Cadmium	1.1 - 1.8	1.36×10^0	1.38×10^0	8/8	100
	Calcium	4320 - 9850	6.53×10^3	6.71×10^3	8/8	100
	Chromium, total	23.3 - 40	3.24×10^1	3.28×10^1	8/8	100
	Cobalt	8.7 - 13.8	1.11×10^1	1.12×10^1	8/8	100
	Copper	22 - 31.6	2.72×10^1	2.75×10^1	8/8	100
	Iron	22600 - 33100	2.71×10^4	2.73×10^4	8/8	100
	Lead	3.7 - 12.4	6.05×10^0	6.41×10^0	8/8	100
	Magnesium	5980 - 10100	8.15×10^3	8.24×10^3	8/8	100
	Manganese	433 - 14100	8.50×10^2	2.27×10^3	8/8	100

Table 4-18

(Continued)

Study Subarea	Detected Compound	Range of Detected Values (mg/kg)	Geometric Mean (mg/kg)	Arithmetic Mean (mg/kg)	No. of Detections/ No. of Samples	Percent of Samples
	Mercury	0.06 - 0.16	5.74×10^{-2}	6.88×10^{-2}	3/8	38
	Nickel	26.1 - 40.9	3.32×10^{1}	3.35×10^{1}	8/8	100
	Potassium	598 - 1080	7.14×10^{2}	7.54×10^{2}	7/8	88
	Selenium	0.11 - 0.31	1.30×10^{-1}	1.49×10^{-1}	3/8	38
	Silver	0.77 - 1.9	5.58×10^{-1}	6.94×10^{-1}	4/8	50
	Sodium	305 - 544	3.17×10^{2}	3.40×10^{2}	5/8	63
	Thallium	0.21 - 0.27	1.47×10^{-1}	1.59×10^{-1}	3/8	38
	Vanadium	43.6 - 70.5	5.33×10^{1}	5.40×10^{1}	8/8	100
	Zinc	49.9 - 140	7.32×10^{1}	7.69×10^{1}	8/8	100

NA = Not Applicable due to only one reported value.

As discussed in Section 2.1.6, a suitable background reference pond not potentially affected by an Elmendorf AFB OU could not be identified. Therefore, the following nature and extent discussions of potential contaminants in pond surface water and sediments cannot be elaborated on in terms of contaminants detected in comparison to background values of the analytes. Conversely, a background reference sample station was established for Ship Creek (SW/SB01), and comparisons of analytes detected downstream are made to the reference station (see discussion in Section 4.4.2.2). Although the Ship Creek reference sample station is upstream of OU 5 (Elmendorf AFB-Fort Richardson boundary), it is possible that chemical concentrations detected could be contributed from runoff from Fort Richardson, Glenn Highway, or some other upstream source.

Additionally, laboratory analyses provided both total and dissolved (soluble) concentrations data of the inorganic analytes detected. For the purpose of brevity, only the maximum dissolved concentrations of inorganic elements detected are discussed in the text. Total metal concentrations are summarized in Table 4-16.

The results of the nature and extent of contamination is organized to follow the upgradient-to-downgradient transition of potential contaminants through OU 5.

4.4.1.1 Beaver Pond (SW/SE13)

Surface water was sampled at this beaver pond to correlate the site specific chemical concentration data with observed stressed vegetation effects at seep SL29 (see Section 6.2.2).

No organic chemicals were detected in the surface water samples. Metals and other inorganics detected include barium (0.053 mg/L), beryllium (0.00061 mg/L), calcium (57.2 mg/L), copper (0.0219 mg/L), iron, lead (0.0007 mg/L), magnesium (11.3 mg/L), manganese (0.042 mg/L), nickel (0.0111 mg/L), potassium (3.58 mg/L), sodium (7.39 mg/L), vanadium (0.0027 mg/L), and zinc (0.0589 mg/L).

All TAL list chemicals were detected, with the exception of mercury, silver, and thallium.

4.4.1.2 Golf Course Beaver Pond (SW/SE04 and SE05)

This beaver pond is downgradient of source area SD40, (the oil seepage from the bluff area) and slightly west and downstream of source area ST46 (the JP-4 fuel line leak). Organics detected in the golf course beaver pond surface water include TFH gas (0.052 mg/L), 1,1,2,2-tetrachlorethane (0.0043 mg/L), benzene (0.0006 mg/L), toluene (0.0007 mg/L), and trichlorethene (0.0066 mg/L). Metals and other inorganics detected include aluminum, arsenic (0.0008 mg/L), barium (0.2035 mg/L), calcium (68.6 mg/L), copper (0.0047 mg/L), iron (0.245 mg/L), lead, magnesium (11.7 mg/L), manganese (1.39 mg/L), potassium (0.941 mg/L), sodium (4.63 mg/L), thallium (0.0008 mg/L), vanadium (0.0021 mg/L), and zinc (0.039 mg/L).

Organic chemicals detected in the sediments include 2-methylnaphthalene (0.1 mg/kg), bis(2-ethylhexyl phthalate (0.45 mg/kg), ethylbenzene (0.26 mg/kg), JP-4 (100 mg/kg), naphthalene (0.069 mg/kg), phenanthrene (0.077 mg/kg), TFH-diesel (21 to 63 mg/kg), TFH-gas (17 mg/kg), and total xylenes (1.1 mg/kg). All TAL metals were detected, with the exception of thallium.

4.4.1.3 Wetland Pond (SW/SE06)

This very shallow wetland pond (up to 6 inches deep) at the base of the lower bluff is located southeast of source areas ST38 (a JP-4 fuel line leak) and SS42 (a diesel fuel spill site). Toluene (0.0027 mg/L) is the only organic contaminant detected in the wetland pond surface water samples. Inorganic chemicals that were detected include: aluminum, arsenic (0.0014 mg/L), barium (0.050 mg/L), calcium (91.1 mg/L), iron (2.4 mg/L), magnesium (12.7 mg/L), manganese (2.85 mg/L), potassium (0.983 mg/L), sodium (5.2 mg/L), and vanadium (0.0023 mg/L).

The organic chemicals detected in sediments include anthracene (0.23 mg/kg), chrysene (0.12 mg/kg), ethylbenzene (0.4 mg/kg), phenanthrene (0.27 mg/kg), total fuel hydrocarbon (TFH) diesel (7,400 mg/kg), TFH gas (17 mg/kg), toluene (0.026 mg/kg), and total xylenes (3.7 mg/kg). All TAL list metals were detected in the sediment, with the exception of thallium.

4.4.1.4 Snowmelt Pond (SW/SE07)

This beaver pond, referred to as the snowmelt pond, is directly below the bluff where base snow disposal occurs. It is also slightly southwest of source area ST38, the JP-4 fuel line leak source.

Organic chemicals detected in the snowmelt pond surface water include: 1,2-dichloroethane (0.0026 mg/L), trans-1,2-dichloroethene (0.0019 mg/L), and TCE (0.0014 mg/L). Metals and other inorganic elements detected include arsenic (0.0015 mg/L), barium (0.16 mg/L), calcium (81.7 mg/L), magnesium (10.7 mg/L), manganese (1.63 mg/L), potassium (1.37 mg/L), sodium (13.2 mg/L), vanadium (0.0059 mg/L), and zinc (0.0031 mg/L).

PCBs (Arochlor-1260) were detected in this composite sediment sample at a concentration of 1.6 mg/kg. Other organics detected in the sediments include 2-methylnaphthalene (0.057 mg/kg), 4-methylphenol (0.089 mg/kg), benzo(a)pyrene 0.091 mg/kg, benzo(b)fluoranthene (0.058 mg/kg), benzo(k)fluoranthene (0.063 mg/kg), bis(2-ethylhexyl) phthalate (0.24 mg/kg), chrysene (0.085 mg/kg), fluoranthene (130 mg/kg), phenanthrene (0.092 mg/kg), and pyrene (0.15 mg/kg). All TAL list metals were detected, with the exception of silver.

4.4.1.5 Bluff Pond (SW/SE08)

This bluff pond (approximately halfway up the side of bluff) is located downgradient of source area ST37, the site of a diesel fuel line leak.

Organic chemicals detected in the bluff pond surface water consist of the following: 1,1-dichloroethane (0.0023 mg/L), 4-methylphenol (0.007 mg/L), benzene (0.0015 mg/L), bromomethane (0.0013 mg/L), ethylbenzene (0.012 mg/L), JP-4 (0.77 mg/kg), naphthalene (0.001 mg/L), TFH-gas (0.3 mg/L), toluene (0.027 mg/L), and total xylenes (0.019 mg/L). Inorganic chemicals detected include arsenic (0.0016 mg/L), barium (0.028 mg/L), calcium (79.2 mg/L), iron (0.309 mg/L), magnesium (17.8 mg/L), manganese (1.56 mg/L), potassium (1.62 mg/L), sodium (7.790 mg/L), and vanadium (0.0015 mg/L).

Organic chemicals detected in the sediments include ethylbenzene (0.93 mg/kg), TFH diesel (1100 mg/kg), TFH-gas (180 mg/kg), and total xylenes (6.2 mg/kg). Metals detected in the sediments are shown on Figure 4-11.

4.4.1.6 Drainage Ditch (SW/SE09)

This drainage ditch sample station is located to the southwest of source area ST37 at the western perimeter of OU 5.

1,1,1-Trichloroethane (0.0018 mg/L) is the only organic chemical detected in the drainage ditch surface water. Inorganic elements detected include barium (0.0155 mg/L), beryllium (0.00062 mg/L), cadmium (0.0014 mg/L), calcium (83.4 mg/L), magnesium (22.4 mg/L), manganese (0.170 mg/L), potassium (1.5 mg/L), sodium (7.63 mg/L), and zinc (0.0136 mg/L).

Organic chemicals detected in the sediments include phenol (0.072 mg/kg). All TAL list metals were detected, with the exception of mercury, silver, and thallium.

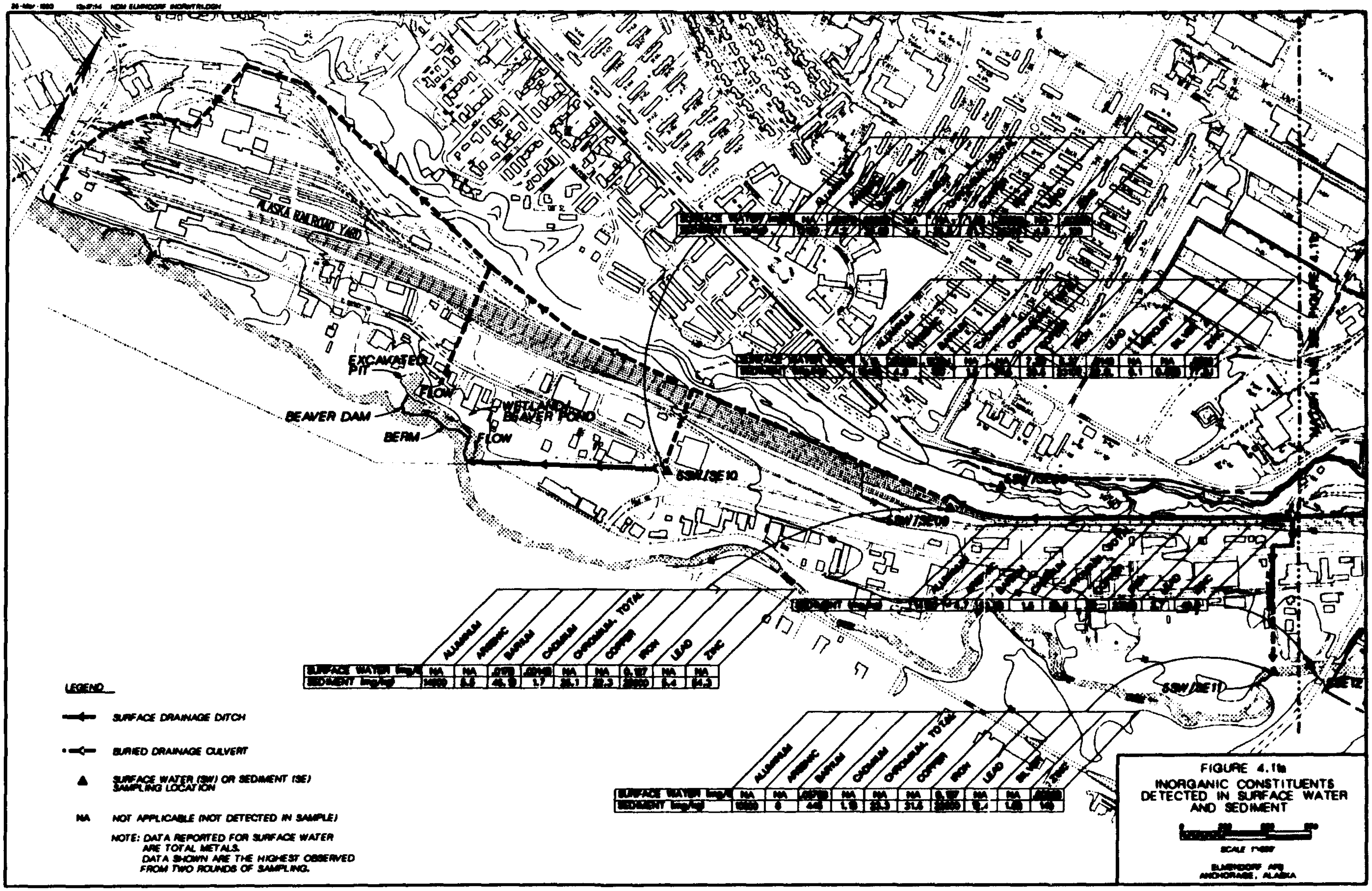


FIGURE 4.11a

INORGANIC CONSTITUENTS DETECTED IN SURFACE WATER AND SEDIMENT

ELMENDORF AFB
ANCHORAGE, ALASKA

FIGURE 4.1b

INORGANIC CONSTITUENTS DETECTED IN SURFACE WATER AND SEDIMENT

ELMENDORF AFB
ANCHORAGE, ALASKA

LEGEND

SURFACE DRAINAGE DITCH

▲ SURFACE WATER (SW) OR SEDIMENT (SE) SAMPLING LOCATION

NA NOT APPLICABLE (NOT DETECTED IN SAMPLE)

NOTE: DATA REPORTED FOR SURFACE WATER ARE TOTAL METALS.
DATA SHOWN ARE THE HIGHEST OBSERVED FROM TWO ROUNDS OF SAMPLING.

4.4.1.7 Drainage Ditch (SW/SE10)

This drainage ditch sampling station (junction of Post Road and Whitney Road) is outside the defined boundary of OU 5, but does receive all the drainage from the stormwater interceptor at sample station SW09, runoff from the Elmendorf AFB bluff outside of OU 5, and possibly drainage or infiltration from the ARRC property between the base of the bluff and its discharge point at Post and Whitney roads.

The only organic chemical detected in the drainage ditch surface water was 1,1,1-trichloroethane (0.0019 mg/L). Inorganic chemicals detected include barium (0.0202 mg/L), beryllium (0.00061 mg/L), calcium (82.2 mg/L), magnesium (25.0 mg/L), manganese (0.0215 mg/L), nickel (0.0097 mg/L), potassium (1.84 mg/L), sodium (9.53 mg/L), vanadium (0.003 mg/L), and zinc (0.0039 mg/L).

All TAL list metals were detected, with the exception of mercury, silver, thallium, and zinc.

4.4.1.8 Ship Creek (SW/SE01, SW/SE02, SW/SE03, SW/SE11, and SE12)

No organic contaminants were detected in Ship Creek surface water. Metals and other inorganics detected include aluminum (0.0618 mg/L), antimony (0.015 mg/L), arsenic (0.0009 mg/L), barium (0.072 mg/L), beryllium (0.0061 mg/L), calcium (95.7 mg/L), copper (0.0098 mg/L), iron (0.161 mg/L), lead (0.0017 mg/L), magnesium (13.3 mg/L), manganese (0.312 mg/L), potassium (1.3 mg/L), selenium (0.00056 mg/L), sodium (7.21 mg/L), vanadium (0.0026 mg/L), and zinc (0.0133 mg/L).

Organic chemicals detected in the Ship Creek sediments include 4-methylphenol (0.16 mg/kg) at SE03, bis(2-ethylhexyl)phthalate (0.076 mg/kg) at SE01, SE02 (0.066 mg/kg), and SE03 (0.057 mg/kg), a diesel-range organic at SE11 (4 mg/kg), phenol

(0.059 mg/kg) at SE11, and toluene (0.015 mg/kg) at SE03. All inorganic chemicals listed on Table 4-18 were detected in the sediments.

4.4.2 Discussion

The following discussion relates the occurrence of potential contaminants at each of the sample sites, with the probable or suspected OU 5 source areas. Background surface water and sediment chemical data are available for comparison of Ship Creek contaminant concentrations, using data from the reference location at the Elmendorf-Fort Richardson boundary, and as previously discussed, background sediment data for ponds and drainage ditches are not available because a suitable reference station was not available. All the TAL metals were detected in the sediments at each of the sample sites, except for mercury in the drainage ditches (SE09 and SE10); thallium, found only in the snowmelt pond sediment (SE07); and zinc, absent in drainage ditch sample SE10.

Based on the absence of pond sediment background data, and because no reliable approaches currently exist for predicting surface water concentrations of inorganic compounds from sediment information, further discussion of sediment inorganics in the ponds and drainage ditches is deferred to Section 6, Baseline Risk Assessment.

4.4.2.1 Ponds and Drainage Ditches

Beaver Pond (SW/SE13)

This beaver pond, near the eastern perimeter of OU 5, appears to be outside the pathway for the migration of fuels and other organic compounds, because none were detected. The concentrations of inorganic elements are consistent with those found in the other ponds, with the exception of elevated surface-water concentrations of copper, potassium, and zinc.

Golf Course Beaver Pond (SW/SE04 and SW/SE05)

Volatiles detected in the surface water (1,1,2,2-tetrachloroethane, TCE, and toluene), and volatiles, semivolatiles, PAHs, and fuel hydrocarbons detected in the sediments—namely bis(2-ethylhexyl)phthalate, ethylbenzene, JP-4, TFH-diesel, TFH-gas, toluene, xylene, naphthalene, and phenanthrene—appear to be consistent with petroleum contamination that would be expected downgradient from sources SD40 and ST46.

Solvents detected in the surface water include 1,1,2,2-tetrachloroethane and TCE. No solvents were detected in the sediments. The origin of the solvents appears to be from upgradient sources based on sample results from upgradient wells.

The concentration of metals and other inorganics in the surface water is consistent with concentrations found in other pond surface waters, except for the unique occurrence of thallium.

Wetland Pond (SW/SE06)

This pond is located downgradient of two OU 5 source areas (ST38 and SS42. The volatiles, PAHs, and fuel hydrocarbons detected in the pond surface water (toluene), and those in the sediments, such as, anthracene, chrysene, ethylbenzene, phenanthrene, TFH diesel, TFH-gas, toluene, and xylene, appear to be from those source areas.

Snowmelt Pond (SW/SE07)

Volatiles were detected in the surface water only, and include trans-1,2-dichlorethene and TCE. This is the only sample station where trans-1,2-dichloroethene was detected (Figure 4-10). The following organic elements were detected in the sediment samples: PCB (Aroclor 1260), 2-methylnaphthalene, 4-methylphenol, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, bis(2-ethylhexyl)-phthalate, chrysene, fluoranthene, phenanthrene, and pyrene. This pond receives snowmelt runoff from the crest of the OU 5 bluff, and is southwest of source areas ST38 (JP-4 fuel line leak) and SS42 (diesel fuel spill). Snow plowed from Elmendorf AFB roads and/or aircraft taxiways may have contributed to the occurrence of volatiles, semivolatiles, and PAHs, as well as the migration of these elements from the ST38/SD40 sources.

PCBs (Aroclor 1260) were detected in the sediments, and may have entered drains or have been landfilled on Elmendorf AFB upgradient of OU 5 (CH2M HILL, 1992a). The origin of the PCBs is unclear.

Bluff Pond (SW/SE08)

Volatiles, semivolatiles, PAHs, and fuel hydrocarbons detected in the surface water include 4-methylphenol, benzene, bromomethane, 1,1-dichloroethane ethylbenzene, JP-4, naphthalene, TFH-gas, toluene, and total xylenes. Organic compounds detected in the sediments include ethylbenzene, TFH diesel, TFH-gas, and total xylenes.

This pond is downgradient of Source ST37 (diesel fuel line leak), and based on the occurrence of brush, grass clippings, and trash observed during sampling activities, appears to have been used as a small disposal area. The fuel line leak and/or past waste disposal practices appear to be the likely source(s) of contamination found in this bluff pond.

Drainage Ditch (SW/SE09)

The sample station at this drainage ditch is southwest of source area ST37 (diesel fuel line leak), and is next to the ARRC railroad tracks. These two areas appear to be the likely sources of the organic compounds detected. No volatiles or fuel hydrocarbons were detected in the surface water. Phenol was detected in the sediments. 1,1,1-Trichloroethane is the only organic element detected in the surface water, and no other organics were detected in the sediments.

Drainage Ditch (SW/SE10)

This sampling location is the outfall of the buried culvert that receives flow from the drainage ditch at location SW/SE09. The only organic compound detected in the surface water was 1,1,1-trichloroethane. No organic chemicals were detected in the sediments. The source of the 1,1,1-trichloroethane is unclear but could be drainage from the Elmendorf AFB bluff west of OU 5, non-point source runoff from the railroad tracks to the drainage ditch, or some other infiltration on the ARRC property.

4.4.2.2 Ship Creek

Surface Water

Five discharge points of surface water runoff from the OU 5 bluff, ponds, and drainage ditches to Ship Creek were identified during the 1992 field investigations. Two from the golf course beaver pond drainage, one from drainage of a stormwater culvert/wetland east of sample station SW06 (across from golf course clubhouse) and immediately upstream of Ship Creek Sample Station SW02, one from a culvert draining the SW06 wetland pond and just upstream of Ship Creek Sample Station SW03, and one discharge culvert at Yakutat Street (SW11) that drains a portion of the lower bluff to the creek.

No organic compounds were detected in the Ship Creek surface water samples. Analyses of inorganics conducted on Ship Creek surface water samples indicate that at Sample Station SW02, the following inorganic elements exceeded concentrations found at the background sample station (SW01): aluminum, barium, copper, iron, lead, magnesium, manganese, potassium, sodium, vanadium, and zinc. However, the inorganic elements in surface water at SW02 are less than those measured upgradient (lower bluff) at Sample Station SW06, with the exception of aluminum, copper, iron, lead, vanadium, and zinc. Because Ship Creek sampling occurred within the mixing zone of bluff runoff, it appears that, in some instances, bluff drainage may contribute to elevated localized inorganic concentrations in Ship Creek.

At Sample Station SW03, approximately 300 feet downstream of SW02, the following inorganic elements in surface water also exceeded background concentrations: barium, calcium, copper, iron, lead, magnesium, manganese, potassium, and sodium. Similar to Sample Station SW02, inorganic concentrations at SW03 are observed to be less than concentrations that were measured at the upgradient station SW06, except for copper and lead. Again, since sampling was conducted within the mixing zone of bluff runoff to Ship Creek, it appears that the bluff drainage may elevate some localized inorganic concentrations within Ship Creek.

At Sample Station SW11, the concentrations of inorganic elements detected in surface water exceeded Ship Creek background reference values for the following potential contaminants: antimony, barium, beryllium, calcium, magnesium, manganese, potassium, sodium, and zinc. However, the concentrations measured are less than those detected at upgradient Sample Station SW07 on the lower bluff, except for calcium and magnesium.

Sediments

The Ship Creek sediment sampling program detected both organic and inorganic chemicals in the sediments that exceed background values obtained from reference site SE01. In one instance, a background semivolatile was detected at a higher concentration than within the OU 5 study area. At Sample Stations SE02 and SE03, bis(2-ethylhexyl) phthalate was detected at 66 mg/kg and 57 mg/kg, respectively, while it was detected at the reference station at 76 mg/kg. Other organics detected in the sediments include: 4-methylphenol (160 μg/kg) and toluene (0.015 mg/kg) at SE03, phenol (59 μg/kg) at SE11, and an unknown hydrocarbon (4.0 mg/kg) at SE11.

4.5 Aquatic Biota

4.5.1 Results

4.5.1.1 Aquatic Macroinvertebrates

Golf Course Beaver Pond (MI04 and MI05)

The structure of the macroinvertebrate community within the golf course beaver pond was composed of organisms that are considered tolerant (family Chironomidae and class Oligochaeta). Very few intolerant species such as Ephemeroptera (Mayflies) were present. The chironomid taxa that were dominant (*Procladius* sp., *Psectrotanypus* sp. and *Tanytarsus* sp.) were associated with the upper detrital layer (leaf packs, twigs, fine detritus). This is particularly true in the case of *Tanytarsus* sp., which maintained fairly consistent numerical abundance at both locations during both sample periods. Aquatic worms (class Oligochaeta) on the other hand, associate closely with the bottom sediments, even burrowing into them. The worms were noticeably absent from Station MI05 benthos. Surface water results do not indicate unusual conditions that could be related to Station MI05 biological anomalies.

Wetland Pond (MI06)

Benthic invertebrates associated with the wetland pond MI06 were consisted of members from the family Chironomidae and class Oligochaeta. These two groups, as mentioned previously, generally represent tolerant organisms. No intolerant organisms were present. The dominant organisms (*Phaenopsectra* sp., *Limbriculidae*, and *Limnodrilus* sp.) are indicative of the habitat structure, soft silty bottom with associated detrital material (leaf packs, twigs). Although these organisms represent tolerant organisms, their diversity was good.

Snowmelt Pond (MI07)

Macroinvertebrates associated with this pond were collected qualitative from the surface substrate material. Cladocerans (water fleas), culicids (mosquitoes), and chironomids (midges) were the dominant organisms. Although aluminum and iron were present in the surface waters above AWQC, the presence of cladocerans suggests that the surface water was probably not acutely toxic. Some hydrocarbons were present in the sediments, and may have restricted the benthic organism structure as represented by the Chironomidae.

Bluff Pond (MI08)

Benthos from the bluff pond were also obtained qualitative from near surface sediments. Cladocerans and culicid (pupa) were the only invertebrates noted. These organisms were associated with the water column. High levels of inorganic and organic elements did not appear to restrict the presence of at least some aquatic life. No organisms were noted in the bottom debris and sediment.

Ship Creek

The benthic community of Ship Creek represented a diverse group of organisms from the order Diptera (flies, mosquitoes and midges), family Chironomidae; the class Oligochaeta (aquatic worms), families Lumbriculidae and Niadidae; the order Ephemeroptera, family Ephemerellidae and Heptageniidae; and order Trichoptera, family Glossosomatidae. Community structure and function exhibited little change between the reference location and that of downstream sites (stations MI02 and MI03) in the May collection. There was a change in structure and function between the May and September collections, but this could be attributed to normal life cycle changes in invertebrate populations. Comparison of community structure and function between locations in the September collections indicated some differences between the reference location and downstream sites. Sensitive species, especially in the order Ephemeroptera (*Drunella doddsi* in particular), decreased downstream. In contrast, the abundance of tolerant species, Chironomidae and Oligochaeta, increased downstream, especially at Stations MI03 and MI11. Analytical data are discussed in Section 4.4. Other than the naturally high iron concentration, there was little to suggest a potential effect on the macrobenthos from OU 5 constituents.

4.5.2 Discussion

4.5.2.1 Golf Course Beaver Pond (MI04 and MI05)

Elevated levels of fuel hydrocarbons appear to restrict the community structure at MI05. This was particularly true of organisms associated with the sediments (oligochaetes). Organisms associated with the surface detritus (leaf packs, detritus) and near bottom water column appeared less affected. The site nearest the beaver dam (MI04) displayed less stress when compared to MI05. Although no reference pond was available, it appears that site MI04 was in better condition ecologically than MI05.

4.5.2.2 Wetland Pond (MI06)

Macroinvertebrate community structure and function was considered restrictive, with an abundance of tolerant taxa. Presence of fuel hydrocarbons and other organic chemicals (phenanthrene, diesel, gas, toluene, and xylenes) suggests potential sources of agents that could influence the biological integrity of this pond.

4.5.2.3 Snowmelt Pond (MI07)

Presence of cladocerans in this pond suggests adequate water quality conditions. These organisms are used in toxicity bioassays and their presence suggests no acute toxicity. This may not be the case with regard to the sediments. Only members of the

Chironomidae were present, again suggesting a restricted community structure. More extensive sampling would be necessary to substantiate this.

4.5.2.4 Bluff Pond (MI08)

The bluff pond also contained cladocerans in the water column, again suggesting that the water column environment was adequate for their survival. Nothing was noted in the near surface sediments, suggesting potential restrictions due to metals and organic elements.

4.5.2.5 Ship Creek

The community structure and function did change between locations in the September sampling. The changes that did occur are more indicative of eutrophication processes than restriction of the benthos structure due to toxic components.

4.5.2.6 Iron Bacteria

An orange/rust colored precipitate was observed within shallow low-flow pond and seep environments during sampling of surface water within OU 5. It appeared predominantly near seep interfaces as an algal substance at Sample Stations SW05 (golf course beaver pond near seep SL23) and SW06 (wetland pond near seep SL16), compared to other sample stations. Although the precipitate was not analyzed, it appeared to be iron bacteria.

Since at neutral pH and in the presence of oxygen ferrous iron is spontaneously oxidized (Wetzel 1975), the iron-oxidizing bacteria are restricted to steep redox gradients in which they are competing effectively with oxygen for the reduced iron. Therefore, the iron bacteria usually are restricted to the interface regions of iron-bearing rock (soil) seeps, swamps, and bogs where the redox potential is sufficiently low for reduced iron to occur. Background soil boring analyses indicate a maximum iron concentration of 32,700 mg/kg detected in surface soils, and 54,100 and 27,800 mg/kg detected in sediment samples from SE06 and SE05, respectively. These relatively high iron concentrations appear to be consistent with the criteria necessary for iron bacteria development.

Based on the similarity of the aforementioned physical characteristics at the OU 5 locations where sampling occurred, and observations of Wetzel (1975), it appears that the conditions observed within OU 5 support iron bacteria development. Although unsightly, the iron bacteria did not appear to cause an adverse impact to shoreline or wetland vegetation where it was predominant.

4.5.2.7 Toxicity Tests

Acute and chronic toxicity tests were conducted on surface water and sediment samples collected during the 1992 sampling. Table 4-19 summarizes the acute toxicity test results.

Acute tests were conducted on selected samples collected during the spring sampling event to screen creek, pond, and drainage ditch surface water and sediment samples for conditions that may be adverse to the survival of aquatic life.

The bioassay test organisms were *Ceriodaphnia dubia*, fathead minnows, *Chironomus tentans*, and *Hyalella azteca*.

The test results indicate the following:

- The surface water samples were not acutely toxic to *Ceriodaphnia dubia* or fathead minnows.
- The sediment samples were not acutely toxic to *Hyalella azteca*.

Table 4-19

Results of Acute Toxicity Testing of Surface Water and Sediments

Surface Water Acute Bioassays		
Field Sample No.	Mean Percent Survival	
	Ceriodaphnia dubia	*Fathead Minnow*
Laboratory Control	100	95
SW02	100	90
SW03	100	90
SW04	100	80
SW05	100	95
SW09	90	100
Sediment Acute Bioassays		
Field Sample No.	***Chironomus tentans***	***Hyalella azteca***
Laboratory Control	100	100
SE02	90	100
SE03	95	100
SE04	55[a]	100
SE05	95	100
SE09	95	100

[a] Indicates significant ($p < 0.05$) difference (reduction) from laboratory control data.

- The sediment samples were not acutely toxic to *Chironomus tentans* except for sample SE04.

- Laboratory control water and sediment were acceptable for all bioassays.

Chronic toxicity tests were conducted with surface water and sediment samples collected from both golf course beaver pond sample stations. The chronic tests were conducted because results of the acute toxicity test indicated that sediments from the southwest end of the beaver pond are acutely toxic to *Chironomus*, a normally pollution-tolerant burrower, and because fuel odors and sheens were very apparent during sampling at the northeast end of the pond. Table 4-20 summarizes the results of the chronic toxicity tests.

The results of these tests show that:

- The surface water samples were not chronically toxic to *Ceriodaphnia dubia* or fathead minnows.

- Laboratory control data for the *Ceriodaphnia* and fathead minnow tests were acceptable.

- The sediment samples were not chronically toxic to *Chironomus tentans*.

- Sediment sample SE04 was not chronically toxic to *Hyalella azteca* based on significant difference testing. *Hyalella* growth was approximately 41% of the laboratory control weight, indicating that the statistical analyses may be inappropriate for toxicity interpretation.

- Sediment sample SE05 was chronically toxic to *Hyalella azteca*. This sample caused a reduction in *Hyalella* survival, also indicating acute toxicity.

- The recovery of live or dead test organisms was greater in the *Chironomus* bioassay than in the *Hyalella* test. Missing organisms were not included in the data analysis (non-recovered organisms were not counted as fatalities.)

- Laboratory control data were acceptable for both bioassays.

Table 4-20

Results of Chronic Toxicity Testing of Surface Water and Sediments

Surface Water Chronic Bioassays

Field Sample No.	*Ceriodaphnia dubia*		*Fathead Minnow*	
	Mean % Survival	Mean No. of Offspring	Mean % Survival	Mean Growth (mg)
Laboratory Control	90	26.7	92.3	0.664
SW04	100	24.7	97.5	0.688
SW05	100	28.4	95	0.833

Sediment Chronic Bioassays

Field Sample No.	*Chironomus tentans*		*Hyalella azteca*	
	Mean % Survival	Mean growth (mg)	Mean % Survival	Mean Growth (mg)
Laboratory Control	100	0.420	83.1	0.098
SE04	100	0.377	92.5	0.040
SE05	100	0.382	46.9[a]	0.054

[a] Indicates significant ($p < 0.05$) difference (reduction) from laboratory control data.

Additionally, benthic macroinvertebrate sample analyses indicate a decrease in tolerant taxa associated with bottom sediments at Sample Station MI05 in the golf course beaver pond, indicative of severe impact (see Section 3.6.1.4). The results of the toxicity tests will be discussed further in the risk assessment (see Section 6.2.1).

4.6 Terrestrial Plants and Animals

4.6.1 Results

Analytical results for soil and plants are presented in Appendix K. Summary data are presented in Tables 4-21, 4-22, and 4-23, and statistical comparisons are in Appendix O.

4.6.1.1 Plants

Several species of plants in widely scattered areas of OU 5 exhibited signs of stress at the time of the June 1992 survey (Figure 4-12). The signs of stress included interveinal chlorosis, which suggests that some stressor found in the soils in various areas has altered the photosynthetic rates of affected plants. The stress could have been caused either directly by effects on the plants or indirectly by effects on soil microorganisms. Affected species included several annuals and perennials at various locations. Horsetail, grasses, fireweed, cow parsnip, red currant, willow, alder, brook veronica, and tall Jacob's ladder (*Polemonium acutiflorum*) were among those affected.

In general, the plants had yellowish leaves but most were still alive. However, in several areas the horsetail was turning brown and dying. This coloration and death are not typical for plants of these various species during early summer.[1]

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[1] This information was obtained from Allen Richmond, natural resource planner at Elmendorf AFB, on June 29, 1992.

Table 4-21

Summary of Inorganic Elements (mg/kg, dry weight) in Soils and Plants from Areas Where Plant Stress Was Observed[a]

Chemical	Soil		Plants	
	Affected[b]	Nonaffected[c]	Affected[b]	Nonaffected[c]
Aluminum	12546 (4380-17600)	13864 (8670-19700)	NA[d]	NA[d]
Antimony	2.3 (1.4-7.3)	2.1 (1.4-4.5)	ND[d]	ND[d]
Arsenic	7.1 (4.0-28)	6.0 (2.7-15)	NA[d]	NA[d]
Barium	149 (51-3650)	137 (37-1240)	NA[d]	NA[d]
Beryllium	0.5 (0.25-1.1)	0.4 (0.16-1.3)	NA[d]	NA[d]
Boron	9.2 (4.6-37)	7.8 (3.4-24)	18 (4.8-65)	16 (3.7-45)
Cadmium	1.3 (0.32-3.1)	1.1 (0.38-1.7)	NC[d]	NC[d]
Calcium	8195 (5330-35300)	8412 (4420-20400)	13399 (5880-26800)	11311 (4080-28100)
Chromium	28 (12-53)	28 (12-64)	0.75 (0.20-1.6)	0.71 (0.20-1.2)
Cobalt	8.9 (3.6-14)	8.1 (3.3-13)	0.41 (0.15-6.9)	0.34 (0.15-2.2)
Copper	24 (14-37)	25 (14-38)	5.8 (3.2-9.8)	5.7 (2.6-11)
Iron	24522 (8440-37800)	20983 (6550-34600)	407 (177-1370)	351 (131-1350)
Lead	18 (4.5-87)	13 (4.7-35)	3.6 (1.7-48)	2.8 (1.7-20)
Magnesium	5816 (1660-9210)	6371 (2250-9810)	2935 (1160-6570)	2298 (1060-6570)
Manganese	1351 (457-7860)[e]	652 (307-10700)[f]	164 (43-484)	125 (50-321)
Mercury	0.06 (0.03-0.1)	0.06 (0.02-0.31)	NA[d]	NA[d]
Molybdenum	1.1 (0.43-25)	0.92 (0.42-3.1)	0.82 (0.20-2.1)	0.77 (0.20-3.9)
Nickel	31 (19-49)	28 (12-55)	2.4 (0.85-5.9)	2.1 (0.85-6.5)
Potassium	641 (361-908)	572 (306-854)	13379 (7070-26600)	11733 (4980-24200)
Selenium	0.15 (0.055-1.1)	0.23 (0.055-3.1)	ND[d]	ND[d]
Silicon	746 (346-2910)	718 (312-1840)	NA[d]	NA[d]
Silver	0.92 (0.25-22)	0.62 (0.29-2.0)	NA[d]	NA[d]

Table 4-21

(Continued)

Chemical	Soil		Plants	
	Affected[b]	Nonaffected[c]	Affected[b]	Nonaffected[c]
Sodium	471 (251-1430)	435 (226-933)	446 (222-943)	419 (190-1750)
Thallium	0.21 (0.080-0.59)	0.20 (0.080-0.59)	NA[d]	NA[d]
Vanadium	49 (21-81)	52 (34-72)	NA[d]	NA[d]
Zinc	60 (35-159)	57 (30-99)	21 (8.4-51)	25 (11-96)

[a] Geometric means and (range of values).

[b] Collected at identified surface locations where plant stress was observed (see also Section 2.1.8.1).

[c] Collected nearby where plants appeared to be normal.

[d] NA = Not analyzed; ND = Not detected (less than 3.2 mg/kg); NC = not calculated (11 of 12 samples below detection limit).

[e] Significant difference ($p < 0.05$) between affected and nonaffected soils; no other significant differences.

Table 4-22

Maximum Measured Concentrations and Location of Fuel Hydrocarbons in Soils from Areas Where Plant Stress Was Observed

Chemical	Sample Type[a]	
	Affected	Nonaffected
Benzene µg/kg	ND[b]	14.9; SL25
Toluene µg/kg	ND	63.9; SL16
Ethylbenzene µg/kg	393; SL04	ND
Xylenes µg/kg	8360; SL04	1980; SL16
Gasoline mg/kg	670; SL04	271; SL16
Diesel mg/kg	151; SL04	720; SL16
Jet Fuel mg/kg	ND; SL04	ND; SL16

[a] Soils collected where plant stress was observed and nearby reference locations where plants appeared to be normal.

[b] ND = Not detected (less than 0.005 mg/kg).

Table 4-23

Comparison of Soil Chemistry for Samples from Areas Where Plant Stress Was Observed[a]

Analysis (units)	Affected	Nonaffected
pH	6.9 (6.2-7.4)	6.5 (5.6-7.7)
Electrical Conductivity (mmhos/cm)	0.54 (0.24-1.6)	0.53 (0.23-1.9)
Phosphorus (mg/kg)	26 (6.8-60)	19 (4.1-56)
Total Kjeldahl Nitrogen (mg/kg)	1560 (168-4410)	1632 (207-8550)
NH_3 (mg/kg)	12 (1.8-68)	13 (1.9-83)
Water-Soluble Cations (meq/100g)		
Calcium	0.22 (0.04-1.4)	0.26 (0.06-1.9)
Magnesium	0.055 (0.010-0.32)	0.062 (0.020-0.33)
Potassium	0.015 (0.010-0.12)	0.014 (0.010-0.090)
Sodium	0.040 (0.010-0.28)	0.037 (0.010-0.15)
Cation Exchange Capacity (meq/100g)	13 (4.8-57)	16 (3.2-67)
Acid-Extractable Cations (meq/100g)		
Calcium	9.0 (2.6-49)	11 (2.5-39)
Magnesium	0.75 (0.19-3.0)	0.86 (0.12-4.1)
Potassium	0.14 (0.040-0.75)	0.10 (0.03-0.20)
Sodium	0.37 (0.18-17)	0.21 (0.14-0.34)

[a] Geometric mean and (range of values) for soils collected where plant stress was observed and nearby reference locations where plants appeared to be normal.

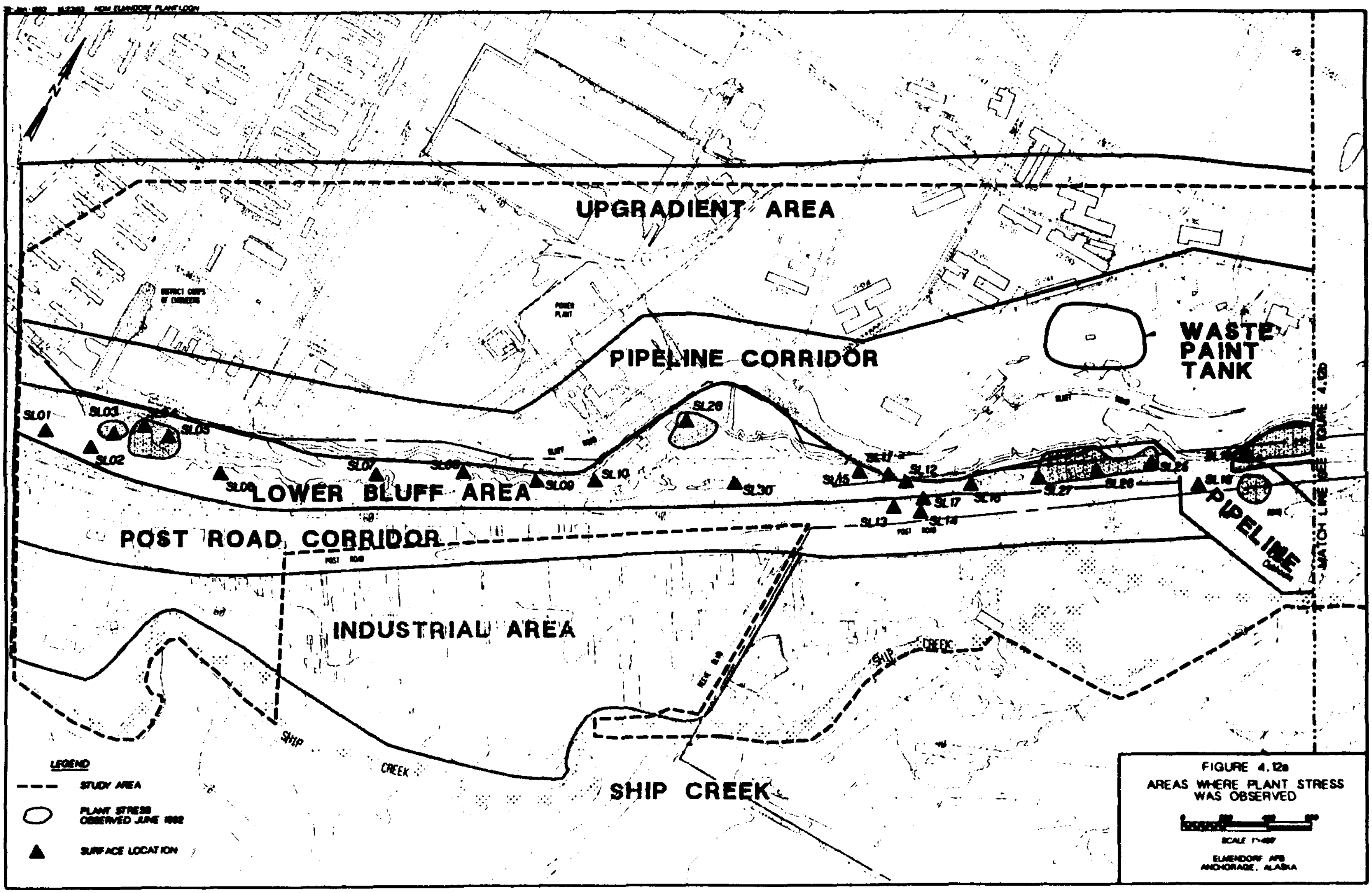

FIGURE 4.12a
AREAS WHERE PLANT STRESS WAS OBSERVED

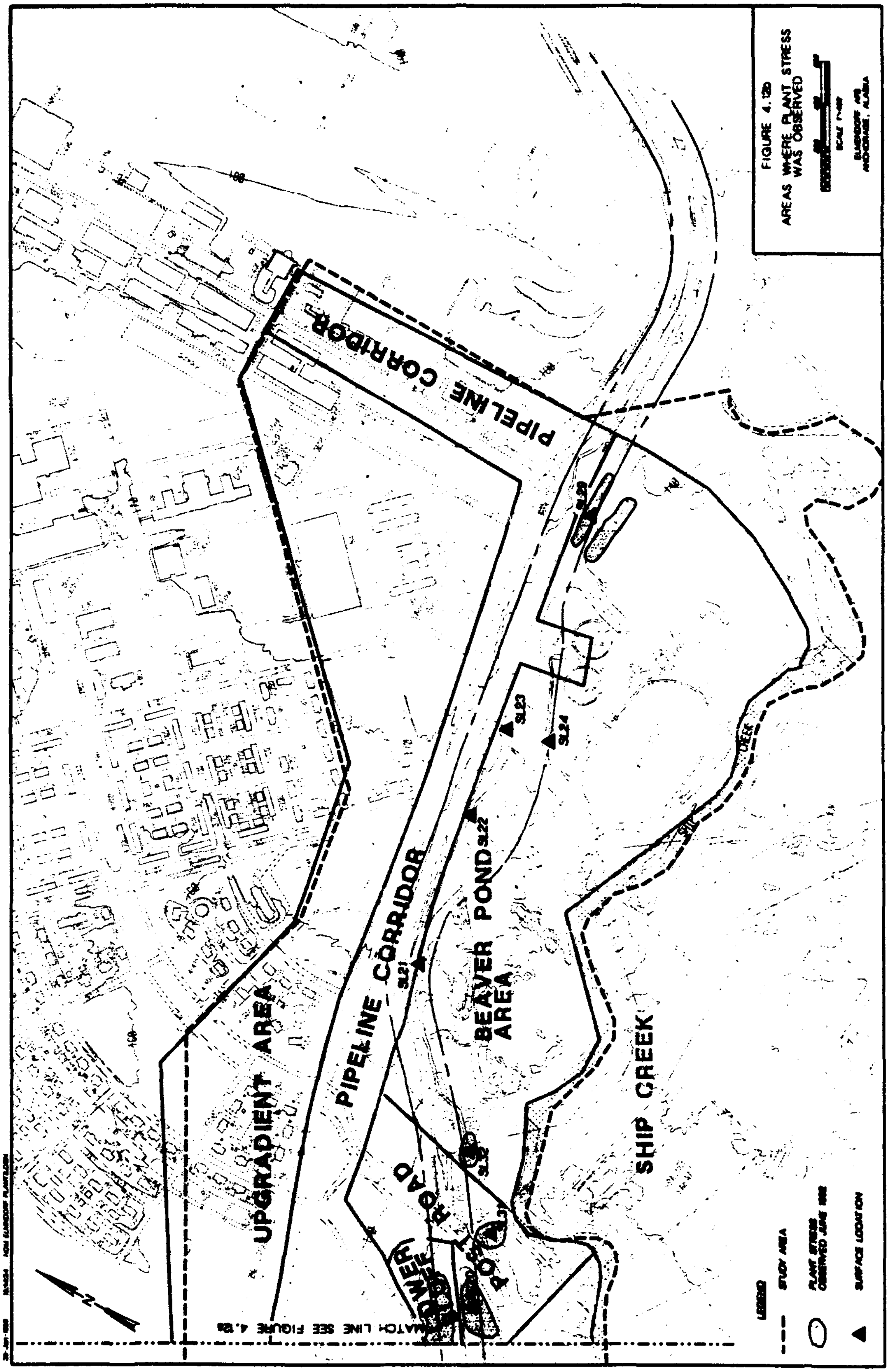

FIGURE 4.12b
AREAS WHERE PLANT STRESS WAS OBSERVED

Apparent plant stress was observed at the following locations:

SL3
SL19
SL25
SL28
SL31
SL4/SL5
SL20
SL26
SL29
SL32.

Some other woody plants apparently were stressed due to the flooding caused by beaver activities or by other hydrologic changes. These changes occurred at SL29 and SL30 more recently (based on dead leaves seen on some trees) and at SL19, SL25/SL26, and SL22/SL23 (in the golf course beaver pond).

The trees in the latter three wetlands died many years ago. At SL19 and SL25/SL26, there was no evidence of beaver activity, but the wetlands apparently developed there after many of the trees were established. The white spruce trees that are showing signs of stress would typically grow in areas with better drainage than now exists. They probably were present before the area became a wetland, but the timing of hydrologic changes in these two areas has not been determined. At the large beaver pond south of SL22 and SL23, the trees may have died as a result of flooding caused by the beaver dams.

In addition, many of the balsam poplar trees between SL7 and SL10 had been substantially defoliated, apparently by insects. The defoliation of the trees has not been attributed to OU 5 contaminants.

Soils and plants were collected from representative areas where plant stress was observed (see Section 2.1.8.1) for analysis of possible causes of plant stress. Because the signs of stress were similar to those induced by iron deficiency (that is, interveinal chlorosis), the analyses focused on factors that may affect iron uptake and availability, in addition to analyses for previously identified contaminants for OU 5.

Soils and plants were collected as paired samples (from the same soil depths and plant species) from both affected and nearby nonaffected locations. Thus, the means shown in these tables provide comparable values between the affected and nonaffected areas. Results of statistical tests comparing the affected and nonaffected soil or plants are in Appendix O; the results are summarized in the following text and in Tables 4-21, 4-22, and 4-23.

Except for manganese, there were no statistically significant differences in concentrations of inorganics for soil or plants (Table 4-21). Soil in which affected plants were growing tended to have higher concentrations of some inorganics (for example, barium, boron, iron, nickel, potassium, lead, and zinc) than those supporting nonaffected plants. Likewise, the affected plants tended to have higher concentrations of certain metals or nutrients (for example, calcium, iron, lead, magnesium, manganese, potassium, and sodium), but lower concentrations of other metals and nutrients (such as zinc), although the differences were not statistically significant ($P > 0.05$).

Halogenated VOCs were not found at measurable concentrations in any of these soils (Appendix K). BTEX and gasoline, diesel, or jet fuel were observed at several sample locations. However, with the exception of SL4, there was no consistent pattern of these chemicals being more common in soil from affected plant sites than the soil from the nonaffected ones. Petroleum hydrocarbons were not detected in most of the soil samples. Maximum concentrations of these chemicals by location and soil sample type are presented in Table 4-22. The highest concentrations of ethylbenzene, xylene, gasoline, and diesel from SL4 were in samples collected for quality control analyses (Appendix K).

Diesel soil analysis results indicate that constituents of these fuels do not have a causal relationship with the affected plants. At SL4/SL5, affected plants were found in soil with higher contaminant concentration than soil in which nonaffected plants were found; although higher concentrations were found in soils at SL16, where no affected plants were found. The affected plant species at SL4/SL5 is horsetail; it is also the affected species at

SL19. However, measurable diesel concentrations were not found to be greater than 12 mg/kg in the soil at SL19. If this species is exhibiting the same symptoms at both locations, one could expect the fuel contaminants to be present at both sites.

Elevated levels of gasoline, ethylbenzene, and xylenes were found at SL4/SL5 in soil from the affected plant site and not in soil from the nonaffected site. However, these chemicals were not found at SL19, where horsetail was similarly affected. Elevated levels of gasoline, toluene, and total xylenes were found at SL16, where no affected plants were found.

Results of soil chemistry analyses comparing the soils in which affected and nonaffected plants grow are presented in Appendix O and summarized in Table 4-23. Soil pH tended to be higher where plants exhibited stress than at nearby nonaffected reference locations where plants appeared to be normal, and the differences approached statistical significance ($0.05<P<0.1$; that is, it was significant at 90% but not 95% as being a true difference). Water-soluble potassium concentrations were similar in the soils, but acid-extractable potassium tended to be higher in affected areas than in nonaffected ones ($0.05<P<0.1$). Although some other analytes (for example, phosphorus, nitrogen, sodium) showed apparent differences between affected and nonaffected locations, the values were highly variable and did not approach statistical significance ($P>0.1$).

Phosphorus concentrations and pH in soil were compared between sites of affected and nonaffected plants. At SL4/SL5, SL20, and SL29, both phosphorus concentrations and pH were elevated in soils from the affected areas when compared to soils from nonaffected areas. At SL19 and SL25/SL26, pH for both affected and nonaffected areas were about the same, while phosphorus concentrations were increased at affected areas. SL31 soils showed an increase in pH but a decrease in phosphorus at the affected site.

4.6.1.2 Birds

Eggs that failed to hatch were found in four nests. Five of the six eggs had dead embryos, but none of them had visible deformities. Three mew gull eggs (apparently the entire clutch, although that nest had not been monitored previously) in a nest at the snow disposal area pond had dead embryos that had reached about one-half term incubation. A single addled egg (no visible development) was found in another gull nest at that pond. One wigeon egg failed to hatch in a nest west of the golf course beaver pond (south of SL22). The embryo was nearly full term and had died about the time the other six eggs in the nest apparently hatched successfully. One of the four eggs failed to hatch in a spotted sandpiper nest on the berm of JP-4 fuel tank 734 (southeast of SL24). It contained an embryo that died after about 1 week of incubation.

4.6.2 Discussion

4.6.2.1 Plants

Whereas elevated levels of diesel, gasoline, ethylbenzene, and total xylenes were found in the soil of affected plants and not in the soil of nonaffected plants at SL4/SL5, these compounds were not present in any soil samples from SL19, or were present at low levels. Since horsetail plants at both sites exhibited the same stress symptom of chlorosis, it is doubtful that any of these chemicals are related to the plant stress. The fact that diesel, gasoline, benzene, toluene, and total xylenes were found at SL16, where there were no affected plants, strengthens the hypothesis that these chemicals are not a contributing factor.

The statistically-significant difference in soil manganese concentrations between affected and unaffected areas may be biologically significant. An imbalance in the ratio of manganese to iron can affect the ability for plants to use iron, and may cause chlorosis of the leaves.

A potential trend may exist between pH levels and phosphorus concentrations in the soils of affected and nonaffected plant sites. The comparisons of these parameters were made for the 2- to 12-inch depth soil samples, and the trend does appear similar for all sample depths. In unfavorable soil pH, mineral imbalances may occur in the plant. At increased soil pH, available ferrous salts can be converted to unavailable ferric salts leading to iron deficiency. Also, iron may be made unavailable by excess soluble phosphates. Based on the data from this exploratory study, a definitive cause for the plant stress, as expressed as chlorosis, cannot be determined. Possible causes of the observed plant stress are discussed further in Section 6.2.2.3.

4.6.2.2 Birds

The limited observations of waterfowl, shorebird, and gull nests did not indicate that eggs were becoming oiled by transfer of oil from the parents' feathers, and oil was not observed on the birds' plumage. However, the number of nests being observed was small, and these findings are inconclusive. Based on observations of other areas, the number of eggs failing to hatch (as a percentage of eggs observed) was higher than expected. Embryo toxicity caused by exposure to potential contaminants of concern in OU 5 cannot be determined on the basis of limited data from this study. Given the observed oily sheen on the beaver pond near SL22, the birds' feathers may become oiled and they may transfer oil to eggs they are incubating. One green-winged teal and two wigeon nests were observed at this pond.

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5.0 CONCEPTUAL MODEL

This section presents an overview of the OU 5 conceptual model (CM) and more detailed discussions of the sources of contamination, the general fate and transport characteristics of the contaminants, and migration pathways in the environment. Exposure routes (inhalation, ingestion, dermal absorption) and exposed populations (humans, aquatic animals, and terrestrial plants and animals) are discussed in Section 6.0, Risk Assessment.

Section 5.0 asks three questions and focuses on the following significant results and interpretations:

1. What are the contaminants of concern and where are they located in OU 5?
    - Fuel constituents were detected in soils at the bluff area south of the COE building, at the base of the bluff below Building 22-010, and at the valve pit near the junction of Post Road and Second Avenue.
    - Low levels of fuel and solvent constituents have been detected in groundwater within OU 5 and in seeps and ponds, both surface water and sediment, below the bluff.
    - Limited testing detected metals in groundwater above background levels at locations near fly ash deposits on the bluff and in soils below the bluff.
    - PCBs were detected at low concentration in one sediment sample collected from the snow-disposal pond (lower bluff pond).
2. What are the potential sources of the contaminants?
    - The fuel constituents in soils and groundwater at OU 5 most likely represent residual contamination from past recorded spills and leaks at underground pipelines. There is no evidence of recent or ongoing leaks.

- The solvent and some fuel contamination of groundwater and surface water enters OU 5 from unknown sources upgradient of the pipelines.

- The limited number of metals analyses do not allow for the identification of sources for the elevated levels of metals in soils and groundwater. The source of some metals, including arsenic and barium, may be fly ash deposits.

- The source of PCBs is unknown but may involve the snow disposal area adjacent to the lower bluff pond or ARRC activities.

3. How are the contaminants being transported?

   - Residual fuel contaminants in subsurface soils near the pipelines are transported downward by physical processes to the groundwater.

   - Groundwater flushes the fuel out of the soil through seeps and into ponds at the base of the bluff.

   - Low levels of fuel and solvent contaminants also enter OU 5 from upgradient sources as dissolved components in the groundwater and discharge through seeps and groundwater into ponds at the base of the bluff.

   - Low levels of fuel and solvent contamination have migrated off base onto railroad property at the western end of OU 5 via the upper aquifer groundwater.

   - The results from the total metals analyses and the leaching tests on the fly ash show that arsenic, barium, vanadium, and zinc may be leaching from the fly ash at levels that represent the detected concentrations in the groundwater.

5.1 Overview

The OU 5 CM describes OU 5 and its environs and presents hypotheses regarding the following components:

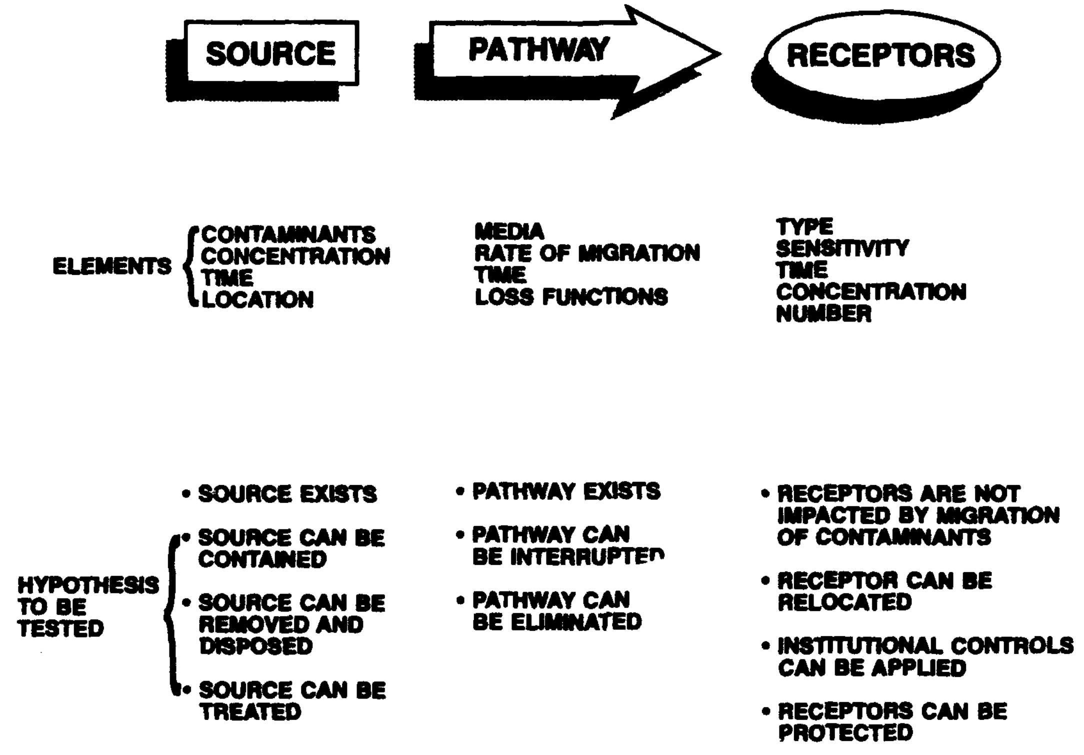
- Source or sources of contamination;
- Contaminant release mechanisms;
- Nature and extent of contaminants present;
- Contaminant routes of migration; and
- Potential impact of contaminants on sensitive receptors.

The CM hypotheses are tested, refined, and modified throughout the RI/FS. A preliminary CM presented in the OU 5 *Management Plan* assisted in the identification of data quality objectives, data needs, remedial alternatives, and general management decisions. The refined conceptual model is useful for evaluating data during the RI and developing remedial alternatives during the FS. Figure 5-1 shows the general elements of a CM.

To aid in the discussion of the OU 5 CM, an illustration is provided as Figure 5-2. Two CM schematics are also provided: Figure 5-3 for human receptors and Figure 5-4 for the ecological receptors. Table 5-1 cross-references the elements of the OU 5 CM with detailed discussions in this RI report.

The Elmendorf FFA grouped six source areas into OU 5 because the contaminants at the sources appeared to be similar:

- **Source of contamination** — The most likely sources of contaminant releases appear to be three fuel pipelines and the associated fuel distribution system and operations. This system includes storage tanks, valve pits, truck fill stands, and abandoned and active fuel lines. Other potential contamination sources within OU 5 include railroad maintenance operations (never verified) and fly ash. Shop drains (OU 4) and sanitary landfills (OU 1), fire training areas (OU 4, OU 7), drums (OU 7), and other storage areas 2 miles upgradient of the pipelines could be influencing groundwater and surface water quality within OU 5 (see Figure 1-2).



SOURCE: EPA 1987a p 3-7

Figure 5.1. General Elements of a Conceptual Model, Elmendorf AFB, Anchorage, Alaska

ELMF51.FH3 - VMG 8/6/93 SAC

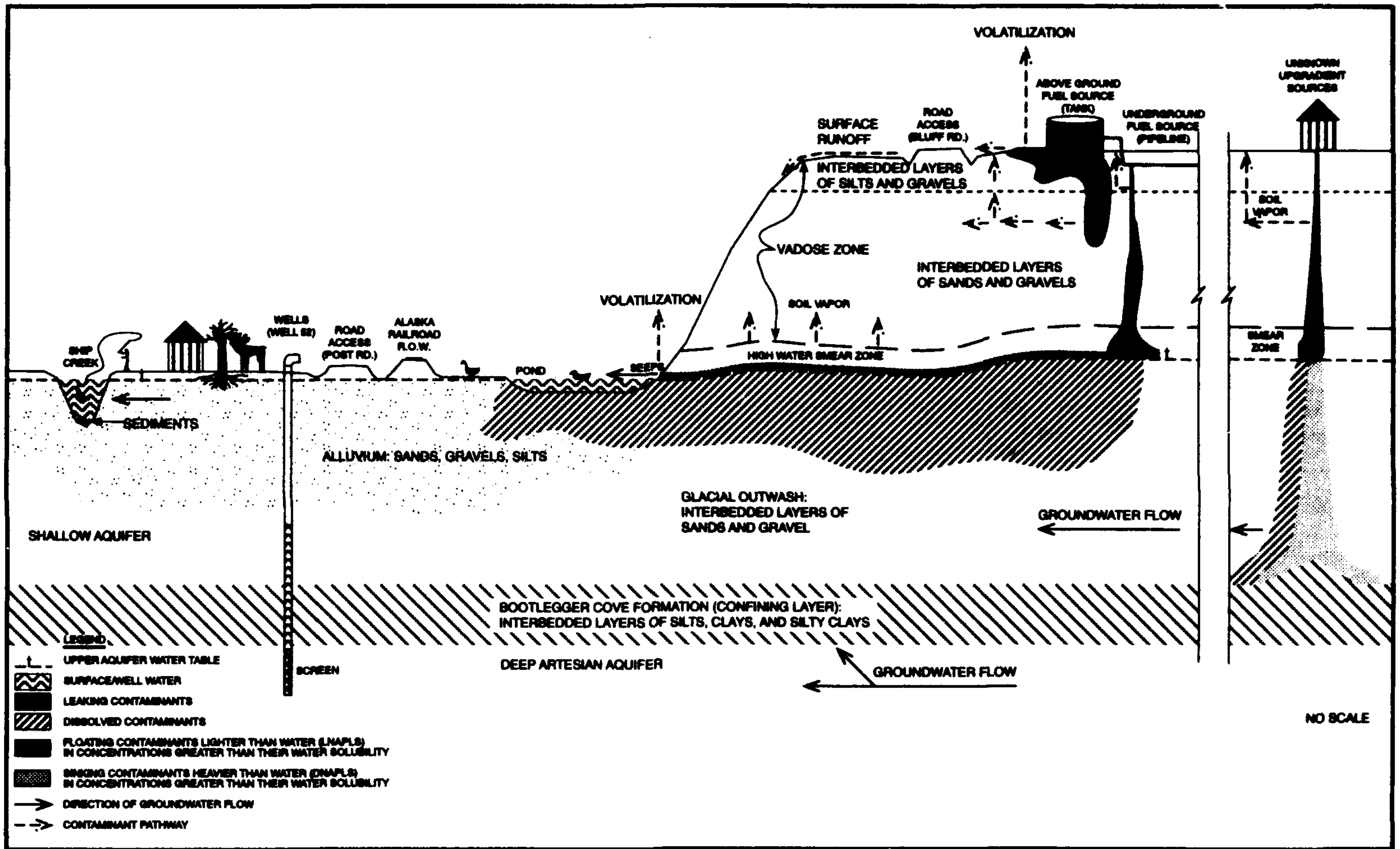
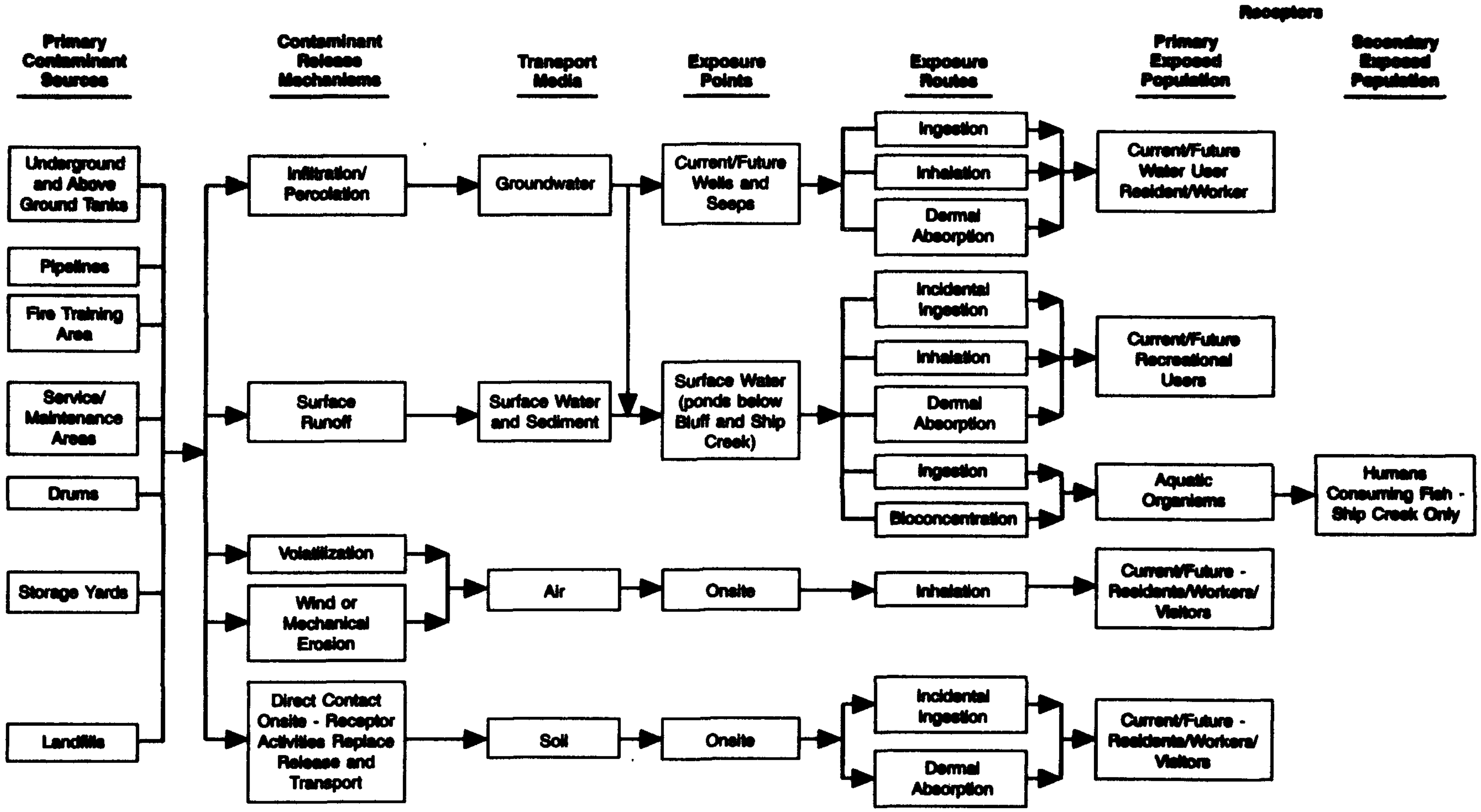


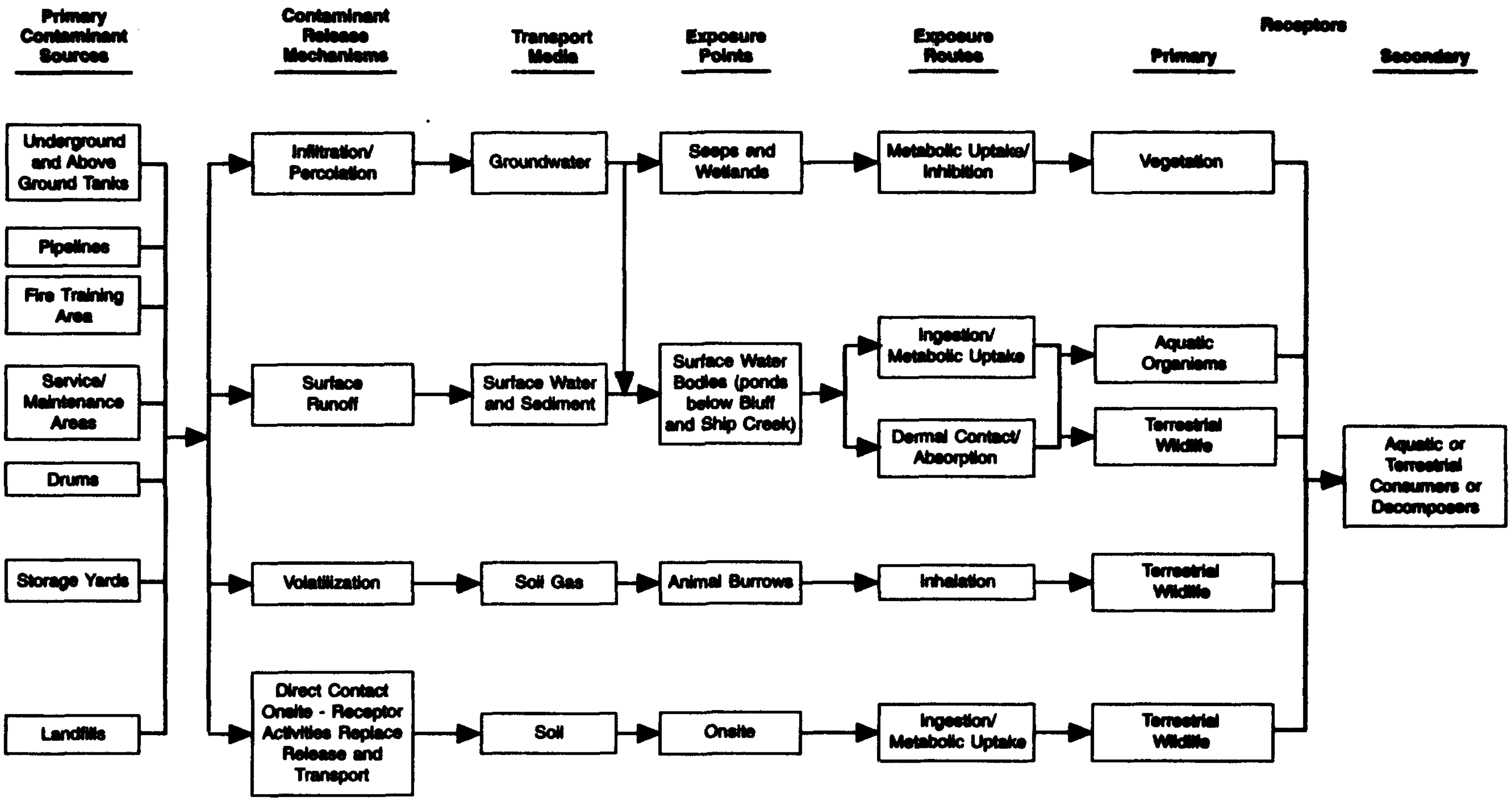
Figure 5.2. Conceptual Model Illustration
Elmendorf AFB, Anchorage, Alaska

ELMF52.PH3 - VMG 8/6/93 SAC



Note: Primary sources are those that are within OU5 (pipelines and tanks) and those in other OUs that are upgradient for groundwater transport into OU5 (Bluff Area and Ship Creek, receiving water from groundwater discharge to surface).

Figure 5.3. Conceptual Model for Potential Human Exposures, Elmendorf AFB, Anchorage, Alaska



Note: Primary sources are those that are within OU5 (pipelines and tanks) and those in other OUs that are upgradient for groundwater transport into OU5 (Bluff Area and Ship Creek, receiving water from groundwater discharge to surface).

Figure 5.4. Potential Exposure Pathways for Ecological Receptors, Elmendorf AFB, Anchorage, Alaska

Table 5-1

Elements of the Conceptual Model Cross-Referenced to Information Sources and Location in RI Report

Elements of the Conceptual Model	Reference[a]	Topic
Sources and release mechanisms		
- OU 5	Section 1.2	Source area histories
	Section 1.2.3.2	POL pipelines and tanks
	Section 1.2.2.1	Fly ash
	Section 3.2.3.3	Fly ash
- Upgradient	CH2M HILL 1991	Site summaries
	CH2M HILL 1992	Basewide Investigation Work Plan
	Jacobs 1992	OU 1 Management Plan
	Jacobs 1992	OU 2 Management Plan
	CH2M HILL 1992	OU 4 Limited Field Investigation Report
Nature and extent of contamination		
- Past investigations	Section 1.2	Source area histories
	Figure 1.3	Contaminants detected in past investigations
- Current RI	Section 4.2	Soils
	Section 4.3	Groundwater and seeps
	Section 4.4	Surface water and sediments
	Section 4.6	Terrestrial plants
	Section 5.3	Contaminant characteristics
Routes of migration (transport media)	Section 3.1	Climate
	Section 3.2	Geology and soils
	Section 3.3	Hydrology
	Section 5.3	Contaminant characteristics
	Section 5.4	Environmental fate and transport pathways
Exposure points, exposure routes, exposed populations		
- Humans	Section 3.4	Land use characteristics
	Section 3.5	Water use characteristics
	Section 6.1	Human health risk assessment
- Aquatic communities	Section 3.6.1	Aquatic communities characteristics
	Section 4.5	Aquatic biota (results)
	Section 6.2.1	Aquatic resources risk assessment
- Terrestrial communities	Section 3.6.2	Terrestrial communities characteristics
	Section 4.6	Terrestrial plans and animals (results)
	Section 6.2.2	Terrestrial resources risk assessment

[a] Section number refers to Section in OU 5 RI Report.

- **Release mechanisms** — Both subsurface breaks in the fuel lines and surface spills have been recorded in the past. Pipelines have been repaired and there are currently no known pipeline leaks at OU 5.

- **Nature of contamination** — The known organic contaminants in soils at OU 5 include fuels (TFH diesel, TFH gas, and JP-4), BTEX, and SVOCs including PAHs. The known organic contaminants in groundwater, surface water, and sediments include fuels; BTEX; SVOCs including PAHs; and chlorinated solvents. PCBs were detected in one sediment sample. Several metals were detected above background levels in all media.

- **Routes of migration** — Runoff and seeps, which leach contaminants from the soil into ground and surface water, appear to be the most important routes of contaminant migration. Local hydrogeology is thought to be similar within OU 5. The three pipelines run along the southern boundary of Elmendorf AFB on a glacial outwash plain composed of interbedded layers of gravel, sand, and small amounts of silt. Just south of the pipelines is a bluff that overlooks lower Ship Creek and its alluvial floodplain. At the base of the bluff are several shallow ponds and seasonally wet areas. Since the 1950s, seeps of fuel from the face of the bluff have resulted in cleanups, environmental investigations, and repairs to the pipelines. Groundwater flow in the upper aquifer moves in a southerly to southwesterly direction almost perpendicular to the pipelines on the bluff. Lower Ship Creek represents the primary recipient of both surface water and groundwater coming from the base, and of any contaminants transported by water. There is a potential for off-base migration of the contaminants via groundwater and surface-water runoff.

- **Human and ecological receptors** — Current land uses within the base, but downgradient of the pipeline sources, include industrial and recreational uses. The downgradient area also serves as a major access route to the base. Land uses between the base and lower Ship Creek include railroad, industrial, and fisheries activities. Water uses vary by source of water. Only the lower groundwater aquifer is used as a source of drinking water. Recreational users may come in contact with the surface water. Surface water from Ship Creek is used for irrigation of the golf course, cooling water for the power plant, and hatchery operations. Ecological receptors include terrestrial and aquatic communities.

Data from both past investigations and the RI will be used to formulate the CM. It should be stressed that the data used from past investigations have not been fully evaluated for completeness, quality, and technical usefulness. However, the past data are sufficient to discuss the previous conditions existing in OU 5. Data from the current RI were validated as described in Section 2.3.

5.2 Sources

Table 5-2 identifies the potential sources of contaminants based on spill records, the type of contaminants, and the past and present distribution of contaminants in the environment. Figure 1-2 shows the relationship of potential upgradient OUs to the OU 5 study area.

The focus of the RI was to investigate fuel contamination at OU 5. Fuel leaks and spills from the pipelines and distribution points along the southern boundary of Elmendorf AFB have been documented. Fuel-contaminated soils with petroleum hydrocarbon levels greater than 100 mg/kg (ADEC, 1991) were detected in three areas of OU 5.

- South of the COE building (SB29, Source ST37);
- Base of bluff below Building 22-0010 (SL16, Source ST38); and
- Near the low-point drain pit at the junction of Post Road and Second Avenue (Source SS53).

The OU 5 sources that led to the current distribution of soil contamination by fuels were probably the pipeline leaks discussed in detail in Section 1.2:

- Source ST37—diesel fuel line leak, 1956 to 1958;
- Source ST38—JP-4 fuel line leak, 1964 and 1965; and
- Source ST53—golf course leak at low-point drain pit of JP-4 fuel line discovered in 1982.

Table 5-2

Potential Sources for Contaminants in OU 5

Contaminant Type	Contaminant Examples	Distribution of Contaminants	Other Evidence	Potential Sources	Comments
Petroleum, oil, lubricants (POLs)	TPH gas, diesel, JP-4 BTEX PAHs	Found in soil, upper groundwater, surface water, and sediment in OU 5 study area	Spill and maintenance reports, observations of fuel seeps and sheens on surface water increasing after rains or spring breakup	OU 5 sources--pipelines and associated tanks (Table 1.1)	Annual pressure testing shows pipelines intact. Current sources of fuel may be residual pockets of fuel in soil from past spills and leaks. Three "hot" spots were verified during the RI to have TPH in soil greater than 100 mg/kg: bluff area south of COE building, the low point valve pit at 2nd Street and Post Road,and a wetland pond along the lower bluff (SL16).
		Found in soil and upper groundwater in upgradient study subarea of OU 5	Past and ongoing investigations at other CERCLA OUs and sources in state cleanup programs	Upgradient fuel tanks and pipelines - OUs 2 and 4 - State UST/POL sources - Base gas stations - Flight line maintenance shops Upgradient shop waste and asphalt disposal areas - OUs 1, 3, and 7 Upgradient fire training - OUs 4/7	No comment.
Solvents	TCE 1,1,1-TCA 1,1,2,2-tetrachloroethane chloroethane 1,1-DCA 1,2 DCA t-1,2-DCE	Found in upper groundwater and surface water at OU 5; not found in soils or sediment	No documented release in OU 5 study area	OU 5 sources - Waste oil and paint tanks (Table 1.1) - Maintenance shops	All waste oil and paint tanks and maintenance shops are in the upgradient or pipeline corridor study area of OU 5. Minor maintenance shops occur at the eastern end of the golf course.
		Found in upper groundwater in upgradient study subarea of OU 5 and in upgradient base well 1	Past and ongoing investigations at other CERCLA OUs and sources in state cleanup programs, BESG data on base supply well 1.	Upgradient sources - Shop drains, OU 4 - Fire training, OU 4/7 - Landfills, OU 1 - Shop waste disposal, OU 3 - Flight line maintenance shops - Storage yards	No comments.

Table 5-2

(Continued)

Contaminant Type	Contaminant Examples	Distribution of Contaminants	Other Evidence	Potential Sources	Comments
Inorganics	Metals	Higher than background levels in soils and groundwater	Boring log of SP1-02 showing ash deposits	OU 5 sources - Coal fly ash in lower bluff study subarea - Fuel components from pipelines and associated tanks (Table 1.1) - Snow disposal area in lower bluff pond area	Metals were analyzed for a small number of soil, sediment, groundwater, and surface water samples during the RI to determine if a problem existed. Most of the soil metals results came from soils collected from stressed and unstressed areas of vegetation for the ecological assessment.
		High total metals in upgradient base hydrology wells; attributed to poor well development (Black & Veatch 1990a)	Past and ongoing investigations at other CERCLA OUs and sources in state cleanup programs	Upgradient sources - Same as for POLs and solvents above	No comment.
PCBs	Aroclor 1260	One sediment sample at Lower Bluff Pond. Not analyzed for in soils, groundwater, or surface water	No documented releases in OU 5 study area	No known OU 5 sources	PCB presence may be related to ARRC activities and snow disposal practices. PCBs were analyzed in only a few sediment samples for interpretation of aquatic toxicity tests.

In each area, the contaminated soil is located at the groundwater table. Upper vadose zone contamination was not encountered in the bluff area, except where free standing water or groundwater was encountered at or near the surface. At sampling locations SB29, SL04, and SL16, diesel fuel was encountered in the 0- to 2-foot depth at 6.1 mg/kg, 151 mg/kg, and 720 mg/kg, respectively; however, groundwater seeps or high water tables were encountered nearby. No contaminant plume was observed in the vadose zone during the RI. Therefore, it is likely that the fuels from past spills have been biodegraded or dispersed through volatilization and flushing.

Because of weathering of the fuel, fingerprints of the fuel (for example, identification as JP-4, TFH gas, and TFH diesel) are also probably not reliable as indicators of which line was responsible for the current contamination. Most weathered fuels in soils would be identified as diesel fuel, regardless of their sources. the residual fuels in the soil could serve as a secondary source of contamination into the groundwater.

No active leaks were encountered during the RI. Current USAF practices of pipeline and tank testing and routine maintenance minimize the recurrence of leaks.

Past investigations showed only trace levels of halogenated VOCs in two monitoring wells (NS3-02 and GW-4A) in OU 5. The current RI revealed that the contamination of the upper groundwater aquifer and surface water by halogenated VOCs is more widespread. The seeps and ponds at the base of the bluff appear to receive water from the upper groundwater aquifer. Consequently, groundwater contamination serves as a secondary source of contamination to the surface water below the bluff.

The groundwater samples from the upgradient study subarea also contained halogenated VOCs and fuel constituents, indicating that the groundwater entering the OU 5 study area is already contaminated from unknown upgradient sources. Previous investigations at upgradient OUs have indicated both fuel and solvents in the shallow groundwater

(Table 5-3; refer to Figure 1-2 for location of OUs on Elmendorf AFB). Three observations of the solvent contamination of the upper aquifer on the base can be made:

- Solvent contamination is widespread.
- Concentrations are generally low (μg/L) and involve more than one compound or breakdown product.
- The most common compound detected is TCE.

The highest solvent concentrations (1400 μg/L for 1,1,1-trichloroethane) were found at the fire training area. Nowhere at upgradient sources were the concentrations of solvents high enough to unambiguously identify the source of the contaminants entering OU 5. Considering their disposal history and upgradient location relative to OU 5, the following sources may be contributing to the low levels of solvents found in OU 5:

- SD16 (OU 3)—abandoned disposal trench for shop wastes;
- FT23 (OU 4, OU 7)—fire training area; and
- SD24, SD25, SD28, SD29, SD31 (OU 4)—floor drains.

Source SD16 (OU 3), the abandoned disposal trench for shop wastes, is located in a flight line area, west of Building 31-260 near the east-west runway, and is less than 1 acre in size. During the 1950s and 1960s, waste solvents, paint thinners, and other liquid wastes from shop operations were poured into a ditch(es) and disposed of directly onto the soil at the source. The area was subsequently backfilled and revegetated so that the actual locations of the trench(es) cannot be determined by visual observation (Engineering Science, 1983).

Source FT23 (OU 4, OU 7), the fire training area, is located west of the north end of the north-south runway near Building 43 585. The source consists of two areas: a drum storage area and a bermed burning area. The drum storage area contained as many as

Table 5-3

Summary of Organic Contaminants in the Upper Aquifer at Upgradient Operable Units

OU Name	Source ID	Source Type	Approximate Location Relative to OU 5	Contaminant	Maximum Concentration Detected (µg/L)	Source(s) of Data[a]
OU 1	LF05 LF07 LF13 OT56 LF59	Landfills	1 mile NE of OU 5	benzene bis(2-ethylhexyl)phthalate chloroethane 1,1-dichloroethane trans-1,2-dichloroethene dichlorofluoromethane methylene chloride tetrachloroethene toluene 1,1,1-trichloroethane trichloroethene trichlorofluoromethane vinyl chloride TPH	1.1 24 9.5 4.7 6.9 19 3.1 1.9 1.0 36 3.5 49 10 3,900	Dames & Moore 1988 Black & Veatch 1990 Jacobs 1992a
OU 2	ST41	Underground fuel storage tanks (avgas, JP-4)	1.5 mile N of OU 5	benzene BTEX (total) trichloroethene TPH	15,000 60,000 12 floating product (730,000)	Jacobs 1992b
	ST20	Underground waste storage tank	0.5 mile N of OU 5	benzene BTEX (total) chloroform trichloroethene TPH	540 1,800 3 2 52,500	Jacobs 1992b
OU 3	SD16	Abandoned disposal trench for shop wastes	1 mile N of OU 5	benzene 1,2-dichloroethane tetrachloroethene trichloroethene trichlorofluoromethane trans-1,2-dichloroethene	1.3 1.1 1.6 47 0.68 30.0	Dames & Moore 1988

Table 5-3

(Continued)

OU Name	Source ID	Source Type	Approximate Location Relative to OU 5	Contaminant	Maximum Concentration Detected (µg/L)	Source(s) of Data^a
OU 4	SD24 Bldg. 42-400	Floor drains Fuel pipelines, tanks	1.5 mile N of OU 5	benzene 1,1-dichloroethane ethylbenzene 1,1,1-trichloroethane toluene xylenes TPH bis-(2-ethylhexyl)phthalate 2-methylnapthalene napthalene	35 7.1 250 3.1 460 1,050 floating product 720 500 280	Black & Veatch 1990
	SD25 Bldg. 42-425	Floor drains Fuel pipelines, tanks	1.5 mile N of OU 5	TPH	700	Black & Veatch 1990
	SD26 Bldg. 42-550	Floor drains Fuel pipelines, tanks	1.5 mile N of OU 5	TPH	1,300	Black & Veatch 1990
	SD27 Bldg. 42-300	Floor drains Fuel pipelines, tanks	1.5 mile N of OU 5	bis-(2-ethylhexyl)phthalate 1,1-dichloroethane 1,1,1-trichloroethane	13 2.2 5.8	Black & Veatch 1990
	SD28 Bldg. 43-410	Floor drains Fuel pipelines, tanks	1.5 mile NE of OU 5	TPH	600	Black & Veatch 1990
	SD29 Bldg. 43-450	Floor drains Fuel pipelines, tanks	1.5 mile NE of OU 5	tetrachloroethene trichloroethene TPH	12 8.1 900	Black & Veatch 1990
	SD30 Bldg. 21-900	Floor drains Fuel pipelines, tanks	0.5 mile N of OU 5	trichloroethene TPH	76 2,000	Black & Veatch 1990

Table 5-3

(Continued)

OU Name	Source ID	Source Type	Approximate Location Relative to OU 5	Contaminant	Maximum Concentration Detected (µg/L)	Source(s) of Data[a]
OU 4 (Cont'd)	SD31 Bldg. 32-060	Floor drains Fuel pipelines, tanks	0.5 mile N of OU 5	1,1 dichloroethane 1,1,1-trichloroethane trichloroethene toluene TPH	2.1 0.93 6.8 11 2,000 (odor, sheen)	Black & Veatch 1990
OU 7	FT23	Fire training area	1.5 mile N of OU 5	benzene ethylbenzene toluene 1,1,1-trichloroethane 1,1,2-trichloroethane xylene TPH	340 1,600 1,000 1,400 110 6,300 floating product	Dames & Moore 1988 JMCE and HMS[b] 1988

[a] Ongoing investigations at the OUs are expected to generate more data from the 1992 field season. Jacobs Engineering, Inc., provided CH2M HILL with preliminary data from OU 1 and OU 2. A review of that preliminary data showed similar chemicals and concentrations as the previously reported data that are summarized in this table.

[b] James Montgomery Consulting Engineers, Inc., and Harza Environmental Services.

one hundred 55-gallon drums of contaminated waste oils, paint thinners, waste fuel, and waste solvents from aircraft maintenance and other shop operations on base. Fire training activities were conducted in the bermed area from the 1940s to 1983. From the 1940s to 1960s, combustible wastes such as oils, fuels, and solvents were used as fuel for fire training exercises. Approximately 250 to 3000 gallons of contaminated waste materials were spread on the ground surface and ignited during each exercise. Protein foams or chlorobromomethane were used to extinguish the fire. The bermed area remained saturated with unconsumed fuel following each training exercise. Visual observations of the source in 1983 indicated very small amounts of residual fuels in the burn area. However, the source is situated on porous soils and gravels through which material infiltrates rapidly. In addition, the berm did not completely enclose the fire training area, resulting in runoff of unconsumed fuel.

Training activities occurred approximately once a month until 1974. Since 1974, only clean fuel has been used and, from 1974 to 1978, training activity decreased to semiannually. From 1978 to 1991, training was conducted on a quarterly basis and unconsumed fuel was collected in containers to prevent further runoff. In 1991, fire training activities ceased. In addition to fire training and storage activities, the source was also used for disposal of empty drums and spent fuel filters. These materials were buried adjacent to the source a few hundred feet east of the bermed area and are covered with local gravel (Engineering Science, 1983).

Sources SD24, SD25, SD28, SD29, and SD31 (OU 4) are floor drains. It is suspected that solvents, as well as POLs, have been disposed of through shop floor drains into dry wells or leach fields. Most of this disposal occurred before the mid-1960s, before building drains were connected to the MOA sewage system or individual septic systems. A limited field investigation (LFI) during the summer of 1992 used geophysical techniques to locate potential drain outfalls. Soil samples were collected to quantify any existing soil contamination at the outfalls. The sources listed above were identified for further remedial investigation. No groundwater samples were collected during the LFI; however, a review of previous groundwater data was performed. The fire training area may be contributing to the groundwater contamination at the floor drain sources (CH2M Hill, 1992e).

Total metal concentrations above upgradient groundwater concentrations (MW01, MW02) or background soil concentrations were found in four upper aquifer groundwater samples (SP1-01, SP1-02, MW15, and MW16) and in soil samples collected near the base of the lower bluff. Of the metals exceeding background levels, arsenic and beryllium are important in the evaluation of risk because of their toxicity (Section 6.1).

The source of the elevated metals is unknown but may be related to naturally occurring geological formations such as in-place coal seams or to anthropogenic sources such as fuel spills, coal fly ash deposits, or storm-water runoff.

Coal fly ash was encountered in five soil borings (SP1-02, SP2/6-05, SP2/6-04, SP2/6-03, and GW-6A) drilled at OU 5 by previous investigators (Black & Veatch, 1990a; Dames & Moore, 1988). During the RI, no new borings contained fly ash, and the areal extent of the fly ash was determined at ST37. The fly ash appears to have been used to extend the bluff and may have been laid down in lifts with covering of other fill material.

Coal was used by the military bases in the Anchorage area to generate power and steam for heating buildings until the 1960s when the power plants switched to natural gas. At least some of the coal came from the coal mines near Sutton in the Matanuska Valley, which closed down when the military switched fuels (O'Hara et al, 1985). It is unlikely that the fly ash at OU 5 originated from the burning of refuse because of the historical and extensive use of landfills for disposal of refuse. Consequently, only metals, rather than other burn products, are suspected in the fly ash.

Metals might also be encountered in snow that was plowed from base roadways and piled on the bluff near the intersection of Maple Street and Bluff Road. The snow melted into a pond at the base of the bluff. During warmer months, storm-water runoff discharges along riprap channels on the lower bluff and may be introducing metals into the wetland areas at the base of the bluff.

One of the six sediment samples contained PCBs. The sample was taken from the lower bluff pond. Potential sources of the PCB may be the railroad next to the pond or snow disposal operations at the top of the bluff.

5.3 Contaminant Characteristics and Release Mechanisms

The primary release mechanisms for contaminants at OU 5 have been identified as spills and leaks. The known contaminants are fuel products and their constituents. Solvents, metals, and PCBs have also been identified. The physical and chemical parameters for the organic and inorganic contaminants identified from OU 5 activities are summarized in Tables 5-4 and 5-5.

The fate and transport of chemicals at a site are evaluated by considering the physical and chemical interaction of the chemicals within the environment. Mobility and persistence are of primary importance. Mobility represents the potential for a chemical to migrate along a given pathway. Persistence is a measure of how long a chemical will remain in the environment.

Several physical and chemical properties affect the transport of inorganic and organic compounds in the environment. The following six parameters are important to contaminant transport:

- Molecular weight;
- Solubility in water;
- Vapor pressure;

Table 5-4

Physical and Chemical Parameters for Organic and Inorganic Chemicals Detected

Probable Source/ Chemical Constituent[a]	CAS Number[b]	Mole Weight (g/g-mole)	Water Solubility[c] (mg/L)	Liquid Vapor Pressure[d] (mm Hg)	Henry's Law Constant[e] (atm-m^3/mol)	Koc[f] (ml/g)	Log K_{ow}[g]	Liquid Density g/ml
POLs								
Acenaphthylene	208-96-8	152	16.1	6.84×10^{-6}	1.13×10^{-5}	2,500	3.92	0.90
Anthracene	120-12-7	178	0.043	2.00×10^{-8}	6.50×10^{-5}	14,000	4.45	1.25
Benzene	71-43-2	78	1,790	7.14×10^{-1}	5.55×10^{-3}	83	2.13	0.87
Benzo(a)anthracene	56-55-3	228	0.0094	2.33×10^{-10}	9.66×10^{-9}	1,380,000	5.66	1.11
Benzo(b)fluoranthene	205-99-2	252	0.0015	3.75×10^{-9}	1.11×10^{-4}	550,000	6.57	NA
Benzo(k)fluoranthene	207-08-9	252	0.0008	7.50×10^{-12}	4.00×10^{-7}	550,000	6.00	NA
Benzo(g,h,i)perylene	191-24-2	276	0.26	1.00×10^{-10}	5.34×10^{-8}	1,600,000	6.51	NA
Benzo(a)pyrene	50-32-8	252	0.0016	4.13×10^{-11}	1.13×10^{-4}	5,500,000	5.97	1.11
Bis(2-ethylhexyl)phthalate	117-81-7	391	0.340	7.31×10^{-8}	1.47×10^{-8}	123,027	5.11	0.90
Carbazole	86-74-8	167	NA	NA	NA	NA	NA	NA
Chrysene	218-01-9	228	0.002	4.65×10^{-11}	9.46×10^{-5}	200,000	5.66	1.11
Dibenz(a,h)anthracene	53-70-3	278	2.49×10^{-4}	7.50×10^{-13}	1.15×10^{-4}	2,029,000	6.50	NA
Debenzofuran	132-64-9	168	3.10	NA	NA	4,600	4.12	1.17
Diesel #2	68476-30-2	142	32.0	4.50×10^{-2}	2.9×10^{-4}	NA	3.86	0.87
Diethylphthalate	84-66-2	222	1,080	1.24×10^{-5}	4.50×10^{-7}	142	3.22	1.12
Di-n-butylphthalate	84-74-2	278	11.2	5.48×10^{-7}	1.81×10^{-6}	170,000	5.20	1.05
Ethylbenzene	100-41-4	106	169	7.20×10^{-2}	8.43×10^{-3}	1,100	3.15	0.86

Table 5-4

(Continued)

Probable Source/ Chemical Constituent[a]	CAS Number[b]	Mole Weight (g/g-mole)	Water Solubility[c] (mg/L)	Liquid Vapor Pressure[d] (mm Hg)	Henry's Law Constant[e] (atm-m^3/mol)	Koc[f] (ml/g)	Log K_{ow}[g]	Liquid Density g/ml
Fluoranthene	206-44-0	202	0.26	1.00×10^{-2}	6.73×10^{-2}	38,000	4.90	1.25
Fluorene	86-73-7	166	1.89	6.32×10^{-5}	1.00×10^{-4}	7,300	4.18	1.20
Gasoline	8006-61-9	178	1,800	9.50	5.6×10^{-3}	NA	2.11	0.73
Indeno(1,2,3-c,d)pyrene	193-39-5	276	5.30×10^{-4}	1.00×10^{-10}	6.90×10^{-8}	20,146	6.51	NA
Kerosene (JP-1 or Fuel Oil #1)	8008-20-6	142	32.0	4.50×10^{-2}	2.90×10^{-4}	NA	3.86	0.87
4-methylphenol	106-44-5	108	21,500	8.25×10^{-4}	7.92×10^{-7}	NA	1.94	NA
2-methylnaphthalene	91-57-6	142	32.0	4.50×10^{-2}	2.90×10^{-4}	NA	3.86	1.02
methyl tert-butyl ether	1634-04-4	88	48,000	245	NA	NA	NA	0.74
naphthalene	91-20-3	128	31.0	6.38×10^{-4}	4.83×10^{-4}	NA	3.59	1.14
n-Nitrosodiphenylamine	86-30-6	198	35	5.02×10^{-6}	5.00×10^{-6}	NA	3.13	1.23
4-Nitrophenol	100-02-7	139	16,000	3.08×10^{-7}	4.15×10^{-10}	NA	1.91	1.40
polynuclear aromatic hydrocarbons (PAHs) (general)	NA	178 to 276	$<2.6 \times 10^{-4}$ to 1.29	10^{-4} to 10^{-11}	NA	NA	4.45 - 7.66	NA
phenanthrene	85-01-8	178	1.15	8.40×10^{-7}	2.28×10^{-5}	14,000	4.46	1.18
pyrene	129-00-1	202	0.130	4.20×10^{-9}	7.00×10^{-9}	38,000	5.32	1.27
toluene	108-88-3	92	526	2.13×10^{-1}	6.64×10^{-3}	300	2.73	0.87
xylenes	1330-20-7	106	200	8.50	5.25×10^{-5}	240	3.26	0.86

Table 5-4

(Continued)

Probable Source/ Chemical Constituent[a]	CAS Number[b]	Mole Weight (g/g-mole)	Water Solubility[c] (mg/L)	Liquid Vapor Pressure[d] (mm Hg)	Henry's Law Constant[e] (atm-m^3/mol)	Koc[f] (ml/g)	Log K_{ow}[g]	Liquid Density g/ml
PCBs								
Aroclor 1260	11096-82-5	376	0.014	6.30×10^{-6}	1.70×10^{-4}	NA	6.00	1.44
PCBs--typical	--	300-376	0.0027 to 0.054	10^{-4} to 10^{-6}	10^{-3} to 10^{-4}	530,000	6.00	NA
SOLVENTS OR RELATED SOURCES								
Bromomethane	74-83-9	95	15,200	12.1	6.24×10^{-3}	NA	1.19	1.73
Chloroethane	75-00-3	65	5,680	7.56	8.82×10^{-3}	NA	1.54	0.92
Dibromochloromethane	124-48-1	208	2,700	6.74×10^{-2}	8.74×10^{-4}	NA	2.23	2.38
1,1-dichloroethane (1,1-DCA)	75-34-3	99	5,060	1.70	5.62×10^{-3}	30	1.79	1.17
1,2-dichloroethane (1,2-DCA)	107-06-2	99	8,520	5.92×10^{-1}	9.79×10^{-4}	14	1.48	1.26
trans-1,2-dichloroethene (t-1,2-DCE)	156-60-5	97	6,300	324	6.56×10^{-3}	59	0.48	1.28
Phenol	108-95-2	94	82,800	2.63×10^{-3}	3.33×10^{-7}	14.2	1.48	1.07
1,1,2,2-tetrachloroethane	79-34-5	168	2,900	5.00	3.81×10^{-4}	118	2.39	1.59
Tetrachloroethene (PCE)	127-18-4	166	200	1.39×10^{-1}	1.84×10^{-2}	364	3.40	1.62
1,1,1-trichloroethane	71-55-6	133	1,490	9.30×10^{-1}	1.72×10^{-2}	152	2.49	1.35
1,1,2-trichloroethane	79-00-5	133	4,420	1.73×10^{-1}	9.13×10^{-4}	56	2.17	1.44
Trichloroethene (TCE)	79-01-6	131	1,100	5.18×10^{-1}	1.03×10^{-2}	126	2.42	1.46
Trichlorofluoromethane (Freon)	75-69-4	137	1,100	6.02	9.7×10^{-2}	159	2.53	1.49

Table 5-4

(Continued)

Probable Source/ Chemical Constituent[a]	CAS Number[b]	Mole Weight (g/g-mole)	Water Solubility[c] (mg/L)	Liquid Vapor Pressure[d] (mm Hg)	Henry's Law Constant[e] (atm-m^3/mol)	Koc[f] (ml/g)	Log K_{ow}[g]	Liquid Density g/ml
METALS								
Aluminum	7429-90-5	27	NA	NA	NA	NA	NA	NA
Antimony	7440-36-0	122	NA	NA	NA	NA	NA	NA
Arsenic	7440-38-2	75	NA	NA	NA	NA	NA	NA
Barium	7440-39-3	137	NA	NA	NA	NA	NA	NA
Beryllium	7440-41-7	9	NA	NA	NA	NA	NA	NA
Boron	7440-42-8	11	NA	NA	NA	NA	NA	NA
Cadmium	7440-43-9	112	NA	NA	NA	NA	NA	NA
Calcium	7440-70-2	40	NA	NA	NA	NA	NA	NA
Chromium (III or IV)	16065-83-1 (III) 18549-29-9 (VI)	52	NA	NA	NA	NA	NA	NA
Cobalt	7440-48-4	59	NA	NA	NA	NA	NA	NA
Copper	7440-50-8	64	NA	NA	NA	NA	NA	NA
Iron	1309-37-1	56	NA	NA	NA	NA	NA	NA
Lead	7439-92-1	207	NA	NA	NA	NA	NA	NA
Magnesium	7439-95-4	24	NA	NA	NA	NA	NA	NA
Manganese	7439-96-5	55	NA	NA	NA	NA	NA	NA
Mercury	7439-97-6	201	NA	1.50×10^{-3}	NA	NA	NA	NA
Molybdenum	7439-98-7	96	NA	NA	NA	NA	NA	NA

Table 5-4

(Continued)

Probable Source/ Chemical Constituent[a]	CAS Number[b]	Mole Weight (g/g-mole)	Water Solubility[c] (mg/L)	Liquid Vapor Pressure[d] (mm Hg)	Henry's Law Constant[e] (atm-m^3/mol)	Koc[f] (ml/g)	Log K_{ow}[g]	Liquid Density g/ml
Nickle	7440-02-0	59	NA	NA	NA	NA	NA	NA
Nitrate	14797-55-8	NA	NA	NA	NA	NA	NA	NA
Potassium	7440-09-7	39	NA	NA	NA	NA	NA	NA
Selenium	7782-49-2	79	NA	NA	NA	NA	NA	NA
Silver	7440-22-4	108	NA	NA	NA	NA	NA	NA
Sodium	7440-23-5	23	NA	NA	NA	NA	NA	NA
Thallium	7440-28-0	204	NA	NA	NA	NA	NA	NA
Vanadium	7440-62-2	51	NA	NA	NA	NA	NA	NA
Zinc	7440-66-6	65	NA	NA	NA	NA	NA	NA

[a] Some chemicals could come from more than one source but are listed only once in this table. Compounds are listed if past reports or the RI showed their presence in the environment at OU 5 and at the upgradient base supply well 1. Not all sources or media were tested for the entire list of compounds shown in the table.

[b] CAS Number = Chemical Abstract Service Number.

[c] Solubility is an upper limit on a chemical's dissolved concentration in water at a specified temperature. Aqueous concentrations in excess of solubility may indicate sorption onto sediments, the presence of solubilizing chemicals such as solvents, or the presence of a non-aqueous-phase liquid.

[d] Vapor pressure values are given for a temperature range of 20°C to 30°C. Vapor pressure is the pressure exerted by a chemical vapor in equilibrium with its liquid form at any given temperature. The higher the vapor pressure, the more likely a chemical is to exist in its gaseous state.

[e] Henry's Law Constant provides a measure of the extent of chemical partitioning between air and water at equilibrium. The higher the Henry's Law Constant, the more likely a chemical is to volatilize than to remain in the water.

[f] Koc = Organic carbon partition coefficient--provides a measure of the extent of chemical partitioning between organic carbon and water at equilibrium. The higher the Koc, the more likely a chemical is to bind to soil or sediment than to remain in water.

[g] Log K_{ow} = Octanol/water partition coefficient--provides a measure of the extent of chemical partitioning between water and octanol at equilibrium. The greater the K_{ow}, the more likely a chemical is to partition to octanol than remain in water. Octanol is used as a surrogate for lipids (fat); K_{ow} can be used to predict bioconcentration in aquatic organisms.

NA = not available or applicable.

Sources: Department of Defense 1991, EPA 1986e.

Table 5-5

Physical and Chemical Properties of Hydrocarbon Fuels

Property	JP-4	Diesel Oil (1-D)[a]	Automotive Gasoline (Unleaded)
Physical state (20°C/1 atm)	Liquid	Liquid	Liquid
Color	Colorless to light brown	Colorless to brown	Colorless to pale brown or pink
Odor	Fuel oil	Kerosene-like	Characteristic
Odor threshold	1 ppm	NA	0.250 ppm
Density (15-20°C)	0.7500 g/ml	0.8100 to 0.9360 g/ml	0.7321 g/ml
Freeze/melt point	-72°C	-48 to 18°C	NA
Boiling point	60 to 270°C	151 to > 588°C	38 to 204°C
Flash point	-23 to -1°C	38 to 74°C	-46 to 38°C
Flammable limits (by volume)	1.3 to 8.0%	0.6 to 7.5%	1.2 to 7.6%
Autoignition temperature	240 to 242°C	177 to 329°C	257 to 471°C
Vapor pressure	91 mm Hg at 20°C	2.12 to 26.4 mm Hg at 21°C	263 to 675 mm Hg at 38°C
Satd. conc. in air (20°C)	660,000 mg/m^3	NA	NA
Solubility in water (20°C)	300 mg/L	5 mg/L	Insoluble
Viscosity (at 20°C)	0.829 cp	1.152 to 1.965 cp	0.451 cp
Surface tension (at 20°C)	25 dyne/cm	21 to 32 dyne/cm	19 to 23 dyne/cm
Range for typical components Log K_{ow} Soil adsorption coefficient Henry's law constant (20°C) Bioconcentration factor	 3.00 to 7.00 240 to 5,000,000 0.0001 to 1.0 atm m^3/mol 5 to 500,000	 3.3 to 7.06 960 to 5,500,000 0.00006 to 7.4 atm m^3/mol NA	 2.13 to 4.87 65 to 36,000 0.0005 to 3.3 atm m^3/mol NA

Table 5-5

(Continued)

Property	JP-4	Diesel Oil (1-D)[a]	Automotive Gasoline (Unleaded)
Approximate chemical composition:			
Alkanes	61.0%		N-alkanes 15.0 - 17.0% Branched 28.0 - 36.0%
Cycloalkanes	29.0%		3.0 - 5.0%
Alkylbenzenes, benzenes	8.0%		20.0 - 49.0%
Indans/tetralins	1.1%		NA
Naphthalenes	0.0%		0.0% - 1.0%
Olefins	NA		1.0% - 11.0%
Selected organics (% by weight)			
Benzene	0.50%[b]	NA	3.2%
Toluene	1.33%[b]	NA	4.8%
Ethylbenzene	0.37%[b]	NA	1.4%
Xylene	2.32%	NA	6.6%
m-xylene	0.96%[b]	NA	NA
p-xylene	0.35%[b]	NA	NA
o-xylene	1.01%[b]	NA	NA
Selected metals (ppm by weight)			
Arsenic	0.5 ppm	0.012 - 0.13	NA
Barium	NA	NA	NA
Cadmium	<0.03	0.089 - 0.89	NA
Chromium	<0.05	0.55 - 2.8	NA
Iron	<0.05	3.8 - 71.0	NA
Lead	0.09	<0.49 - 2.0	NA
Magnesium	NA	NA	NA
Manganese	NA	0.29 - 6.2	NA
Mercury	NA	NA	NA
Selenium	<0.03	NA	NA
Silver	NA	NA	NA

[a] Because of differences in feed stocks, refining methods, and blending practices, the composition of diesel fuel samples is expected to be highly variable. In Alaska, the Air Force uses DF-A-Arctic fuel, for which chemical composition data are not available. The data in the table above for diesel fuel are either for Grade 1-D or for a range of several diesel fuels.

[b] A single sample of JP-4.

NA = Not available.

Source: Biomedical and Environmental Information Analysis 1989.

- Henry's law constant;
- Density; and
- Organic carbon partition coefficient.

Other properties not listed that may affect migration of contaminants include viscosity and temperature. A brief description of the six parameters follows.

The molecular weight of a pure compound influences other physical characteristics of a compound. For example, VOCs with higher molecular weights have less tendency to volatilize than those with lower molecular weights.

Water solubility is the maximum concentration of a compound that can dissolve in water at a specific pH and temperature. Highly soluble compounds tend to be more mobile in groundwater and the leach from soils.

Density and solubility of contaminants are among the primary physical properties affecting the transport of separate phase liquids in soil and water. The density of a slightly soluble compound determines whether it will sink or float in the saturated zone.

Vapor pressure is a relative measure of volatility of a contaminant in its pure state. Compounds with high vapor pressures volatilize readily from the liquid form.

Henry's law constant describes the distribution of a chemical between air and soil or water at equilibrium. It is usually defined as the ratio of the partial pressure of the compound in air, measured in atmospheres, to the mole fraction of the compound in a water solution. A high Henry's law constant indicates a higher tendency for a compound to volatilize from soil or water.

The organic carbon partition coefficient (K_{oc}) indicates the tendency for a chemical to be absorbed by organic carbon in the solid matrix of the vadose and waterbearing zone. Low K_{oc} values indicate faster leaching from the source areas and less retardation of the contaminant as it is transported by groundwater movement.

Another parameter, the octanol/water partition coefficient or Log K_{ow}, can be used to predict bioconcentration in aquatic organisms. The Log K_{ow} provides a measure of the extent of chemical partitioning between water and octanol at equilibrium. The greater the Log K_{ow}, the more likely a chemical is to partition to octanol than remain in water. Octanol is used as a surrogate for lipids (fats), and is stored as fat by animals.

The following paragraphs describe the contaminants of concern, the physical parameters that affect the fate and transport of the contaminants in the environment, and the general distribution of the contaminants in the environment. Detected concentrations are also compared to established federal and state regulations where appropriate. Any exceedances are discussed. (Note: Appendix N in this RI report contains the preliminary ARAR evaluation that was completed for the *OU 5 Management Plan* [CH2M Hill, 1992d].)

5.3.1 Fuel Products and Constituents

Previous investigations and spill records have shown that fuels, fuel constituents, and their weathered decomposition products are the primary environmental contaminants expected at OU 5. The physical and chemical properties of these products are summarized in Table 5-5.

Laboratory reports and military specifications obtained from Elmendorf AFB Fuels Management address gross performance levels of the fuels and do not quantify specific chemicals. For example, JP-4 jet fuel is made by blending various proportions of distillate stocks, such as naphtha, gasoline, and kerosene, to meet military specifications. There is considerable variability in the concentration of major components and performance characteristics, depending on the source of crude oil.

Diesel, JP-4, and gasoline differ in the average molecular length of the hydrocarbon constituents. This difference can be useful in fingerprinting the source of a leak if more than one fuel type is involved. The molecular length of hydrocarbon constituents is also necessary information for selecting the most appropriate EPA laboratory test method (such as, EPA Method 418.1, 8100 Modified, or 8015 Modified [ADEC, 1991]) to maximize recovery during analysis. The fingerprinting of fuels is most useful for fresh spills or leaks. Petroleum spills lose their short-chain hydrocarbon components by volatilization to the air or solubilization to the groundwater. Old weathered spills in soils tend to retain the more persistent, longer-chain components (Biomedical and Environmental Information Analysis, 1989).

In general, automotive gasoline is composed of hydrocarbons in the range of C_4 to C_{11}, with boiling points from approximately 30°C to 210°C. The reported distillation range for JP-4 is approximately 140°C to 270°C, recovering hydrocarbons in the range of C_4 to C_{14}. Diesel fuel usually distills after kerosene, in the range of 200°C to 400°C. Several grades of diesel fuel are obtained by blending various feedstocks to achieve performance specifications, but diesel fuel is predominantly a mixture of C_{10} through C_{19} hydrocarbons (Biomedical and Environmental Information Analysis, 1989).

Fuel was seen seeping from the base of the bluff near the railroad track at Source ST37 in the late 1950s, and thousands of gallons of fuel were reportedly recovered at the site. Other fuel seeps have been sighted along the entire length of OU 5. Fuel-like sheens have also been reported on the ponds and seasonally wet areas of the lowlands north of Ship Creek. Because fuels are lighter than water (LNAPLs), they can form a floating layer on the groundwater table or on surface water when in concentrations greater than their solubilities. No LNAPLs were encountered in the monitoring wells during this investigation.

Based on the physical and chemical parameters in Table 5-4, volatile components of fuels such as BTEX generally have a relatively high solubility in water, high vapor pressure, low molecular weight, and low K_{oc}. These characteristics result in relatively high mobility of these fuels. BTEX compounds are expected to leach easily from the unsaturated zone and move with the groundwater.

The federal (40 CFR 141) and state (18 AAC 80) drinking water maximum contaminant level (MCL) for benzene is 5 μg/L. Alaska regulations also state that fuel contamination must not result in a sheen or odor. In a past investigation, a water sample from monitoring well SP1-01 exceeded the standards with 13 μg/L benzene and fuel odor. This same well had concentrations of 8.5 μg/L benzene, 290 μg/L TFH diesel, and 1600 μg/L TFH gas when resampled during this 1992 investigation. Because benzene is a known carcinogen, it often drives risk-based calculations and cleanup parameters.

In contrast to BTEX, PAHs have relatively high molecular weight, low vapor pressure, low Henry's law constant, low solubility, and high K_{oc}. In general, PAHs have a high affinity for sorption to most soils and tend to leach more slowly than VOCs. Once in groundwater, they tend to migrate at a slower rate than the groundwater. However, some PAHs, such as naphthalene and acenaphthene, are relatively mobile in groundwater compared with other PAHs.

PAHs are often found at low concentrations in or near surface soils and in stagnant surface water and sediments. The low background levels can result from the ubiquitous use and incomplete combustion of fuels and the use of petroleum products as road surfacing compounds. Background levels for PAHs are not known for Elmendorf AFB.

During this investigation, PAHs were detected in some soil and sediment samples. Several PAHs were detected in two duplicate samples from the surface and one sample from the 4-foot depth at soil boring SB29. Boring SB29 is located in the lower bluff study subarea below the COE building and next to monitoring well SP1-01, which also contained naphthalenes. This location also appears to have grass cuttings and other ground maintenance debris dumped here on a regular basis, and could possibly be a site where small quantities of waste oil have been discarded from individuals changing their automotive oil. Sediment samples in the lower bluff ponds also contained PAHs.

Components with low solubilities and low vapor pressures, such as the heavier and often weathered hydrocarbon components, are likely to remain in the soil and could be transported away from the release area by windblown dusts or by surface runoff. It is possible for compounds with low water solubilities to reach the groundwater if they have higher solubilities in other liquids that occur at the source (for instance, PCBs dissolve in diesel fuel or gasoline).

Spills and leaks at OU 5 have been reported for up to 40 years, especially during the 1950s and 1960s. Therefore, considerable weathering, transport of more soluble or volatile components, and natural biological degradation may have already occurred. Natural attenuation of contaminants will be a vital factor, especially in assessing the off-base migration of groundwater and in defining in-situ treatment parameters.

A more detailed conceptual assessment of the environmental fate and transport of fuel contaminants at OU 5 is found in Section 5.4.

5.3.2 Solvents

During previous investigations, TCE was found in one groundwater monitoring well (NS3-02) at Source SS53, at a trace level of 1.2 μg/L. Well NS3-02 is between the ARRC railroad track and Ship Creek, near the golf course. PCE (0.4 μg/L), TCE (3.0 μg/L), and DCE (2.4 μg/L) were detected in well GW-4A at Source SD40/ST46 in 1986 by Dames & Moore (1988), but were not detected when the well was resampled in 1988 (Black & Veatch, 1990). NS3-02 and GW-4A were not resampled for halogenated VOCs during the 1992 investigation. However, new monitoring wells (MW-30 and MW-31) in nearby areas were sampled and no halogenated VOCs were detected.

During the RI, no soil samples or sediment samples were found to contain halogenated VOCs. However, both upper groundwater aquifer and pond surface water had halogenated VOCs, including the following compounds:

- TCE;
- 1,1,1-TCA;
- 1,1,2,2-tetrachloroethane;
- Chloroethane;
- 1,1-DCA;
- 1,2-DCA; and
- t-1,2-DCE.

The following three solvents occurred in monitoring wells from the upgradient study subarea:

- TCE;
- 1,1,1-TCA; and
- 1,1,2,2-Tetrachloroethane.

Past investigations have found the following halogenated VOCs in Well 1, which is also upgradient of the OU 5 study area (Black & Veatch, 1990; BESG data, Section 1.2.3.3 herein):

- TCE;
- 1,1,1-TCA;
- 1,1,2,2-Tetrachloroethane; and
- 1,1-DCA.

Of the solvents found in OU 5, TCE occurs in the most locations spread across the study area. TCE exceeds the federal (40 CFR 141) and state (18 AAC 80) drinking water regulations of 5 μg/L at monitoring wells in the upgradient subarea (MW02, MW06, MW07) and in the pipeline corridor subarea (SP1-02). TCE was also detected in surface water samples at the golf course beaver pond and the lower bluff pond.

In the past, TCE was used for cleaning activities in flightline shops and at other areas of the base. TCE and its decomposition products, such as DCE and chloroethane, have been detected in the groundwater and/or soils at areas upgradient of OU 5 at concentrations approaching or above established maximum contaminant levels. These areas are the landfills in OU 1, the shop waste disposal site (Source SD16) of OU 3, and near shop drains of OU 4. TCE is also a degradation product of PCE. PCE has been detected in OU 1, OU 3, and OU 4.

TCE has a moderate solubility in water; therefore surface spills are likely to migrate to groundwater or surface water. If a small quantity spill occurred, downward migration to the aquifer or through the water column would be controlled by vertical gradients or dispersion. TCE is heavier than water, so if free product reached the water table, it could sink and eventually become solubilized or collect on a low-permeability layer. A large release of TCE into the permeable alluvial aquifer could result in more rapid vertical migration than would be expected for solubilized contaminants. No layers of contaminants heavier than water (DNAPLs) were encountered during the RI in either the soil borings or the monitoring wells that reached the low permeability Bootlegger Cove Formation. TCE would also be expected to volatilize into the air and soil gas.

A more detailed conceptual assessment of the environmental fate and transport of solvent contaminants at OU 5 is found in Section 5.4.

5.3.3 Heavy Metals

The form, bioavailability, and transport of metals in soils depend on the parent rock material, soil, pH, amount of moisture and organic matter, oxidation-reduction processes, and other complex chemical processes.

At OU 5, lead exceeded background levels in soils in the lower bluff, Post Road corridor, and golf course beaver pond where maximum detected concentrations of 206 mg/kg, 87.2 mg/kg, and 35.2 mg/kg, respectively, were found. No lead was detected in the groundwater samples. Lead has been used as a fuel additive and, therefore, can be found in releases of leaded fuels. Other metals can also be found in fuels (Table 5-5).

Heavy metals may be concentrated in fly ash from the burning of coal. The type and concentrations of metals found in fly ash are dependent on the source of the coal and the particle size. Potentially toxic elements such as arsenic, cadmium, chromium, copper, nickel, antimony, selenium, tin, lead, vanadium, and zinc have been found to be preferentially concentrated on the surfaces of small fly ash particles (Norton et al, 1986).

Arsenic exceeded background (or upgradient) levels in soil, fly ash, and the upper aquifer groundwater at OU 5. According to O'Neill (1990), the proportion of arsenic in fly ash that is water soluble varies, and the value obtained depends on the method of estimation. He reports that fly ash in the United States contained 4 percent of the arsenic in a soluble form by using a high liquid-to-solid ratio. The arsenic in the water extract was determined to be the pentavalent form of arsenic.

In December 1992, upper aquifer groundwater samples were collected from two upgradient subarea wells (MW01 and MW02), one pipeline subarea well (SP1-02), and three lower bluff subarea wells (SP1-01, MW15, and MW16). Fourteen metals were found in higher concentrations in the pipeline corridor or lower bluff subareas than in the upgradient subarea. Comparing the maximum groundwater concentrations detected, the following trends can be identified:

- Aluminum, barium, iron, manganese, and vanadium were detected in the lower bluff subarea at greater than five times the upgradient levels. The concentrations of the five metals also increased over the site in a downgradient direction.
- Arsenic, chromium, copper, lead, nickel, selenium, and zinc were detected in the lower bluff subarea at between two and five times the upgradient levels. The maximum concentrations of arsenic and lead in the pipeline corridor well (SP1-02) were slightly less than in the maximum concentrations in the upgradient subarea. The maximum concentration of selenium on the site was in the pipeline corridor well. The remaining four metals increased across the site in a downgradient direction.
- Calcium and potassium were slightly higher in the lower bluff subarea and slightly less in the pipeline corridor subarea, compared to the maximum upgradient concentrations.

Fly ash samples collected from Source ST37 in December 1992 were analyzed for total metals. Comparison of the fly ash metals to total metals in background soils shows that barium is present in the fly ash at greater than five times the background levels. Lead, potassium, sodium, and thallium only slightly exceeded the background levels. Aluminum, iron, manganese, and vanadium, which are elevated in the lower bluff area groundwater, are not above soil background levels in the fly ash. Arsenic, barium, vanadium, and zinc in the fly ash may be leaching out at levels that represent the detected concentrations in the groundwater.

5.3.4 Polychlorinated Biphenyls

PCBs are potential, but unlikely, contaminants at OU 5. PCB-contaminated oils may have entered drains or been landfilled on the base upgradient of OU 5. Waste oils containing PCBs may also have been sprayed along roadways or the railroad for dust control. PCBs generally have a strong affinity for soils and are expected to have limited mobility unless carried by a non-aqueous liquid or windblown dust. PCB spills on water may result in a surface film when the PCBs are dissolved in petroleum products that are lighter than water, or sink to the bottom when the PCBs are in a heavier-than-water matrix.

PCBs may accumulate in sediments after surface application or spills. Benthic organisms associated with sediments at the bottom of ponds and creeks are known to ingest PCBs; hence, the compounds can be transferred up the food chain. PCBs are stored in the fatty tissue of higher animals and can accumulate to toxic levels, as indicated by the high Log K_{ow} value (Table 5-4).

In past investigations, only subsurface soil samples from Source SD40 (railroad maintenance area) were tested for PCBs (Black & Veatch, 1990); no PCBs were detected. At a meeting on February 21, 1992, project managers for the USAF, EPA, and ADEC agreed that a few sediment samples should be tested for PCBs to determine if they are chemicals of concern and to provide adequate chemical data to assist in evaluating the results of toxicity tests for the ecological investigation at OU 5. One of six sediment samples contained PCBs. The sample was collected from the lower bluff beaver pond. Potential sources of this PCB may be the railroad located next to the pond or snow disposal operations at the top of the bluff.

5.4 Environmental Fate and Migration Pathways

Contaminant migration pathways for unsaturated (vadose) zone soil, groundwater, sediment and surface water, and air are discussed in this section. The conceptual illustration of the pathways is depicted in Figure 5-2. The environmental fate of the following three groups of compounds is emphasized because they are contaminants of concern at OU 5:

- Fuel and its constituents, particularly BTEXs and PAHs, in soil and water;
- TCE and related solvents in water; and
- Metals in soil and water.

Fuels are complex mixtures of hundreds of chemicals. The transport and transformation of individual constituents of fuel will depend on the physical, chemical, and biological properties of the constituents. Some constituents will dissolve more quickly (in percolating groundwater), be sorbed less strongly on soils (transported more rapidly), and may be more or less susceptible to degradation by chemical or biological action. Thus, the relative concentrations of the constituents will vary with time and distance from the source. This effect is called weathering. Weathering may have played a large role in OU 5 already due to the time that has elapsed since the first reported leaks and spills. Current USAF handling procedures for fuels minimize the occurrence of spills, and recent pipeline pressure tests show no current leaks.

Based on the observed distribution of contaminants in soil, groundwater, surface water, and sediments at OU 5, transport is assumed to occur by three principal mechanisms:

- Adsorption to vadose zone particles or sediment particles and transport or disposition with those particles;
- Solution and transport in percolated water, groundwater, and surface water; and
- Flow of LNAPL fuel products through the soil/sediment to the groundwater with seepage to surface water (observed as fuel seeps at the bluff and sheens on surface water).

Although air toxics were not measured at OU 5 during the RI, a fourth transport mechanism will also be evaluated:

- Volatilization and particulate release to the air.

5.4.1 Soils and Vadose Zone Migration Pathways

The major landform of OU 5 is a bluff that traverses from east to west. The bluff is approximately 60 feet high in the west and 20 to 30 feet high in the east. It bisects OU 5 into two areas: deep vadose zone soils on top of the bluff, and soils with a shallow groundwater table in the lowlands at the base of the bluff and along Ship Creek. The soils consist of mixtures or beds of gravel and sand with small amounts of silt. Infiltration of surface precipitation through the deep vadose zone soils on the top of the bluff may be low. Evapotranspiration rates at Elmendorf AFB are greater than the average annual precipitation, so the net precipitation is negative (Section 3.1.1). A negative value for net precipitation indicates a low potential for leachate production. The gravelly and sandy soils at OU 5, however, would not be expected to retard the infiltration of water downward to the groundwater.

Layered strata of different permeability can affect the vertical and horizontal movement of liquids through the unsaturated zone. The less permeable layers of silt and coal lenses found in OU 5 (Section 3.2.3.1) may deflect groundwater flow toward the bluff in the form of seeps after heavy rains or spring thaw. The seeps investigated by soil gas/groundwater studies during the RI had halogenated VOC contamination. Because no known sources of solvents occur in OU 5 and halogenated VOCs are also found in upgradient groundwater samples, the seeps probably represent groundwater rather than water infiltrating directly from the surface.

In addition to the native soil formations, gravel fill material mined from on-site borrow pits has been used to construct roads, building pads, and the railroad. The gravel fill tends to be well drained and have moderate to high permeability. Artificial features, including utility corridors and gravel fill around pipelines, will also affect the migration of contaminants. Data from nearby boring logs may not predict these pathways.

Fly ash, concrete, and bricks have been used to extend the face of the bluff at OU 5. Nothing in the fill material is expected to retard the movement of contaminants to the groundwater, and the fly ash may be a source of metals. The fly ash and construction rubble extend into the apparent water table at OU 5, indicating that as the bluff was extended outward, the water table also extended into the fly ash. Another source of metals may be naturally occurring coal seams. In addition, snow dumped over the bank west of ST38 during snow removal operations on base may have contributed metals and POLs and may affect contaminant migration through the soils due to the volume of water added.

The unsaturated zone, or vadose zone, at OU 5 ranges from zero to approximately 40 feet below ground surface. In general, the vadose zone:

- Is a pathway for the transport of gases and volatile organics;
- Can be a zone of significant biodegradation;
- Can have greater retention than the saturated zone and can thus act as a source of contamination even after the surface has been remediated; and
- Is more difficult to characterize than the saturated zone.

The vadose and saturated zones are part of a continuous subsurface system. Consequently, any investigations and remedial decisions must address both zones. The saturated zone (groundwater) has basewide implications because it crosses source boundaries. The vadose zone is more source-area specific, but can serve as a secondary contamination source to the air and groundwater.

Because of the shallow nature of the groundwater and the permeability of the vadose zone soils, contaminants from large spills of POLs or solvents might be expected to reach the upper aquifer. In fact, both product sheens and dissolved components have been discovered in investigation of OU 5 sources.

The surface aquifers are recharged and surface soils are flushed during the spring thaw. Seasonal water level fluctuations will also occur in wetlands, surface drainage ditches, and in stream banks. This is accompanied by a rise in the groundwater table that peaks in the summer to early fall because of continuous input from snow melt in the Chugach Mountains and from summer precipitation. Hence, movement of residual contaminants from the vadose zone to the groundwater system is expected to be greatest during spring thaw and summer. The August-September sampling period during the RI coincided with the period of maximum annual precipitation (Section 3.1).

Freezing of surface soils during the winter retards infiltration. This has helped in the containment and cleanup of several POL spills that occurred during the winter, including the diesel fuel spill at Source SS42. No significant permafrost occurs on Elmendorf AFB, so it is not expected to be a determinant in the migration pathways of contaminants.

Mechanisms for degradation of vadose zone contaminants (biodegradation, volatilization, and photodegradation) are greatest during the summer, when biologic activity and solar radiation are at their peak. Rates for various biological and chemical degradation processes are expected to be largely temperature and oxygen dependent.

Large releases of fuel may exceed the sorptive capacity of the soil, thereby filling the pore spaces of the soil with fuel. In this situation most of the fuel would move as a bulk fluid downward through the soil and to the groundwater. Volatilization of the fuel components to the air would not be expected to be a significant factor if the releases came from underground sources, as is thought to be the case at most areas of OU 5. At Source SS42, however, a diesel fuel spill occurred at the surface. Volatilization and surface runoff could have been important factors in contaminant migration, except that the ground was frozen, temperatures were low, and most of the fuel was reported to have been recovered.

Often, fuel contaminants are in concentrations below the aqueous solubility. This situation may be found at the edge of a migrating plume, at a slow leak, or after long-term weathering. The fate of the fuel in the soil environment then becomes a function of the solubility, volatility, sorption, and degradation of its major components. The relative importance of each of these processes is influenced by the following factors (Biomedical and Environmental Information Analysis, 1989, Vol. 4):

- Type of release—surface versus underground; small versus large;
- Soil type—organic content; previous history of soil contamination; and
- Environmental conditions—pH, temperature, oxygen content.

Migration of fuels through soils may be retarded by sorption of the fuel to soil particles. The higher the organic content of the soil, the greater the sorption. The deep gravels and sands at OU 5 probably contain little organic matter. The total organic content of soil samples from soil boring SB01 in the upgradient study area was 4,400 mg/kg at the 5-foot depth and 2,160 mg/kg at the 15-foot depth. The total organic contents of the soils at the base of the bluff were found to be high during the RI, ranging from 4,000 to 229,000 mg/kg in the zero- to 3-foot zone. These soils at the base of the bluff tended to be saturated at least part of the year, and well vegetated. Considering only relative organic contents, the soils at the base of the bluff would be expected to retard fuels more than the vadose zone soils beneath the pipelines.

Migration is expected to be fastest through previously contaminated soils where the sorptive sites may be unavailable. Therefore, fuel might flow quite rapidly at locations in the bluff where seeps have been repeatedly reported. Some fuel is left behind in the soil through which the plume traveled. That residue tends to be more concentrated in the fine sands than in the coarser gravels. The residually contaminated soils may serve as sources of leachable fuels for a long time.

Transport processes are more important than degradation in the fate of low-molecular-weight components of fuels. Initially, a large portion of the surface spills of fuels may evaporate or be transported by surface runoff. For subsurface contamination, partitioning to the soil-vapor phase is common for the lower molecular weight aliphatic hydrocarbons (C_4—C_8, JP-4, and gasoline), which are characterized by high vapor pressures and low water solubility. The alkyl benzenes and BTEX have higher water solubilities and may be carried by the infiltrating water. Larger compounds ($>C_9$) are weathered primarily by evaporation and biodegradation (Biomedical and Environmental Information Analysis, 1989). No halogenated VOCs were detected in vadose zone soils during the OU 5 RI.

5.4.2 Groundwater Migration Pathways

Two major sources of groundwater have been identified at Elmendorf AFB:

- A shallow, unconfined aquifer system; and
- A deeper, confined aquifer.

The Bootlegger Cove Formation forms the lower limit of the shallow aquifer and is the confining layer of the deeper aquifer. It is not known whether connections between the aquifers exist under Elmendorf AFB, but the Bootlegger Cove Formation is believed to prevent the downward migration of contaminants to the lower aquifer (Patrick et al, 1989). The only known estimate of the travel time for pollutants between aquifers is a theoretical analysis of the Merrill Field sanitary landfill in Anchorage. The landfill has refuse buried below the upper aquifer water table, thereby creating an environment in which the refuse is continuously leached and the resulting local pollution is high. Nelson (1982) indicated that minor amounts of pollutants may reach the upper part of the confined aquifer after "many tens of years, but that water of the composition of the leachate probably would not reach the aquifer for more than three centuries."

The shallow aquifer at OU 5 is composed of alluvial and outwash deposits. Most sediments consist of alluvial and outwash deposits of sands, gravels, and small amounts of silts with high permeability and a yield of 10 to 1,500 gpm (Patrick et al, 1989). The shallow aquifer is estimated to be 10 to 80 feet thick, based on a review of boring logs from the RI and previous investigations.

Data collected during the RI indicate that the shallow-aquifer groundwater flow across the southern part of Elmendorf AFB occurs in a south or southwest direction (Figure 3-11). Consequently, OU 5 is downgradient of other OUs and potential contamination sources on the base (Figure 1-2). Groundwater monitoring wells placed upgradient of the pipelines at OU 5 had low levels of dissolved fuels and solvents, indicating that contaminants are coming into OU 5 from unknown upgradient sources. Some uncertainty exists with these interpretations because of data limitations. Water level measurements and chemical sampling were done only during a high groundwater and stream flow period (August through October). Consequently, that data cannot address the issue of seasonal variability. Ongoing groundwater studies on Elmendorf AFB will provide a more complete picture in the future.

Groundwater velocities depend on hydraulic gradient, hydraulic conductivity, and porosity; all are moderate to high in the unconfined aquifer at the southern part of the base. The hydraulic gradient within the unconfined aquifer along the southern portion of the base at the east end of OU 5 is 95 feet per mile and at the west end of OU 5 is 264 feet per mile in a south or southwest direction based on the data from the RI. Locally, hydraulic gradients may increase near surface water bodies or shallow operating wells. Hydraulic conductivity was estimated by slug tests at newly installed wells during the 1992 RI. The inherent limitations in the slug test data are discussed in Section 2.1.5.7. Hydraulic conductivity ranged from 1.4 feet per minute (ft/min) (0.71 cm/sec) at MW14 to 0.027 ft/min (0.016 cm/sec) at MW16 (Appendix F).

The magnitude of seasonal water level fluctuations in the unconfined aquifer is not well known. Water levels are expected to rise in the spring in response to the spring thaw and through the summer from continued input from the Chugach Mountains and precipitation. The levels then should fall slowly in fall and winter. Any free product layer (for example, fuel contaminants) floating on the water table would be smeared or spread over the aquifer materials that were dehydrated as water levels in the aquifer declined. The smear zone often proves to be the most important secondary source of contamination and is often the most difficult area to remediate.

During the RI, water level measurements were taken three to four times on OU 5 monitoring wells from early August to late October 1992. Little change in water level elevations was observed during that short interval (Appendix E).

Advection and dispersion are believed to be the primary transport mechanisms for dissolved phase contaminants. Advection, movement as a consequence of groundwater flow, primarily influences horizontal transport of contaminants in the saturated zone. Dispersion, fluid mixing due to effects of heterogeneities in permeability, influences both the vertical and lateral spreading of a contaminant plume.

Molecular diffusion caused by concentration gradients would be expected to play a minor role in transporting contaminants, compared to advection and dispersion.

The capacity of the unconfined aquifer to retard contaminant migration is expected to be low because of limited amounts of organic material and silt and/or clay in the soils on the bluff. Most contaminants are expected to migrate at approximately the rate of groundwater flow. However, individual contaminants may have particle velocities that differ significantly from water velocity.

Once in solution, most fuel-related contaminants (such as hydrocarbons and BTEX compounds at saturation) are expected to concentrate and migrate near the top of the aquifer. Conversely, nonaqueous liquids with densities greater than water (for example, TCE and PCE) could migrate vertically downward through the aquifer if free product reached the water table. Chlorinated compounds in solution at concentrations much less than saturation will move primarily by advection and dispersion near the top of the aquifer. To date, chlorinated compounds and BTEX have been found only in concentrations below saturation and, hence, are dissolved and carried by advection near the top of the aquifer.

Results of the RI show that fuel and perhaps solvent contamination has moved off base via the upper aquifer. The Elmendorf AFB boundary runs roughly along the top of the bluff on the western end of OU 5. Off-base monitoring wells SP1-01, MW16, MW15, and MW13 in the lower bluff and Post Road corridor subareas each had at least three of the following contaminants (maximum amount detected in the wells):

- JP-4 (730 μg/L);
- TFH gas (1600 μg/L);
- TFH diesel (290 μg/L);
- Benzene (8.5 μg/L);
- Ethyl benzene (16 μg/L);
- Xylenes (570 μg/L);
- 2-Methylnaphthalene (9 J μg/L);
- Naphthalene (13 J μg/L); and
- 1,1-DCA (1.3 μg/L).

Monitoring Wells MW14 and MW17, downgradient of the aforementioned off-base wells, did not have any organic contaminants.

The confined aquifer is overlain by substantial thicknesses of the Bootlegger Cove Formation. Cederstrom et al (1964) estimated the thickness of the confining layer in the vicinity of OU 5 to be 50 to 150 feet. The clays and silts that make up the formation have low hydraulic conductivity and would be expected to retard contaminant flow between the two major aquifer systems. Whether connections exist between the two aquifer systems under the base is not known due to lack of stratigraphic data. The historic artesian nature of the confined aquifer may serve to force any groundwater movement between the two systems upward rather than downward. However, well pumping in localized areas may cause cores of depression and reverse the assumed direction of vertical flow.

5.4.3 Surface Water and Sediment Pathways

Surface water bodies in the vicinity of OU 5 include Ship Creek, ponds, and permanently and seasonally wet areas. Surface water is an important source of drinking water for the base. However, surface water supplies come from sources upgradient of the base, such as Eklutna and Ship Creek reservoirs.

South of the Elmendorf moraine, surface water drains south and west into Ship Creek. The surface water travels through culverts and road ditches to arrive at Ship Creek (Figure 2-2). The upper Ship Creek basin is an important recharge area for the Anchorage confined aquifer and provides approximately 25% of the total recharge to the system (Weeks, 1970). Surface water quality on Elmendorf AFB is monitored by the base Bioenvironmental Engineering Services group (Section 1.2.3.2), Black & Veatch (1990) collected several samples from Ship Creek (Section 1.2.3.1), and more samples were analyzed for the RI (Section 4.4). Generally, the water quality of the analyzed samples from Ship Creek has been good. However, there are reports from previous investigators of foam in Ship Creek, and fuel sheens and petroleum odors on ponds in road ditches at OU 5.

Contaminant migration in surface water and sediment is strongly influenced by the spring thaw, when large volumes of water are flushed through the surface water drainage system. This event would influence the following primary contaminant migration mechanisms:

- Flushing, solubilization, and/or erosion of contaminated surface soils by surface runoff, with eventual discharge to the receiving surface water body;
- Flushing of vadose zone contaminants to the groundwater system, and later discharge to a receiving surface water body; and
- Resuspension and transport of sediments during peak discharge periods.

Similar processes would occur during heavy summer or fall rains.

Contaminants are mobilized primarily either as dissolved constituents or adsorbed particulate matter. Once introduced to the surface water systems, many contaminants will undergo various transport, transformation, or degradation processes, including volatilization, adsorption, biodegradation/bioaccumulation, and photodegradation.

Ship Creek appears to be a gaining stream in the OU 5 study area. Studies during the RI showed good hydraulic communication between the groundwater in the Ship Creek alluvium and the creek, and a general trend of groundwater flow toward Ship Creek. Chemical analysis of surface water from Ship Creek during the RI shows it to be free of organic contaminants.

Estimated Worst-Case Surface Water Concentrations

The surface water and sediment monitoring conducted as part of the OU 5 investigation was performed on two occasions, both during the summer months when flow within Ship Creek was at or near maximum. Historical data for Ship Creek (USGS, 1976) indicate that minimum flows, ranging from 17 to approximately 20 cfs, occur during the late winter months (February through April). Seepage studies conducted by the USGS (Weeks, 1970) indicate that groundwater discharges into Ship Creek as base flow in the vicinity of

OU 5. Therefore, the maximum impact that contaminated groundwater could have on Ship Creek water quality would be expected to occur during the low flow period.

No water quality data are available for Ship Creek during the low flow period. However, groundwater data collected as part of the OU 5 investigation were used in conjunction with historical flow records to estimate potential worst-case concentrations in Ship Creek during the low flow period. The estimated concentrations do not represent a prediction of actual concentrations for this period, but rather what concentrations could be in Ship Creek in a worst-case scenario based on the available data.

The estimated worst-case concentrations were calculated by comparing the estimated volume of groundwater flowing through OU 5 with minimum Ship Creek flows, and using the results to estimate the extent to which measured groundwater concentrations are diluted upon entering Ship Creek. The estimated worst-case concentrations are based on a series of assumptions, including the following:

- The flow volume in Ship Creek equals the lowest average daily flow rate of 17 cfs recorded at the Ship Creek gaging station (no longer in service) below the power plant at Elmendorf AFB on March 29, 1975.
- The estimated groundwater flow rate of 4 cfs through the unconfined aquifer beneath OU 5, based on water level data collected on September 24, 1992, is representative of groundwater flow at other times of the year.
- The available stratigraphic data are sufficient to estimate the cross-sectional area of the unconfined aquifer through which groundwater flowing into OU 5 must move.
- All groundwater flowing into OU 5 through the unconfined aquifer enters Ship Creek along the southern boundary of OU 5.
- Groundwater concentrations measured in samples from OU 5 monitoring wells completed in alluvium near Ship Creek are representative of groundwater concentrations entering Ship Creek.

- Groundwater concentrations are reduced by an amount proportional to the ratio of groundwater flow (4 cfs) to Ship Creek flow (17 cfs), to a value that is approximately 25% of the original concentration.

The volume of groundwater flowing through OU 5 was estimated by drawing a cross section through the unconfined aquifer, perpendicular to the direction of flow, along the 125-foot contour line (refer to Figure 3-11). Stratigraphic information obtained from monitoring well logs (for wells located along the 125-foot contour line) was used to estimate the cross-sectional area of the saturated zone (approximately 1.86×10^{4} square feet). This cross-sectional area was multiplied by a linear groundwater flow velocity to estimate a steady state groundwater flux through OU 5. The linear velocity is based on an estimated gradient of 0.02, a hydraulic conductivity of 3.3×10^{4} feet per second, and an aquifer porosity of 30 percent.

The groundwater concentrations used in this exercise are actually upper-confidence limits (for a 95% confidence interval) for a mean concentration calculated using data from 11 wells located near Ship Creek. (The wells include the following: MW08, MW09, MW10, MW12, MW13, MW14, MW15, MW16, MW17, MW30, and MW31. The parameters for which mean concentrations were calculated—gasoline-range hydrocarbons, JP-4-range hydrocarbons, diesel-range hydrocarbons, and benzene—were each detected in at least one of the wells used in the calculation. Although other parameters were detected in several of these wells, they were not used to estimate worst-case concentrations because no standards exist against which they may be compared.

The worst-case concentrations and applicable standards are listed in Table 5-6. The results listed in Table 5-6 indicate several points of importance:

- Most of the chemical-specific organic compounds included in this investigation are not expected to enter Ship Creek in measurable quantities.
- Benzene concentrations are well below the only applicable standard.

Table 5-6

Estimated Worst-Case Concentrations for Ship Creek During Low Flow Periods

Parameter	Estimated Worst-Case Concentration	Surface Water Criteria[a]	
		CWA Criteria[b]	Alaska Criteria[c]
Benzene	1.21 μg/L	5300 μg/L[d,e]	
Gasoline	0.182 mg/L		0.015 mg/L[f]
JP-4	0.237 mg/L		0.015 mg/L[f]
Diesel	0.083 mg/L		0.015 mg/L[f]

[a] The surface water criteria used as a basis for comparison with the estimated worst-case concentrations apply to the protection of aquatic life and wildlife rather than human health criteria. Ingestion of water from Ship Creek by humans was not considered in the human health risk assessment.

[b] Clean Water Act Ambient Water Quality Criteria for Protection of Aquatic Life.

[c] Alaska Water Quality Criteria (18 AAC 70.020) for petroleum hydrocarbons, oil and grease in water; class (1)(C) Aquatic Life and Wildlife.

[d] This value is an acute standard; no CWA chronic standard is available for benzene.

[e] Lowest observed effect level.

[f] The value of 0.015 mg/L applies to total hydrocarbons.

- **The calculated worst-case concentrations exceed the only applicable Alaska surface water criterion by more than an order of magnitude for gasoline and JP-4, and by a factor of 5 for diesel.**

The method detection limits for gasoline-, JP-4-, and diesel-range hydrocarbons are 0.050 mg/L, 0.100 mg/L, and 0.100 mg/L, respectively. The total hydrocarbon standard of 0.015 mg/L is much lower than any of these method detection limits. This difference is largely responsible for the estimated worst-case concentrations exceeding the standard because gasoline- and JP-4-range hydrocarbons were only detected in 2 of 11 samples considered, and the diesel-range hydrocarbons were detected in only 1 sample. Given the gap between the method detection limits and the current standard, it is probably not reasonable to conclude that total hydrocarbon concentrations in Ship Creek would rise to levels that pose a threat to aquatic life and wildlife. This is consistent with the results of the ecological risk assessment (Section 6.2).

5.4.4 Airborne Volatile and Particulate Migration Pathways

Contaminant transport to the atmosphere results from two primary mechanisms: volatilization and air entrainment of contaminated particulates.

Volatilization from contaminant sources and windblown dusts is expected to be greatest during the summer, when solar radiation is at a peak, and ambient soil, groundwater, and surface water temperatures rise. Constituents most likely to volatilize are those with vapor pressures greater than 10^{-3} mm of mercury (Table 5-3). Such constituents include aromatic hydrocarbons, such as BTEX, and chlorinated solvents, such as TCE. Volatilization is expected to be greatest where fuels have seeped to the surface soils or reached surface waters.

Airborne volatiles near building foundations or in basements are not expected to be pathways of concern at OU 5 now or in the future because of low concentrations of volatiles and limited future building sites in the OU. Soil contamination was found only in low concentrations and at depth near the groundwater table in the pipeline corridor and upgradient subareas where current buildings are located. The groundwater throughout the OU has volatiles only in the low parts-per-billion range, and soil gas studies during the RI showed few areas where volatiles were venting through the vadose zone (see Section 4.1). The bluff area is not likely to be used as building sites. Slope failure occurred along the bluff just west of OU 5 and near the snow disposal pond during the Alaska earthquake of 1964. Also, much of the area between the bluff and Ship Creek is unsuitable for building because of standing water and areas that would probably be delineated as wetlands.

Where contaminated surface soils are exposed or not covered by surface vegetation, contaminants can be transported as windblown dusts. Contaminants which may migrate as dusts are those with a strong adsorptive affinity, such as PCBs, metals, and PAHs. The only PCBs detected at OU 5 were in a single sediment sample at the bottom of the snow disposal pond; they are not likely candidates for particulate transport.

Air is not expected to be a significant pathway for the transport of volatiles or contaminated particulates at OU 5 for the following reasons:

- The primary sources are thought to be underground pipelines and therefore are not directly exposed to the air or wind.
- Soil overburden and heavy vegetative cover at OU 5 will restrict volatilization to the air and prevent contaminated soil from reaching the surface as particulates.
- Cold temperatures for 6 months of the year will restrict volatilization.
- Snow cover for 6 months each year will further limit transport of soil particles. Areas below the bluff are saturated or moist for most of the rest of the year.
- Existing field reports and interviews with base personnel do not indicate any air quality problem related to the suspected sources.

Surface soil contamination at OU 5 was limited in areal extent and magnitude. A surface sample (0- to 2-foot depth) at SB29 had an estimated 5 mg/kg total PAHs, 6.1 mg/kg diesel fuel, and both lead and barium concentrations slightly above background. The surface contamination at SB29 is speculated to be limited to a small area of surface dumping (grass cuttings). Surface soil samples (0- to 1-foot depth) near seep areas SL04, SL16, SL19, SL20, and SL29 had diesel contamination of 151, 49, 9, 2, and 29 mg/kg, respectively. Those seep area samples also slightly exceeded background levels for one or more of the following metals: arsenic, barium, cadmium, chromium, selenium, and silver. the surface soils near those seeps tend to have high moisture contents (13 to 76 percent moisture) and would be unlikely to contribute to particulate production.

Direct air sampling was not done during the RI, but potential air exposures will be estimated from surface soil and surface water samples concentrations in Section 6.0. Data from direct air measurements are seldom available from source investigations because measuring air volatiles and contaminants on particulates is a complex, expensive endeavor. Other sources, such as power plants and off-base industrial activities, may also confound data obtained during air sampling.

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6.0 BASELINE RISK ASSESSMENT

This section presents the results of the baseline risk assessments for organisms potentially exposed to contaminants in OU 5. The overall purpose of the risk assessments is to provide a qualitative and/or quantitative appraisal of actual or potential effects of contaminants on humans, other animals, and plants to help determine whether there is a need for remedial action (or no action) and to help determine the scale of a remedial action.

A baseline risk assessment evaluates potential threats to public health and the environment in absence of any remedial action (the no-action alternative) (EPA, 1988a). It identifies and characterizes the toxicity of chemicals of potential concern, the possible exposure pathways, the potential human and ecological receptors, and the upper bound on possible risks under the conditions defined for the facility.

The no-action alternative assumes that no corrective actions will take place and no restrictions will be placed on future uses of the areas currently occupied by OU 5. The baseline human health and ecological evaluations address potential risks from OU 5 under current and reasonable future land uses. Evaluation of this no-action alternative is required under Section 300.430(d) of the NCP (EPA, 1990).

6.1 Human Health Evaluation

6.1.1 Introduction

This section presents the results of the baseline human health evaluation for the OU 5 RI/FS. The potential pathways for human exposure to contaminants at OU 5 are shown in the conceptual model diagram, Figure 5-3.

6.1.1.1 Risk Assessment Guidance

This baseline human health evaluation was performed in accordance with the following guidance documents and advisories:

- *Risk Assessment Guidelines* (EPA, 1986a, 1986b, and 1986c);
- *Exposure Factors Handbook* (EPA, 1989a);
- *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual (Part A)* (EPA, 1989b);
- *Supplemental Guidance for Superfund Risk Assessments in Region 10*, (EPA, 1991a); and
- *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors* (EPA, 1991b).

This assessment is based on the following major assumptions:

- No remedial actions have been or will be conducted.
- There is potential for future development of areas currently occupied by OU 5 under reasonable assumptions of future land use.
- For the purpose of risk calculations, chemical concentrations are assumed to remain constant over the assumed exposure periods.

This human health evaluation is based on chemical analysis of surface and subsurface soils, surface water, sediments, and groundwater samples collected during the RI.

6.1.1.2 Report Organization

The human health evaluation for OU 5 is organized into six sections:

- Identification of chemicals of concern;
- Toxicity assessment;
- Exposure assessment;
- Risk characterization;
- Uncertainties and assumptions; and
- Summary and comparison to EPA benchmarks.

Identification of the chemicals of concern is based on the conceptual site model, sampling and analysis data, background concentrations of the chemicals detected, environmental transport and fate, nature and extent of contamination, and the toxicology of the chemicals detected.

The toxicity assessment involves gathering the available toxicology information regarding the chemicals or concern to answer two questions:

- What adverse health effects are associated with exposure to the chemicals of concern?
- What level of exposure is associated with the occurrence of adverse health effects?

The toxicity information gathered includes quantitative toxicity estimates that the EPA has developed. These estimates are collectively known as toxicity values and usually include reference doses for assessing noncancer effects, and cancer slope factors for assessing the risk of cancer.

The objective of the exposure assessment is to assess the potential routes of exposure, and the frequency, duration, and magnitude of potential exposures to the chemicals of concern. The result of the exposure assessment is usually a quantitative estimate of the level of exposure. This information is combined with the results of the toxicity assessment to develop the risk characterization.

The objective of the risk characterization section is to qualitatively and quantitatively characterize the risk of developing noncancer adverse effects or cancer in potential receptors exposed to the chemicals of concern under conditions specified in the exposure assessment. The risk of developing noncancer effects is estimated by the hazard index method wherein the estimated daily intake of a chemical is compared to the reference dose for that chemical. The risk of developing cancer is estimated by calculating the excess lifetime cancer risk, which is the product of the estimated daily intake of a chemical and the cancer slope factor for that chemical.

The section on uncertainties and assumptions describes the basic assumptions used in the risk assessment and limitations of data and methodology.

The final section summarizes the results of the human health evaluation.

6.1.1.3 Approach to Risk Estimate Calculations

A two-phased approach is used to calculate risk estimates for the exposure pathways:

- **Phase I: Maximum Screen.** For each pathway, the maximum concentration for each chemical (sitewide or within a study subarea) is used as the exposure concentration to calculate a risk estimate using reasonable maximum exposure assumptions. If the estimated hazard index for the noncancer health evaluation is less than 1 and the lifetime excess cancer risk is less than 1 x 10^{-6} (one in a million) the evaluation is considered complete.

- **Phase II: Baseline Risk Assessment.** For each pathway that is not eliminated through the maximum screening calculations, risk estimates are calculated using both the arithmetic average (Average Case) and the

95% upper confidence limit on the arithmetic average (Reasonable Maximum Case) as exposure concentrations.

The phased approach has the benefit of rapidly screening out pathways of low risk to human health. The maximum screen is a conservative approach, and risk estimates for pathways generated by using the averaging statistics of the baseline risk assessment can be expected to be even lower. This approach follows EPA guidance, which states:

> For some sites, where a screening level analysis is regarded as sufficient to characterize potential exposures, calculation of the upper confidence limit on the arithmetic average is not required. In those cases, the maximum detected or modeled concentration should be used as the exposure concentration (EPA, 1989b, p. 6-22).

The criteria chosen to trigger the baseline risk assessment are also based on EPA guidance. The EPA uses the general 10^{-4} to 10^{-6} excess lifetime cancer risk range as a "target range" within which the agency strives to manage risks as a part of a CERCLA cleanup. A noncancer hazard index greater than 1 can also trigger management decisions (EPA, 1990, 1991c).

6.1.2 Identification of Chemicals of Concern

The results of the chemical analyses of soil, sediment, groundwater, and surface water samples collected from OU 5 were evaluated to determine whether the analyses were valid and useful for risk assessment. Data validation procedures are described in Section 2.3 of this report.

Only EPA Level III (CLP equivalent) laboratory data are used in the human health risk assessment. The field screening (EPA Level II) data obtained during soil gas and groundwater probe studies are not used in the evaluation.

During data validation, the data were reviewed to eliminate results that might represent contamination of samples in the laboratory or in the field or that failed to meet quality control guidelines (for example, insufficient surrogate spike recovery). Estimated results (data with a J qualifier) that met data validation requirements were considered usable for risk assessment (EPA, 1989b).

Chemicals detected in the samples collected from OU 5 were identified as chemicals of concern for the evaluation of human health risk based on the following criteria:

- Positively detected at least once in at least one medium (soil, sediment, groundwater, or surface water) sampled at OU 5.
- At least one detection exceeded background criteria described in Sections 4.2 and 4.3 This criterion was applied only to total metals because background concentrations were not available for organic compounds. Total metals, not dissolved metals, in groundwater were used in the human health risk assessment.

The chemicals that met either or both of these criteria were designated as chemicals of concern and are listed in Table 6-1 by the medium in which they were detected. The chemicals of concern were then grouped by study subarea, as described in Section 4, for exposure assessment and risk characterization. Data summaries for the chemicals detected in soil, sediments, groundwater, and surface water are presented in Section 4.

6.1.3 Toxicity Assessment

The purpose of the toxicity assessment is to weigh the available evidence regarding the potential for particular contaminants to cause adverse effects in exposed individuals and to provide, where possible, an estimate of the relationship between the extent of exposure to a contaminant and the increased likelihood or severity of adverse effects. Toxicity assessment for contaminants found at Superfund sites is generally accomplished in two steps: hazard identification and dose-response assessment.

Table 6-1

Compounds Detected by Media

Chemical	Surface Soil	Subsurface Soil	Groundwater		Sediment	Surface Water
			Upper	Lower		
Petroleum-Related Compounds						
JP-4	X	X	X		X	X
TPH-Gasoline	X	X	X		X	X
TPH-Diesel	X	X	X		X	
Semivolatile Organic Compounds						
Acenaphthylene	X					
Anthracene	X	X			X	
Benzo(a)anthracene	X	X			X	
Benzo(b)fluoranthene	X	X			X	
Benzo(k)fluoranthene	X	X			X	
Benzo(g,h,i)perylene	X	X				
Benzo(a)pyrene	X	X			X	
Bis(2-ethylhexyl)phthalate	X	X	X		X	
Carbazole	X					
Chrysene	X	X			X	
Dibenz(a,h)anthracene	X					
Dibenzofuran	X					
Diethylphthalate		X	X			
Di-n-butylphthalate		X	X			
Fluoranthene	X	X			X	
Fluorene	X	X				
Indeno(1,2,3-c,d) Pyrene	X	X				
2-Methylnaphthalene	X	X	X		X	
4-Methylphenol					X	X
Naphthalene	X		X		X	X
N-Nitrosodiphenylamine			X			

Table 6-1

(Continued)

Chemical	Surface Soil	Subsurface Soil	Groundwater		Sediment	Surface Water
			Upper	Lower		
4-Nitrophenol		X				
Phenanthrene	X	X			X	
Phenol					X	
Pyrene	X	X				
Volatile Organic Compounds						
Benzene	X	X	X			X
Bromomethane						X
Chloroethane			X			
1,1-Dichloroethane			X			X
1,2-Dichloroethane						X
trans-1,2-Dichloroethene						X
Ethylbenzene	X	X	X		X	X
Tert-butyl Methyl Ether			X			
1,1,2,2-Tetrachloroethane			X			X
Toluene	X	X	X		X	X
1,1,1-Trichloroethane			X			X
Trichloroethene			X			X
Xylenes, Total	X	X	X		X	X
Polychlorinated Biphenyls						
Aroclor 1260	NA	NA	NA	NA	X	NA
Inorganics						
Aluminum	X	X	X		X	X
Antimony		X	X			
Arsenic	X	X	X	X	X	X
Barium	X	X	X	X	X	X
Beryllium	X	X	X		X	X

Table 6-1

(Continued)

Chemical	Surface Soil	Subsurface Soil	Groundwater		Sediment	Surface Water
			Upper	Lower		
Boron	X	X	NA	NA	NA	NA
Cadmium	X	X	X		X	X
Calcium	X	X	X	X	X	X
Chromium	X	X	X		X	
Cobalt	X	X	X		X	
Copper	X	X	X	X	X	X
Iron	X	X	X	X	X	X
Lead	X	X	X		X	X
Magnesium	X	X	X	X	X	X
Manganese	X	X	X	X	X	X
Mercury	X	X	X		X	
Molybdenum	X	X	NA	NA	NA	NA
Nickel	X	X	X		X	X
Nitrate				X		
Potassium	X	X	X	X	X	X
Selenium	X	X	X	X	X	X
Silver	X	X			X	
Sodium	X	X	X	X	X	X
Thallium	X	X			X	X
Vanadium	X	X	X		X	X
Zinc	X	X	X	X	X	X

NA = Not analyzed

The first step, hazard identification is the process of determining whether exposure to an agent can cause an increase in the incidence of a particular adverse health effect (for example, cancer or a birth defect) and whether the adverse health effect is likely to occur in humans. Hazard identification involves characterizing the nature and strength of the evidence of causation. The second step, dose-response evaluation, is the process of quantitatively evaluating the toxicity information and characterizing the relationship between the dose of the contaminant administered or received and the incidence of adverse health effects in the exposed population. From this quantitative dose-response relationship, toxicity values (such as reference doses and slope factors) are derived that can be used to estimate the incidence or potential for adverse effects as a function of human exposure to the chemical. These toxicity values are used in the risk characterization step to estimate the likelihood of adverse effects occurring in humans at different exposure levels. EPA has performed the toxicity assessment step for many chemicals and has made available the resulting toxicity information and toxicity values, most of which have undergone extensive peer review.

6.1.3.1 Hazard Identification

For assessing human health risks, health effects are divided into two broad groups—noncancer effects and cancer. This division is based on the different mechanisms of action currently associated with each category. Thus, for this assessment, chemicals causing noncancer effects are handled independently from those having cancer effects. However, some chemicals are considered in both categories.

Noncancer Effects

Noncancer health effects include a variety of toxic effects on body systems ranging from renal toxicity (toxicity to the kidney) to central nervous system disorders. Noncancer health effects fall into two basic categories: acute toxicity and chronic toxicity. Acute toxicity can occur after a single exposure (usually at high doses) and the effect is most often seen immediately. Chronic toxicity occurs after repeated exposure (usually at low doses) and is seen weeks, months, or years after the initial exposure. Noncancer effects, in contrast to cancer effects, are assumed to result only after a critical level of exposure (a toxic threshold) is exceeded. It is believed that organisms may have adaptive mechanisms that must be overcome before a toxic endpoint (effect) is manifested. The noncancer effects observed in toxicology studies of the chemicals of concern at OU 5 are presented in Tables 6-2 and 6-3.

Cancer

Some chemical exposures result in or are suspected of resulting in cancer. EPA as developed a carcinogen classification system (EPA, 1986a) using a weight-of-evidence approach to classify the likelihood that a chemical is a human carcinogen. Information considered in developing the classification includes human studies of the association between cancer incidence and exposure, as well as long-term animal studies under controlled laboratory conditions. Other supporting evidence considered includes short-term tests for genotoxicity, metabolic and pharmacokinetics properties, toxicological effects other than cancer, structure-activity relationships, and physical and chemical properties of the chemical.

The weight-of-evidence classification (Table 6-4) is an attempt to account for the uncertainty in the evidence of carcinogenicity. The evidence is characterized separately for human studies and animal studies as sufficient, limited, inadequate, no data, or evidence of no effect.

6.1.3.2 Dose-Response Evaluation

The development of toxicity is dependent on the dose of a chemical and the route of administration or exposure. The dose-response relationship is a qualitative or quantitative expression of the response observed in a test population of either humans or other animals at a given dose or range of doses. Toxicity values are quantitative expressions

Table 6-2

Oral Reference Dose Values for the Chemicals of Concern at OU 5

Chemical	Reference Dose (RfD) (mg/kg/day)	Source[a]	Critical Effect	UF[b]	MF[c]	Confidence in RfD[d]
Antimony	0.0004	IRIS	Longevity, blood glucose, and cholesterol effects	1,000	1	Low
Arsenic	0.0003	IRIS	Keratosis and hyperpigmentation	3	1	Medium
Barium	0.07	IRIS	Increased blood pressure	3	1	Medium
Beryllium	0.005	IRIS	No adverse effects	100	1	Low
Bis(2-ethylhexyl) phthalate	0.02	IRIS	Increased relative liver weight	1,000	1	Medium
Boron	0.09	IRIS	Testicular lesions	100	1	–
Bromomethane	0.0014	IRIS	Epithelial hyperplasia of the forestomach	1,000	1	Medium
Cadmium	0.0005	IRIS	Significant proteinuria	10	1	High
Chromium III	1	IRIS	No effects observed	100	10	Low
Chromium VI	0.005	IRIS	No effects reported	500	1	Low
Copper	0.037[e]	HEAST	Local gastrointestinal irritation	–	–	–
1,1-Dichloroethane	0.1	HEAST	No effects reported	1,000	1	–
trans-1,2-Dichloroethene	0.02	IRIS	Increased serum alkaline phosphatase in male mice	1,000	1	Low
Dibenzofuran	0.0042[f]	MEMO 1/92	Kidney effects	3,000	1	Low
Di-n-butylphthalate	0.1	IRIS	Mortality	1000	1	Low
Diethylphthalate	0.8	IRIS	Decreased growth rate and food consumption and altered organ weights	1,000	1	Low

Table 6-2

(Continued)

Chemical	Reference Dose (RfD) (mg/kg/day)	Source[a]	Critical Effect	UF[b]	MF[c]	Confidence in RfD[d]
Ethylbenzene	0.1	IRIS	Liver and kidney toxicity	1,000	1	Low
Fluoranthene	0.04	IRIS	Nephropathy, increased liver weights, hematological changes, and clinical effects	3,000	1	Low
Fluorene	0.04	IRIS	Decreased red blood cells, packed cell volume, and hemoglobin	3,000	1	Low
Fluoride	0.06	IRIS	Dental Fluorosis	1	1	–
JP-4	0.08[h]	EPA	Fatty changes in livers of female mice	10,000	1	Low
Manganese	0.1	IRIS	Central nervous system effects	1	1	Medium
Mercury, inorganic	0.0003	HEAST	Kidney effects	1,000	1	–
4-Methyl phenol	0.05	HEAST	Decreased weight gain and neurotoxicity	1,000	1	Medium
Molybdenum	0.005	HEAST	Increased uric acid pain and swelling in joints	30	–	–
Naphthalene	0.04	HEAST	Decreased body weight gain	1,000	1	–
Nickel	0.02[g]	IRIS	Decreased body and organ weights	100	3	Medium
Nitrate	1.6	IRIS	Early clinical signs of methemoglobinemia in excess of 10% (0-3 months old infants formula)	1	1	High

Table 6-2

(Continued)

Chemical	Reference Dose (RfD) (mg/kg/day)	Source[a]	Critical Effect	UF[b]	MF[c]	Confidence in RfD[d]
Phenol	0.6	IRIS	Decreased fetal weight in rats	100	1	Low
Pyrene	0.03	IRIS	Kidney effects	3,000	1	Low
Selenium	0.005	IRIS	Clinical selenosis	3	1	High
Silver	0.005	IRIS	Argyria	3	1	Low
TFH Diesel	0.008[h]	EPA	Fatty changes in livers of female mice	10,000	1	Low
TFH Gas	0.2[h]	EPA	Reduced body weight gain in female mice	1,000	1	Low
Thallium (soluble salts)	0.00007	HEAST	Increased SGOT and serum LDH levels, alopecia	3,000	1	–
Toluene	0.2	IRIS	Changes in liver and kidney weights	1,000	1	Medium
1,1,1-Trichloroethane	0.09	HEAST	Hepatotoxicity	1,000	1	–
Vanadium	0.007	HEAST	None observed	100	1	–
Xylenes	2	IRIS	Hyperactivity, decreased body weight and increased mortality (males)	100	1	Medium
Zinc	0.2	HEAST	Anemia	10	1	–

[a] Sources of toxicity values:
IRIS–Integrated Risk Information System (EPA 1992e)
HEAST–Health Effects Assessment Summary Tables–Annual Summary (EPA 1992d, for all chemicals except thallium; EPA 1991f, for thallium).

[b] UF–Uncertainty factor.

[c] MF–Modifying factor.

[d] Confidence in RfD as reported in IRIS.

[e] Based on proposed drinking water standard of 1.3 mg/L.

[f] Provisional RfD. Source: Memorandum from Kenneth Poirier, EPA, to Bill Dana, DEQ, on Jan. 24, 1992.

[g] Nickel value based on nickel-soluble salts.

[h] Provisional RfD. Source: Memorandum from Joan Dollarhide, Superfund Health Risk Technical Support Center to Carol Sweeney, EPA Region 10 on March 24, 1992.

Table 6-3

Inhalation Reference Concentrations for the Chemicals of Concern at OU 5

Chemical	Reference Concentration (RfC, mg/m³)	Source[a]	Critical Effect	UF[b]	MF[c]	Confidence in RfC[d]
Barium	0.0005	HEAST	Fetotoxicity	1,000	1	--
Trivalent chromium	0.000002	HEAST	Nasal mucosa atrophy	300	1	--
Hexavalent chromium	0.000002	HEAST	Nasal mucosa atrophy	300	1	--
1,1-Dichloroethane	0.5	HEAST	Kidney damage	1,000	1	--
Ethylbenzene	1	IRIS	Developmental toxicity	300	1	Low
Manganese	0.0004	IRIS	Increased prevalence of respiratory symptoms and psychomotor disturbances	300	3	Medium
Mercury (inorganic)	0.0003	HEAST	Neurotoxicity	30	1	--
Toluene	0.4	HEAST	Central nervous system effects and eye and nose irritation	300	1	--
1,1,1-Trichloroethane	1	HEAST	Hepatotoxicity	1,000	1	--
Xylenes	0.3	HEAST	Central nervous system effects and nose and throat irritation	100	1	--

[a] Sources of toxicity values:
IRIS--Integrated Risk Information System (EPA 1992e).
HEAST--Health Effects Assessment Summary Tables--Annual Summary (EPA 1992d, for all chemicals except hexavalent chromium; EPA 1991f, for hexavalent chromium).

[b] UF--Uncertainty factor.

[c] MF--Modifying factor.

[d] Confidence in RfC as reported in IRIS.

Table 6-4

Carcinogen Weight-of-Evidence Classification Scheme

Weight-of-Evidence Group	Comments
A	Known human carcinogen.
B1	Probable human carcinogen: sufficient evidence in animals, limited evidence in humans.
B2	Probable human carcinogen; sufficient evidence in animals, inadequate or no evidence in humans.
C	Possible human carcinogen.
D	Not classifiable as to human carcinogenicity.
E	Evidence of noncarcinogenicity for humans.

Source: EPA 1989b

of the dose-response relationship for a chemical. These values are expressed as noncancer reference doses (RfDs) and cancer slope factors, both of which are affected by exposure routes.

Two primary sources of critical toxicity values were used for this assessment. The primary source was IRIS database (EPA, 1992e), the EPA repository of agencywide verified toxicity values. If a toxicity value was not available through IRIS, then the latest available quarterly update of the HEAST issued by the Office of Research and Development (EPA, 1992d) was used as a secondary source. For some chemicals detected at OU 5, no toxicity value from IRIS or HEAST was available, and toxicity values were provided by Region 10 as provisional RfDs.

Reference Doses for Noncancer Effects

The toxicity value describing the dose-response relationship for noncancer effects is the RfD. The apparent toxic threshold value is used by EPA, in conjunction with uncertainty factors based on the strength of the toxicological evidence, to derive an RfD. The EPA RfD Work Group (EPA, 1989e) defines an RfD as follows:

> In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfD is generally expressed in units of milligram per kilogram of body weight per day (mg/kg/day).

RfDs are developed based on studies of laboratory animals or humans. Briefly, a no-observed-effects-level (NOAEL) or lowest-observed-effects-level (LOAEL) is identified in a study that is considered of sufficient quality to support an RfD. The NOAEL or LOAEL is then divided by uncertainty factors to account for the use of a LOAEL if a NOAEL is not available, data from a subchronic study if a chronic study is not available, variability in toxicological responses between animals and humans, and the variability in toxicological responses between humans. Modifying factors are sometimes used to account for the quality of the toxicological information available for a given chemical. Finally, the confidence level of the EPA work group that reviewed the development of the RfD is recorded as low, medium, or high. The RfD value, critical effect, uncertainty factor, modifying factor, and confidence level are reported for the chemicals of concern at OU 5 in Table 6-2.

Some of the RfDs listed in the HEAST update (Health Effects Assessment Summary Tables [EPA, 1992d]) have not yet been verified by the EPA. This assessment uses the term RfD to describe both EPA-verified and unverified critical toxicity values for noncancer effects. RfDs for some inorganic compounds are for specific forms such as hexavalent versus trivalent chromium. Yet in most cases, the contract laboratory program (CLP) analyses do not report concentrations of specific forms, but rather give results in terms of total inorganic chemical. In such situations, it was assumed that, unless otherwise known, the most toxic form is present and its RfD was used. For the inhalation pathway, the threshold toxicity value for noncancer effects is termed the inhalation reference concentration (RfC). RfCs are developed under methodology similar to that for RfDs. The RfCs for the chemicals of concern at OU 5 are listed in Table 6-3.

Cancer Slope Factors

The dose-response relationship for cancer effects is usually expressed as a cancer slope factor that converts estimated exposures directly to incremental lifetime cancer risk. Slope factors are presented in units of risk per level of exposure (or intake).

Toxicity values for carcinogenic effects also can be expressed in terms of risk per unit concentration of the substance in the medium where human contact occurs. These measures are called unit risks, and the standard duration is continuous lifetime exposure.

The data used for estimating the dose-response relationship are taken from lifetime animal studies or human occupational or epidemiological studies where excess cancer risk has been associated with exposure to the chemical. However, because risk at low intake levels cannot be directly measured in animal or human epidemiological studies (EPA, 1987), a number of mathematical models and procedures have been developed to extrapolate from the high doses used in the studies to the low doses typically associated with environmental exposures. The model choice leads to uncertainty. EPA assumes linearity at low doses and uses the linearized multistage procedure when uncertainty exists concerning the mechanism of action of a carcinogen and when information suggesting nonlinearity is absent. Thus, it is assumed that if a cancer response occurs at the dose levels used in the study, there is some probability that a response will occur at all lower exposure levels (that is, a dose-response relationship with no threshold is assumed). Moreover, the dose-response slope chosen is usually the upper confidence limit on the dose-response curve observed in the laboratory studies. As a result, there is uncertainty and conservatism built into the EPA risk extrapolation approach. EPA has stated that cancer risks estimated by this method produce estimates that "provide a rough but plausible upper limit of risk." In other words, it is not likely that the true risk would be much more than the estimated risk, but "the true value of the risk is unknown and may be as low as zero" (EPA, 1986a). The cancer slope factors and unit risks used in this assessment are summarized in Table 6-5.

Lead is classed as a B2 carcinogen by EPA, but no cancer slope factor or RfD has been established. For the purposes of this human health evaluation, a soil concentration of 500 mg/kg is used as a level of concern for lead. This value is based on use of the EPA uptake biokinetic (UBK) model to predict blood lead levels in a potentially exposed population. Using the UBK model, and assuming a benchmark of 95% of the sensitive population has blood lead levels below 10 μg/dL, EPA has stated that a value of approximately 500 ppm is predicted as an acceptable level (EPA, 1991e). The highest level of lead detected in soil samples at OU 5 was 206 mg/kg.

Table 6-5

Cancer Slope Factors for the Chemicals of Concern at OU 5

Chemical	Oral Route of Exposure			Inhalation Route of Exposure		
	Weight of Evidence	Slope Factor (mg/kg/day)$^{-1}$	Source[a]	Weight of Evidence	Unit Risk (µg/m^3)$^{-1}$	Source[a]
Arsenic	A	2	b	A	0.0043	IRIS
Benzene	A	0.029	IRIS	A	0.0000083	IRIS
Benzo(a)anthracene	B2	7.3	c	B2	0.0017	c
Benzo(b)fluoranthene	B2	7.3	c	B2	0.0017	c
Benzo(k)fluoranthene	B2	7.3	c	B2	0.0017	c
Benzo(a)pyrene	B2	7.3	IRIS	B2	0.0017	HEAST
Beryllium	B2	4.3	IRIS	B2	0.0024	IRIS
Bis(2-Ethylhexyl)phthalate	B2	0.014	IRIS	B2	--	IRIS
Cadmium	--	--	--	B1	0.0018	IRIS
Carbazole	B2	0.02	HEAST	B2	--	--
Hexavalent Chromium	--	--	--	A	0.012	IRIS
Chrysene	B2	7.3	c	B2	0.0017	c
Dibenz(a,h)anthracene	B2	7.3	c	B2	0.0017	c
1,1-Dichloroethane	C	--	IRIS	C	--	HEAST
1,2-Dichloroethane	B2	0.091	IRIS	B2	0.000026	IRIS
Indeno(1,2,3-cd)pyrene	B2	7.3	c	B2	0.0017	c
Lead	B2	--	IRIS	B2	--	HEAST
N-Nitrosodiphenylamine	B2	0.0049	IRIS	B2	--	HEAST
Polychlorinated biphenyls	B2	7.7	IRIS	B2	--	HEAST
1,1,2,2-Tetrachloroethane	C	0.2	IRIS	B2	0.000058	IRIS
Tetrachloroethylene[d]	B2	0.051	HEAST	B2	0.00000052	HEAST
TFH Gas[e]	C	0.0017	EPA[e]	--	--	--
Trichloroethene[d]	B2	0.011	HEAST	B2	0.0000017	HEAST

[a] Sources of toxicity values:
IRIS--Integrated Risk Information System (EPA 1992e).
HEAST--Health Effects Assessment Summary Tables--Annual Summary (EPA 1992d).

[b] Based on Risk Assessment Council unit risk of 5x10^{5} (µg/L)$^{-1}$ (EPA 1988a).

[c] Based on benzo(a)pyrene.

[d] Withdrawn from IRIS. Value previously listed in HEAST is used.

[e] Provisional Slope Factor. Source: Memorandum from Joan Dollarhide, Superfund Health Risk Technical Support Center to Carol Sweeney, U.S. EPA Region 10, March 24, 1992.

The EPA has set an MCL goal for lead in drinking water at zero. An MCL for lead in drinking water does not currently exist, and has been replaced by a treatment technique requirement. Treatment technique requirements are triggered when the action level of 0.015 mg/L lead is exceeded at the consumer's tap. During the RI, no lead was detected in the lower aquifer supply wells. The maximum level of lead detected in the upper aquifer monitor wells in the December 1992 sampling event was 0.0032 mg/L.

6.1.3.3 Toxicology Uncertainty

Uncertainties in the toxicological information available can influence the outcome of the risk assessment and the reliability of risk management decisions. The toxicity values used for quantifying risk in this assessment have varying levels of confidence that will affect the usefulness of the resulting risk estimates. The level of uncertainty for RfDs and RfCs, judged by EPA based on uncertainty factors and modifying factors, is listed in Tables 6-2 and 6-3 for the OU 5 chemicals of concern. For those chemicals suspected of resulting in cancer, uncertainty is in part expressed in terms of the EPA weight-of-evidence classification, listed in Table 6-4. As previously stated, the models used to extrapolate toxicological information between species, doses, and exposure durations also contribute to the uncertainty in the outcome of the risk assessment.

6.1.4 Exposure Assessment

The objective of the exposure assessment is to estimate the type and magnitude of exposures to the chemicals of potential concern that are present at or are migrating from a site. Exposure is defined as the contact of an organism (humans in the case of health risk assessment) with a chemical or physical agent. The magnitude of exposure is determined by measuring or estimating the amount of an agent available at the exchange boundaries (for example, the lungs, gut, or skin) during a specified time period.

Superfund exposure assessments are generally concerned with current and future exposures to site contaminants. Estimates of current exposures can be based on measurements or models of existing conditions; those of future exposures can be based on models of or assumptions regarding future conditions. The exposure assessment for OU 5 is based on the conceptual site model, as explained in Section 5, the potential exposure pathways, the potential receptors, and the estimation of the potential daily chemical intake from exposure to contaminated media.

An exposure pathway is the means by which a chemical moves from a source to a receptor, which is a potentially exposed organism. A complete exposure pathway has five elements:

- Chemical source;
- Mechanism for chemical release (leak, spill, volatilization, process emission);
- Environmental transport medium (groundwater, surface water, air, bulk phase transport, etc.);
- Exposure point (receptor location); and
- Route of exposure.

Exposure may occur when chemicals migrate from their source to an exposure point (a location where receptors can come into contact with the chemicals) or when a receptor moves into direct contact with chemicals or contaminated media close to the source. An exposure pathway is complete (there is exposure) if there is a way for the receptor to take in chemicals through ingestion, inhalation, or dermal absorption. No exposure exists (and therefore no risk) unless the exposure pathway is complete. This is an important requirement in the risk assessment process.

6.1.4.1 Potential Receptors at OU 5

The activity patterns of potentially exposed populations are largely determined by the land uses for which the areas have been zoned. The MOA has zoned the area immediately southwest of the Elmendorf AFB boundary as heavy industrial and it is unlikely that this land designation will change in the future. The industrial area has a single land owner, ARRC, which leases the land to numerous businesses.

The current uses of the OU 5 area within the boundaries of Elmendorf AFB are shown on Figure 3-12. The current uses include recreational, residential, commercial/ service, light industrial, and fish hatchery production. There are no plans to shift the boundaries of the uses as shown on Figure 3-12 (Environmental Science & Engineering et al, 1991).

Potential receptors in the OU 5 study area include residents, workers, children at play (recreationists), and infrequent visitors or trespassers.

Estimates of the number of potential receptors currently on Elmendorf AFB are as follows:

- **Residents:** about 8600 military and family residents basewide (CH2M Hill, 1992b), including approximately 3,200 children less than 18 years of age (Harding Lawson Associates, 1988a); only a few of those residents live immediately upgradient of the pipeline (north of Second Street or west of the COE building).

- **Workers:** about 7,400 workers basewide, including 1,300 civilians and 6,100 military (CH2M Hill, 1992b); less than 50 workers might be expected to come in direct contact with OU 5 contaminants by working in fuel distribution or trenching operations for utilidor repair and installation (based on size of work crews, interviews, and field observations during the RI); approximately 400 administrative employees work at the COE Building 21-700, upgradient of the pipelines.

- **Recreationists:** a few children, numbers unknown, hike and play in the woods on the bluff and near the golf course beaver pond (based on field observations during the RI); military families and civilian workers, numbers unknown, picnic and golf along Ship Creek in the summer (Section 3.4).

- **Sensitive populations:** no schools, hospitals, or nursing homes within 0.5 miles of OU 5.

- **Visitors and Trespassers:** Visitors cannot enter Elmendorf AFB via the Post Road gate, but must enter by the Government Hill or Boniface gates. Once on the base, visitors can be expected to remain on the roadways or to enter buildings on business.

Estimates of the current number of potential receptors at the Elmendorf Fish Hatchery (land leased from the USAF) or just off base in the ARRC industrial area are as follows:

- **Residents:** eight (including four children) at the Elmendorf Fish Hatchery (Section 3.4).

- **Workers:** about 250 workers (based on the water use surveys, Section 3.5); about half of those workers (railroad yard workers, freight operators) may spend time outside in the industrial yards.

- **Recreationists:** a limited fishery takes place on Ship Creek, number of fishermen in the vicinity of OU 5 not known; most fishing occurs near the mouth of Ship Creek, 2 miles from OU 5.

- **Sensitive populations:** no schools, hospitals, or nursing homes within 0.5 miles of OU 5.

- **Visitors and Trespassers:** about 55,000 visitors stop at the Elmendorf Fish Hatchery viewing area each summer, visits usually last less than 1/2 hour (Section 3.4); customers, numbers or length of visits not known, will enter businesses in the industrial area; a few homeless individuals, numbers not known, may live near Ship Creek and the railroad right-of-way for short periods of time.

For the purpose of this risk assessment the following exposure settings were used for the indicated transport media:

- Lower aquifer groundwater—current and future residential;
- Upper aquifer groundwater—future residential (no current use);
- Surface water and sediment—current and future recreational;
- Surface soils—current residential for the upgradient subarea and future residential for all other subareas;
- Subsurface soils—current and future trench worker; and
- Air—current and future residential.

6.1.4.2 Pathways of Exposure for OU 5

Based on a review of the area setting, the nature and extent of chemical contamination, and the possible exposure routes, the potential exposure pathways most pertinent to OU 5 are evaluated in this assessment. Figure 5-3 shows the exposure pathways for OU 5 that potentially are complete under current and reasonable future land use conditions. For OU 5, the most pertinent pathways involve soils and groundwater. Potential health risks are also associated with sediments and surface water at OU 5.

Exposure to Chemicals in Surface Soils. Current or future residents, current or future workers, or people who infrequently gain access to OU 5 as visitors or trespassers could come into contact with chemicals in surface soils. Exposure to surface soils could occur via inadvertent ingestion, skin contact, or by inhaling dusts. The frequency, duration, extent, and route of exposure would depend on the particular activity of the receptor and location of the activity. For this assessment, soil ingestion exposures were estimated for a maximum screening exposure scenario in which residential reasonable maximum exposure (RME) assumptions were made and the maximum concentrations of each chemical detected used in the calculation of risk.

Dermal absorption of contaminants in the surface soils of OU 5 may occur by direct contact. Contaminants in the soil may adhere to and become absorbed by the skin.

Estimates of dermal absorption of contaminants are generally unreliable and of limited usefulness in assessing human health risks because the efficiency of chemical absorption from contaminated soil across the skin is not known for most chemicals and because toxicity values (RfDs or slope factors) are not currently developed or verified by the EPA. In spite of this, a highly conservative approach has been used to develop an upper bound estimate of exposure by the dermal absorption pathway. Thus, risk estimates based on this pathway are not likely to be exceeded under any reasonable scenario that might occur at OU 5.

Inhalation of chemicals can occur if wind releases soil into the air as dust. However, this may not be a major release pathway for OU 5 because most of the ground is covered with vegetation or pavement and any exposed soils are wet or under snow cover for much of the year. The possibility that the air pathway could be of potential concern at OU 5 is evaluated using a screening procedure agreed to by the USAF, EPA, and ADEC project managers in the OU 5 *Management Plan*. OU 5 surface soil concentrations are used to estimate dust concentrations, assuming a particulate concentration (PM_{10}) equivalent to the federal annual standard of 50 $\mu g/m^3$ or the MOA measured data of 30 $\mu g/m^3$.

Exposure to Chemicals in Subsurface Soils. Chemicals have been detected in on-site subsurface soils. Receptors coming into contact with chemicals in subsurface soils may become exposed through incidental ingestion, skin contact, or inhalation of vapors. Because the major current or future land use for the areas occupied by and surrounding OU 5 is industrial, a plausible exposure scenario would be short-term exposure during excavations and trenching to repair or place utility lines or pipes. Potential receptors would be current or future short-term workers such as utility personnel. Exposures under this scenario would be expected to be infrequent (at most a few times per year).

While the primary exposure route would probably be incidental ingestion during work activities, exposure to some chemicals detected in subsurface soil at OU 5 can occur via absorption through unprotected skin, resulting in exposure. However, trench workers would likely wear protective clothing during excavation activities, limiting contact.

The same uncertainties associated with calculated dermal exposures to surface soils also apply to subsurface soils.

Trench workers could, to some extent, be exposed to chemicals by inhalation of dusts or vapors. However, dusts are not likely to exist in trenches during short-term excavations because soils will probably be wet and relatively protected from wind. Some of the more volatile compounds could form vapors, making inhalation exposure possible. A conservative modeling approach is used to estimate risk based concentrations of volatiles in subsurface soils. Using the EPA guidance method and assumptions (EPA, 1991a), subsurface soil concentrations that could result in air concentrations for volatiles at target levels (1 x 10^{-6} excess lifetime cancer risk for carcinogens and a hazard quotient [HQ] of unity for noncarcinogens) are calculated. Measured subsurface soil concentrations of VOCs are then compared to the calculated risk-based concentrations.

Exposure to Chemicals in Groundwater. Human exposure to chemicals in groundwater can occur through ingestion as drinking water, by dermal contact during bathing, etc., or by inhaling chemicals volatilized from water during showering, cooking, or other household activities.

Current Groundwater Use Conditions. The upper aquifer groundwater is not currently used for domestic or industrial uses on Elmendorf AFB and OU 5. Previous uses of the upper aquifer included fish production at the hatchery; however, low yield and suspected contamination resulted in the shallow wells being abandoned in the mid-1980s. A shallow base supply well, Well 1, was used as a backup for base drinking water until contamination forced the well to be shut down in the late 1980s. Well 1 is located upgradient of the OU 5 study area along Ship Creek. The MOA abandoned the use of shallow wells along Ship Creek in the 1940s due to contamination.

The lower aquifer is tapped by wells for drinking water supply in the Anchorage Bowl. Base Well 2 is in the OU 5 study area and serves as a backup supply for cooling water at the power plant and for drinking water when other supplies are low. Base Well 52 is used seasonally at the golf course clubhouse for all domestic uses associated with the clubhouse and its restaurant. Four deep aquifer offbase wells were located in the industrial area downgradient of Elmendorf AFB during the water use survey. All four wells are apparently used by workers for drinking water but no residents or sensitive subgroups such as children or elderly persons use the water on a regular basis. Two of the offbase wells closest to Elmendorf AFB (Inlet and IGM companies) and base wells 2 and 52 were sampled as part of the RI. The only residences between the OU 5 pipelines and Ship Creek are located at the hatchery and are connected to Municipality of Anchorage drinking water supplies, not to on-site wells. The hatchery pumps water from two on-site wells screened into the lower aquifer for use in fish production.

Future Groundwater Use Conditions. Given the industrial land use that surrounds OU 5, industrial water supply wells might be constructed in the future. Personal use of this water is unlikely, however, because the area is connected to municipal water supplies and this arrangement will probably continue.

Groundwater modeling was not conducted for this human health evaluation, and current on-site concentrations in groundwater have been assumed to represent future concentrations in potential on-site wells. This could be a health-conservative assumption and may overestimate exposures, because groundwater chemical concentrations will probably decrease with time as the result of natural attenuation (migration and degradation). Barring any unanticipated future releases, contaminant concentrations in groundwater at OU 5 are not expected to increase because no ongoing releases or significant pockets of contaminated soil were encountered during the RI. In the 6 years (1986-1992) of investigations at OU 5, the concentration of contaminants in groundwater has remained in the low μg/L range.

Exposure to Chemicals in Surface Water and Sediments. Chemicals have been detected in surface water and sediments in the OU 5 study area. Receptors coming in contact with chemicals in surface water or sediment may be exposed through incidental ingestion, skin contact, or inhalation of vapors.

The surface water in OU 5 primarily flows through the golf course or parkland as Ship Creek or occupies unused marshy habitat (beaver ponds) at the base of the bluff. No organized swimming occurs because of the cold water temperatures, shallow and swift water (Ship Creek), and the short summer season. Occasionally children will raft on the golf course beaver pond or harvest golf balls from the bottom of Ship Creek. Potential receptors are primarily children as recreationists. Exposure under a swimming scenario would be expected to be infrequent (for example, a couple of days per month in the summer), and military tours of duty would limit Elmendorf children to 5 years or less of exposure.

The inhalation of volatiles from surface water is expected to be a pathway of low concern for the following reasons:

- VOCs were detected in low (ppb) concentrations in the surface water.
- The VOCs are highly water soluble, hence are expected to remain dissolved in the water.
- The atmospheric temperatures are cold and the water is frozen approximately 6 months of the year, reducing volatilization of the compounds.
- The surface water is not in a confined space and the prevailing winds can be expected to mix the air above the ponds. Hence, any VOCs escaping into the air will be rapidly diluted.

Consequently, the risk of inhaling VOCs in surface water will not be quantified.

Miscellaneous Exposure Pathways. Two other exposure pathways, human consumption of contaminated fish and vegetables, are not quantified in this evaluation because neither is likely to be a completed pathway. No vegetable gardening currently takes place at OU 5. Future vegetable gardening is also unlikely because of MOA zoning restrictions and forecast land uses (Environmental Science & Engineering et al, 1991). The land is also not suitable for agricultural purposes because of steep or unstable slopes or wetlands. Surface soil contamination was not encountered in areas suitable for the growth of wild berries or mushrooms.

Project managers from the USAF, EPA, and ADEC agreed in the OU 5 Management Plan to a phased approach to determining the influence of OU 5 contaminants on Ship Creek and its indigenous fish species. During the RI, Ship Creek was found to be free of organic contaminants. Hence, it is unlikely that OU 5 sources influence fish in Ship Creek. No fish tissue analyses, or human use surveys were conducted as part of the RI, and none are planned.

6.1.4.3 Estimation of Exposure Point Concentrations

Estimation Method. In order to estimate cancer and noncancer risks from possible exposures to media at OU 5, it is necessary to know concentrations of each chemical of potential concern at possible exposure points. Exposure point concentrations can be estimated by direct measurement of concentrations in the exposure medium at a potential point of contact, or by modeling chemical release and transport to a exposure point. For soil, groundwater, surface water, and sediment, this assessment used the direct measurement approach (actual analytic data were used to quantify risks). Inhalation exposures to contaminants in dust were estimated from sitewide detected concentrations as screening tool. Modeling chemical movement in these media was not considered appropriate because of data uncertainties (for example, source release rates and fates).

Where possible, pathways were first screened out using maximum sitewide concentrations or maximum subarea concentrations in each media and reasonable, conservative exposure scenarios. When this maximum screening approach demonstrated a Hazard Index greater than one or an excess lifetime cancer risk of greater than 10^{-6}, as in the case of groundwater, exposure point concentrations were estimated for assumed average case and reasonable maximum case exposure settings.

Average case exposures represent exposures to arithmetic average concentrations at the site. Reasonable maximum exposure estimates, developed according to EPA guidance (1989b), represent the highest exposures that are reasonably expected to occur to site chemicals of potential concern. The concentrations used to estimate exposure under reasonable maximum exposure conditions were calculated as the 95% upper confidence limit of the arithmetic mean concentrations in a particular medium at a particular study subarea (EPA, 1992f).

The detected concentrations plus one-half of the detection limits for the samples with nondetects are used to generate the averaging statistics. In instances in which the only detected values are below the detection limit (identified as J values), this procedure can result in averages and UCLs that are greater than the detected values at the site and their use in the risk assessment would be overly conservative. In this latter case, averages and UCLs are generated only with the detected values (EPA, 1989b).

In some data subgroups in which variability in the measured data is high due to small sample size, the UCLs on the average concentrations are above the maximum detected value. In these cases, the maximum detected concentration is used to estimate the reasonable maximum exposure concentration according to EPA guidance (EPA, 1989b). An example of this occurs in the upper aquifer groundwater data for the lower bluff subarea where the sample size is three.

All input concentrations and exposure parameters used in this risk assessment are shown in Appendix P.

Grouping of Data. Sampling data resulting from the RI were grouped according to study subareas for each medium of concern. Study subareas were determined by considering distinct geographic locations within OU 5.

Surface soils were taken from the zero to 2-foot depth. Subsurface soils were soils collected at greater than 2-foot depth. All soil metal concentrations were compared to background metals concentrations as described in Section 4.0. Background concentrations were not subtracted from analytical data that exceeded background comparisons when estimating exposure point concentrations.

Groundwater samples were collected from monitoring wells screened at varying groundwater depths in the upper aquifer and from active supply wells screened into the lower, confined aquifer. The groundwater results were grouped into upper and lower aquifer. Upper aquifer samples were also divided into study subarea. Groundwater total metals for the lower aquifer were compared to regional (background) data (Section 4.3). Upper aquifer metals were compared to metals in samples collected from the upgradient subarea. Individual wells were assessed to determine the relative contribution of each well to the overall risk. A more complete description of the wells and depths to groundwater is given in Sections 2.1.5 and 3.3.

Sediment and surface water samples were grouped into three subareas. No background sediment or surface water sample was collected for comparison with pond samples. Upgradient surface water and sediment samples were collected for Ship Creek.

6.1.4.4 Quantification of Exposure

This section describes the calculation of chemical intakes for individual pathways of exposure, summarizes the assumptions that were made to estimate exposure, and describes the means used to estimate concentrations. Specific exposure equations, exposure parameters, and concentration values used in this risk assessment are found in Appendix P.

Estimation of Chemical Intake. Chronic exposure (chronic daily intake) is expressed in terms of milligrams of chemical contacting the body per kilogram body weight per day (mg/kg/d). For the exposure routes evaluated, the following generic equation was used:

$$\text{Exposure (mg/kg body weight/day)} = (C \times I \times F \times D)/(W \times T)$$

Where:

C = Concentration of Chemical (for example, mg/kg soil)
I = Media Intake Rate (for example, kg soil ingested/day)
F = Exposure Frequency (days/year)
D = Exposure Duration (years)
W = Body Weight (kg)
T = Averaging Time (period over which exposure is averaged, in days)

This equation requires variables (exposure parameters) which are specific to a particular exposure scenario. Exposure parameters are usually estimated values. The reliability of the values chosen can also contribute substantially to the uncertainty of resulting risk estimates. Many of the exposure parameters assumed for OU 5 have default values that are used by convention. These assumptions, based on estimates of body weights, media intake levels, and exposure frequencies and durations, are provided by EPA guidance (1989a, 1989b; 1991b), and in EPA Region 10 guidance (EPA, 1991d). Other assumptions (for example, for the subsurface trenching scenario) required consideration of location-specific information and were determined using professional judgment.

Reasonable Maximum Exposure Case. EPA guidance states that actions at Superfund sites should be based on an estimate of the RME expected to occur under both current and future land use conditions. The RME is defined as the "highest exposure that is reasonably expected to occur at a site" (EPA, 1989b). The intent of the RME scenario is to estimate a conservative exposure case (that is, well above the average case) that is still within the range of possibilities. Many of the exposure parameters used to estimate RME are upper confidence limit values.

Average Case Exposure. EPA has recently stated the need for providing risk information that includes both the average and the high end RME portions of the risk distribution (EPA, 1992c). Presentation of the plausible range of risks allows risk management decisions to incorporate the relative uncertainty in the risk estimates. Thus, this human health evaluation assesses exposures under both RME and more likely "average" exposure conditions. The average case exposure assumptions largely represent the 50th percentile values within the population.

The exposure assumptions used to estimate potential RME and average case exposures to chemicals of potential concern at OU 5 are summarized in Tables 6-6 through 6-9 for the subsurface soil, surface soil, groundwater, surface water, sediment, and air pathways. The exposure assumptions used in preliminary maximum screens were the same as the RME exposure assumptions. The exposure estimates (in terms of chronic daily intakes) for each of the chemicals of concern in each sample, derived using the estimated exposure point concentrations (discussed below), are given on the risk calculation data sheets in Appendix P.

In spite of the uncertainties inherent to estimates of exposure by dermal absorption, this exposure pathway has been evaluated using highly conservative assumptions. This approach is intended to provide an upper bound estimate of exposure by dermal absorption. Thus, risk estimates based on the dermal absorption pathway are not likely to be exceeded under any reasonable scenario that might occur at OU 5.

The dermal absorption efficiency for soils and sediment assumed the following values:

- Six percent for semivolatile organic compounds based on the value reported for PCBs (EPA, 1992a);
- One percent for metals based on the value reported for cadmium (EPA, 1992a); and
- Fifty percent for VOAs based on best judgment. (No published values exist.)

Table 6-6

Exposure Assumptions for Subsurface Soil Pathways

Exposure Parameters	Reasonable Maximum Exposure
Exposed Individual	Trench Worker
Body Weight (kg)	70[a]
Soil Ingestion Rate (mg/day)	480[b]
Exposed Skin Surface Area (cm^2)	5000[c]
Soil to Skin Adherence Factor (mg/cm^2)	1.0[c]
Days/year Exposed	24[d]
Years Exposed	5[d]

[a] Source: EPA, 1991b
[b] Source: EPA, 1991d
[c] Source: EPA, 1992a
[d] Source: Personal communication from Roseanne Lorenzana, EPA, Region 10, to Dennis Shelton, CH2M Hill, 1992.

Table 6-7

Exposure Assumptions for Surface Soil Pathways

Exposure Parameters	Reasonable Maximum Exposure	Average
Exposed Individual	Resident	Resident
Body Weight (kg)	15 (0-6yr) 70 (>6yr)[a]	70[d]
Soil Ingestion Rate (mg/day)	200 (0-6yr) 100 (>6yr)[a]	100[d]
Dust Inhalation Rate (M^3/day)	20	20
Particulate Concentration ($\mu g/M^3$)	50[b], 30[e]	50[b], 30[e]
Exposed Skin Surface Area (cm^2)	5,800[c]	5,000[c]
Soil-to-Skin Adherence Factor (mg/cm^2)	1.0[c]	0.2[c]
Days/year Exposed (Ingestion and Inhalation)	350[a]	275[d]
Days/Year Exposed (Dermal)	350[a]	40[c]
Years Exposed	30[a]	9[d]

[a] Source: EPA, 1991b
[b] Source: National Annual Ambient Air Quality Standard, 36 FR 22384
[c] Source: EPA, 1992a
[d] Source: EPA, 1991d
[e] Source: MOA PM_{10} data obtained from Mr. Lawrence Taylor.

Table 6-8

Exposure Assumptions for Groundwater Pathways

Exposure Parameters	Exposure Case	
	Average Case	Reasonable Maximum Exposure
Exposed Individual	Resident	Resident
Body Weight (kg)	70[a]	70[a]
Ingestion Rate (L/day)	1.4[b]	2[a]
Inhalation Rate (M^3/day)	15[a]	15[a]
Exposed Skin Surface Area (cm^2)	20,000[c]	23,000[c]
Days/Year Exposed	275[d]	350[a]
Time in Water (min/day)	10[c]	15[c]
Years Exposed	9[b]	30[a]

[a] Source: EPA, 1991b
[b] Source: EPA, 1989a
[c] Source: EPA, 1992a
[d] Source: EPA, 1991d

Table 6-9

Exposure Assumptions for Surface Water and Sediment Pathways

Exposure Parameters	Reasonable Maximum Exposure
Exposed Individual	Recreational User
Body Weight (kg)	35[a]
Surface Water Ingestion Rate (L/day)	0.05[b]
Sediment Ingestion Rate (mg/day)	100[c]
Exposed Skin Surface Area for Water (cm^2)	10,000[c]
Time in Water (min/day)	60[c]
Exposed Skin Surface Area for Sediment (cm^2)	3,900[c]
Sediment to Skin Adherence Factor (mg/cm^2)	1.0[c]
Days/Year Exposed	26[a]
Years Exposed	5[a]

[a] Best judgment
[b] Source: EPA, 1989a
[c] Source: EPA, 1992a

For dermal contact with groundwater and surface water, the estimated chemical-specific skin permeability constants were as listed in Table 5-8 of EPA guidance on dermal exposure (1992a). For chemicals for which no estimated values exist (for example, JP-4), the permeability constant for water (1.6×10^{-4} cm/hr) was used.

Exposure of potential receptors to the contaminants of concern at OU 5 was quantified for estimating human health risks by the following exposure routes:

- Oral ingestion of surface and subsurface soils, sediments, surface, and groundwater;
- Inhalation of organics that volatilize during domestic use (showering) of groundwater and of particulates from surface soil; and
- Dermal absorption of surface and subsurface soils, surface and groundwater, and sediments.

6.1.4.5 Uncertainties Related to Exposure Estimation

Uncertainties in risk characterization of exposure assessment include assumptions about future land and groundwater use, sample collection and analyses, and chemical intake.

Future land uses at OU 5 are likely to remain industrial off base and a mixture of residential, industrial, and recreational onbase. Use of the upper aquifer for potable water is not likely due to the availability of public water sources and the low yield of the upper aquifer beneath OU 5. Exposure estimates for groundwater were quantified to provide a frame of reference for risk management decision making.

Uncertainties associated with sampling and analyses include the inherent variability (standard error) in the analysis, representativeness of the samples, sampling errors, and heterogeneity of the sample matrix. While the QA/QC program used in the RI serves to reduce these errors, it cannot eliminate all errors associated with sampling and analyses. The degree to which sample collection and analyses reflect real exposure point concentrations will determine the reliability of resulting risk estimates. Many of the sample data used for this assessment were generated from samples collected at known or suspected source areas, rather than randomly. Since exposure is not likely to be limited solely to higher concentration areas, risk estimates for these areas may be conservatively high. This assessment made the simplifying assumption that media concentrations remain constant over the duration of exposure, specifically, that no chemical loss or transformation occurs in the future. This assumption may also result in conservative risk estimates.

The estimation of exposure required numerous assumptions to describe potential exposure situations. The use of upper bound exposure assumptions to estimate RME exposures provides a bounding estimate on exposure. The use of average exposure parameters in estimation of exposure allows accounting for some of the uncertainties due to use of reasonable maximum exposure assumptions.

6.1.5 Public Health Risk Characterization

The approach used to develop the human health risk estimates is summarized in this section. A quantitative risk characterization is presented for the OU 5 media of concern under the assumed exposure settings described in Section 6.1.4, Exposure Assessment. Cancer and noncancer risks associated with the potential site exposures are evaluated. The estimation of risks is based on the assumption that contaminant concentrations and intake levels are constant.

6.1.5.1 Noncancer Effects Risk Characterization

For noncancer effects, risks were estimated by comparing the predicted level of exposure for a particular chemical to the highest level of exposure that is considered protective (its RfD). The ratio of exposure divided by RfD is termed the hazard quotient (HQ):

$$HQ = exposure/RfD$$

When the HQ for a chemical exceeds 1 (exposure exceeds RfD) there is a concern for potential noncancer health effects. To assess the potential for noncancer effects posed by exposure to multiple chemicals, a hazard index (HI) approach was used according to EPA guidance (1986c). This approach assumes additivity and does not account for synergistic or antagonistic effects. When two or more chemicals in the same sample have HQs less than one, but the aggregate sum of HQs, the HI, exceeds one, the potential for health effects exists if the chemicals act by the same toxicologic mechanism.

6.1.5.2 Cancer Risk Characterization

The potential for cancer effects is evaluated by estimating excess lifetime cancer risk. Excess lifetime cancer risk is the incremental increase in the probability of developing cancer over one's lifetime over the background probability of developing cancer (if no exposure to site chemicals occurs). For example, a 1×10^{-6} excess lifetime cancer risk means that for every 1 million people exposed to the carcinogen throughout their lifetimes, the average incidence of cancer may increase by one case of cancer. The background probability of developing cancer is about one in four.

As previously mentioned, cancer slope factors developed by the EPA represent upper bound estimates, so any cancer risks generated in this assessment should be regarded as upper bounds on the potential cancer risks rather than accurate representations of true cancer risk. The true cancer risk is likely to be less than that predicted (EPA, 1989b). For OU 5, excess lifetime cancer risks were estimated using the following formula:

$$\text{risk} = \text{cancer slope factor} \times \text{exposure (or intake)}$$

Although synergistic or antagonistic interactions might occur between cancer-causing chemicals and other chemicals, information is generally lacking in the toxicological literature to quantitatively predict the effects of these potential interactions. Therefore, cancer risks were treated as additive within an exposure route in this assessment. This is consistent with the current EPA guidelines on chemical mixtures (1986c).

6.1.5.3 Quantitative Risk Estimation

The potential risks associated with OU 5 are quantified in this section. Based on the analysis of exposure pathways presented earlier in this assessment, the potential current and future risks for the site are characterized and described in this section for each particular medium of concern. Descriptions are limited primarily to the maximum screen and RME risk estimates. Average case risks are also provided in the summary tables when RME estimates did not screen out the pathway. Detailed risk tables listing individual chemical risks and percentage contributions to total risk are contained in Appendix P.

Subsurface Soil Exposure Pathways

Short-term worker risks are independently quantified for subsurface soils in six study subareas. Table 6-10 summarizes the risk estimates for ingestion and dermal absorption of subsurface soils. The estimates use maximum chemical concentrations in each subarea in order to eliminate subsurface soil exposure as a pathway of concern.

No HI values exceed 1.0. The maximum on-site excess lifetime cancer risk is 4×10^{-7} for subsurface soil ingestion in the lower bluff subarea.

To evaluate the possibility of exposure to short-term workers by inhalation of vapors in trenches, a conservative modelling approach is used to estimate risk-based concentrations of VOCs in subsurface soils. Using the EPA guidance method and assumptions (EPA, 1991a), subsurface soil concentrations that could result in air concentrations for volatiles at target risk levels (1×10^{-6} excess cancer risk for carcinogens, HQ of unity for noncarcinogens) are calculated. Of the four VOCs that could be modelled in subsurface

Table 6-10

Summary of Maximum Risk Screening Estimates for Subsurface Soils[a]

Study Subarea	Exposed Individual (current and future)	Exposure Setting[b]	Noncancer Effects		Cancer Effects	
			Noncancer Hazard Index	Risk-Contributing Chemicals[c]	Excess Lifetime Cancer Risk	Risk-Contributing Chemicals[c]
Upgradient	Trench Worker	Incidental Ingestion	<0.01	NA	3×10^{-9}	NA
		Dermal Absorption	<0.01	NA	2×10^{-9}	NA
		Additive Risk	<0.01	NA	5×10^{-9}	NA
Pipeline Corridor	Trench Worker	Incidental Ingestion	0.01	NA	2×10^{-11}	NA
		Dermal Absorption	<0.01	NA	1×10^{-10}	NA
		Additive Risk	0.02	NA	1×10^{-10}	NA
Lower Bluff	Trench Worker	Incidental Ingestion	0.02	NA	4×10^{-7}	NA
		Dermal Absorption	<0.01	NA	1×10^{-8}	NA
		Additive Risk	0.02	NA	4×10^{-7}	NA
Post Road Corridor	Trench Worker	Incidental Ingestion	<0.01	NA	ND	NA
		Dermal Absorption	<0.01	NA	ND	NA
		Additive Risk	<0.01	NA	ND	NA
Golf Course Beaver Pond	Trench Worker	Incidental Ingestion	ND	NA	ND	NA
		Dermal Absorption	ND	NA	ND	NA
		Additive Risk	ND	NA	ND	NA
Waste Paint Tank	Trench Worker	Incidental Ingestion	<0.01	NA	4×10^{-10}	NA
		Dermal Absorption	<0.01	NA	3×10^{-10}	NA
		Additive Risk	<0.01	NA	7×10^{-10}	NA

[a] The estimated risks are for current or future utility workers who spend 24 days per year for 5 years working in trenches exposed to maximum concentrations of contaminants in subsurface soils. Exposure assumptions are shown in Table 6-6.

[b] Inhalation of vapors in trenches is discussed in text. Additive risk equals the sum of the ingestion and dermal risks.

[c] Risk-contributing chemicals are listed only when the excess lifetime cancer risk exceeds 1×10^{-6} or when the Hazard Index exceeds 0.5.

NA = Not applicable.

ND = No applicable chemicals detected.

soils, risk-based concentrations are estimated to be 1.75 mg/kg for benzene, 19,300 mg/kg for ethylbenzene, 3,820 mg/kg for toluene, and 2,570 mg/kg for xylenes. None of the subsurface soil concentrations at OU 5 exceed these risk-based levels. The highest concentrations detected are 0.2 mg/kg benzene, 0.660 mg/kg ethylbenzene, 0.510 mg/kg toluene, and 9.3 mg/kg xylenes. These results suggest that inhalation of BTEX in trenches is a pathway of low concern.

Surface Soil Exposure Pathways

Risk estimates are calculated for residential receptors exposed to surface soils via incidental ingestion and dermal absorption. Currently residents are only found in the upgradient subarea; therefore, estimates for the other subareas are for future residents over a lifetime. Table 6-11 summarizes the risk estimates for surface soils. The estimates first used maximum chemical concentrations in each subarea to eliminate surface soil ingestion and dermal absorption as pathways of concern.

Risks were recalculated using UCL and average concentrations if the sum of the maximum screening estimates for ingestion and dermal absorption exceed an HI of 1.0 or an excess lifetime cancer risk of 1 x 10^{-4}. Only the lower bluff subarea exceeded those criteria. The additive RME estimate for the HI for the lower bluff area was less than unity.

The maximum excess lifetime cancer risk for ingestion is 1 x 10^{-4} for the lower bluff subarea. The risk was recalculated using UCL and average concentrations, yielding an excess lifetime cancer risk for ingestion of 6 x 10^{-5} for the RME exposure case and 4 x 10^{-6} for the average exposure case. Approximately 76% of the RME cancer risk in the lower bluff subarea is contributed by metals (arsenic 69%; beryllium 7%). The remaining 24% of the cancer risk is contributed by PAHs. The PAHs concentrations are estimated values found below the detection limit in one sample (SB29-00A); however, no PAHs were detected in that sample's field duplicate (SB29-00). Although the subarea maximum arsenic concentration was greater than the background screening levels, the

Table 6-11

Summary of Risk Estimates for Surface Soils[a]

Study Subarea	Exposed Individual	Exposure Setting[b]	Noncancer Effects		Cancer Effects	
			Noncancer Hazard Index	Risk-Contributing Chemicals[c]	Excess Lifetime Cancer Risk	Risk-Contributing Chemicals[c]
Upgradient	Current Resident	Incidental Ingestion	NS	NA	NS	NA
		Dermal Absorption	NS	NA	NS	NA
Pipeline Corridor	Future Resident	Incidental Ingestion	ND	NA	ND	NA
		Dermal Absorption	ND	NA	ND	NA
Lower Bluff	Future Resident	Incidental Ingestion	1.0 MAX 0.4 RME 0.07 AVE	Arsenic (43%) Barium (18%) TFH diesel (22%)	1×10^{-4} MAX 7×10^{-5} RME 4×10^{-6} AVE	Arsenic (69%) PAHs (24%) Beryllium (7%)
		Dermal Absorption	0.6 MAX 0.2 RME 0.002 AVE	TFH diesel (61%) Arsenic (20%) Barium (8%)	2×10^{-5} MAX 9×10^{-6} RME 4×10^{-8} AVE	Arsenic (85%) Beryllium (10%) TFH gas (5%)
		Additive Risk	2. MAX 0.6 RME 0.07 AVE	NA	1×10^{-4} MAX 8×10^{-5} RME 4×10^{-6} AVE	NA
Post Road Corridor	Future Resident	Incidental Ingestion	0.1 MAX	NA	ND	NA
		Dermal Absorption	0.03 MAX	NA	ND	NA
		Additive Risk	0.1 MAX	NA	ND	NA
Golf Course Beaver Pond	Future Resident	Incidental Ingestion	0.05 MAX	NA	ND	NA
		Dermal Absorption	0.03 MAX	NA	ND	NA
		Additive Risk	0.08 MAX	NA	ND	NA

Table 6-11

(Continued)

Study Subarea	Exposed Individual	Exposure Setting[b]	Noncancer Effects		Cancer Effects	
			Noncancer Hazard Index	Risk-Contributing Chemicals[c]	Excess Lifetime Cancer Risk	Risk-Contributing Chemicals[c]
Waste Paint Tank	Future Resident	Incidental Ingestion	NS	NA	NS	NA
		Dermal Absorption	NS	NA	NS	NA

[a] The estimated risks are for a residential setting over a lifetime. Residents currently live only in the upgradient subarea. Exposure assumptions are shown in Table 6-7.
Exposure Cases:
MAX = maximum concentrations used to estimate risks as a screening approach
RME = reasonable maximum exposure case
AVE = average case

[b] Inhalation of volatiles and particulates from surface soil is discussed under the Air Pathway and associated risks are shown in Table 6-14. Additive risk equals the sum of the ingestion and dermal risks.

[c] Value in parentheses is the percent contribution to the total pathway risk estimate. The percentages are for the RME estimated risk. A value is listed only when any excess lifetime cancer risk exceeds $1\text{x}10^{-6}$ or when any HI exceeds 0.5.

NS = No samples at this location.
ND = No applicable chemicals detected.
NA = Not applicable.

subarea UCL and average concentrations would have been screened out. Consequently, the RME and average case risk estimates for excess lifetime cancer risks are equivalent to background risks for metals.

No HI for dermal absorption exceeds 1.0. The maximum case excess lifetime cancer risk for dermal absorption is 2×10^{-5} in the lower bluff subarea; the RME case is 9×10^{-6}, and the average case is 1×10^{-6}. Approximately 95% of the cancer risk is contributed by metals.

Residents currently live in the upgradient subarea north of 2nd Street and on fish hatchery leases next to the Post Road corridor. No surface soil samples were collected from the upgradient subarea, which is largely covered by lawns or pavement with little exposed surface soils. The residential exposure scenario applies the most conservative exposure assumptions (see Table 6-7) used in risk assessments. Actual exposure to surface soils at OU 5 may be much less: examples, military families' tours of duty seldom exceed 5 years (not the 30 years used in assumptions) on Elmendorf AFB and the ground surface is free of snow only about 6 months of the year (not 350 days). The lower bluff subarea was the only area where the excess lifetime cancer risk for ingestion and dermal exposure exceeded 1×10^{-6}. This subarea is unlikely to be used for residences because of unstable, steep bluffs and wetlands. Consequently, the residential scenario is highly conservative and the actual risk because of future exposure to chemicals in surface soils may be much less than estimated.

Inhalation of chemicals released to the ambient air from surface soils is considered in the Air Pathways subsection.

Groundwater Exposure Pathways

For the groundwater pathways, risk estimates are developed for potential future residential ingestion, inhalation, and dermal exposures to the upper aquifer groundwater. No residential or industrial potable water wells draw water from the upper aquifer in the OU 5 study area. For the lower aquifer, the risk estimates apply to both current and future residential scenarios. Risks are estimated for each subarea for the upper aquifer, for the pooled sample data for the lower aquifer, and for individual monitoring wells. Ingestion, inhalation (during showering), and dermal (during showering) exposure routes are evaluated. Risks are calculated by using the metals data from the December 1992 sampling effort, and not from the August 1992 sampling effort.

Groundwater Risks for Study Subareas and Lower Aquifer: Risk estimates are summarized in Table 6-12.

No HI for inhalation or dermal absorption during showering exceeds 1.0 for residents under RME conditions. The highest risk estimates for RME excess lifetime cancer risks for future residents through inhalation during showering is 2 x 10^{-5} at the pipeline corridor subarea and 1 x 10^{-5} at the lower bluff subarea and the upgradient subarea. Benzene contributed 100% to the inhalation risk estimated in the lower bluff subarea. TCE contributed 100% to the inhalation risk estimated in the pipeline corridor and upgradient subareas. The highest risk for future residents as the result of dermal absorption during showering is 5 x 10^{-7} in the lower bluff subarea. The dermal absorption risks are due largely to metals.

A potential future ingestion of groundwater from the upper unconfined aquifer constitutes the highest estimated health risks for OU 5. HI estimates for ingestion of groundwater exceed 1.0 under RME case conditions for the upper aquifer in the lower bluff subarea. Metals are the largest contributor to the overall risk, followed by TFH diesel. Arsenic and manganese contribute to the risk at the lower bluff.

The RME excess lifetime cancer risks for ingestion of groundwater from the upper aquifer by future residents range from 3 x 10^{-6} at the waste paint tank, Post Road

Table 6-12

Summary of Risk Estimates for Groundwater

				Noncancer Effects			Cancer Effects		
				Noncancer Hazard Index			Excess Lifetime Cancer Risk		
Aquifer	Study Subareas	Exposed Individual	Exposure Setting	Average Case	Reasonable Maximum Case	Risk-Contributing Chemicals[a]	Average Case	Reasonable Maximum Case	Risk-Contributing Chemicals[a]
Upper	Upgradient	Future Resident	Ingestion	0.1	0.4	NA	1 x 10^{-6}	1 x 10^{-5}	1,1,2,2-Tetrachloroethane (67%) TCE (23%) TFH gas (8%)
			Inhalation (Showering)	<0.01	<0.01	NA	1 x 10^{-6}	1 x 10^{-5}	TCE (100%)
			Dermal (Showering)	<0.01	<0.01	NA	3 x 10^{-8}	4 x 10^{-7}	NA
			Additive Risk	0.1	0.4	NA	2 x 10^{-6}	2 x 10^{-5}	NA
	Pipeline Corridor	Future Resident	Ingestion	0.4	0.7	Manganese (60%) TFH diesel (32%) Other metals (8%)	3 x 10^{-7}	5 x 10^{-6}	TCE (91%) N-nitrosodiphenylamine (6%)
			Inhalation (Showering)	ND	ND	NA	1 x 10^{-6}	2 x 10^{-5}	TCE (100%)
			Dermal (Showering)	<0.01	<0.01	NA	1 x 10^{-8}	2 x 10^{-7}	NA
			Additive Risk	0.4	0.7	NA	1 x 10^{-6}	3 x 10^{-5}	NA

Table 6-12

(Continued)

				Noncancer Effects			Cancer Effects		
				Noncancer Hazard Index			Excess Lifetime Cancer Risk		
Aquifer	Study Subareas	Exposed Individual	Exposure Setting	Average Case	Reasonable Maximum Case	Risk-Contributing Chemicals[a]	Average Case	Reasonable Maximum Case	Risk-Contributing Chemicals[a]
Upper (Cont'd)	Lower Bluff	Future Resident	Ingestion	0.8	3	Manganese (39%) TFH diesel (32%) Arsenic (16%)	1×10^{-5}	1×10^{-4}	Arsenic (88%) TFH gas (10%)
			Inhalation (Showering)	0.02	0.05	NA	1×10^{-6}	1×10^{-5}	Benzene (100%)
			Dermal (Showering)	<0.01	<0.01	NA	4×10^{-8}	5×10^{-7}	NA
			Additive Risk	0.8	3	NA	1×10^{-5}	1×10^{-4}	NA
	Post Road Corridor	Future Resident	Ingestion	0.2	0.5	NA	3×10^{-7}	3×10^{-6}	TFH gas (90%) Benzene (4%)
			Inhalation (Showering)	ND	ND	NA	9×10^{-8}	5×10^{-7}	NA
			Dermal (Showering)	<0.01	<0.01	NA	9×10^{-10}	1×10^{-8}	NA
			Additive Risk	0.2	0.5	NA	4×10^{-7}	4×10^{-6}	NA

Table 6-12

(Continued)

Aquifer	Study Subareas	Exposed Individual	Exposure Setting	Noncancer Effects			Cancer Effects		
				Noncancer Hazard Index		Risk-Contributing Chemicals[a]	Excess Lifetime Cancer Risk		Risk-Contributing Chemicals[a]
				Average Case	Reasonable Maximum Case		Average Case	Reasonable Maximum Case	
Upper (Cont'd)	Golf Course Beaver Pond	Future Resident	Ingestion	0.02	0.08	NA	2×10^{-7}	3×10^{-6}	TFH gas (84%) TCE (10%) Benzene (6%)
			Inhalation (Showering)	ND	ND	NA	4×10^{-7}	2×10^{-6}	TCE (63%) Benzene (37%)
			Dermal (Showering)	<0.01	<0.01	NA	2×10^{-9}	2×10^{-8}	NA
			Additive Risk	0.02	0.08	NA	6×10^{-7}	5×10^{-6}	NA
	Waste Paint Tank	Future Resident	Ingestion	0.02	0.03	NA	5×10^{-7}	3×10^{-6}	bis(2-ethylhexyl)phthalate (100%)
			Inhalation (Showering)	<0.01	<0.01	NA	ND	ND	NA
			Dermal (Showering)	<0.01	<0.01	NA	2×10^{-10}	2×10^{-9}	NA
			Additive Risk	0.02	0.03	NA	5×10^{-7}	3×10^{-6}	NA

Table 6-12

(Continued)

				Noncancer Effects			Cancer Effects		
				Noncancer Hazard Index			Excess Lifetime Cancer Risk		
Aquifer	Study Subareas	Exposed Individual	Exposure Setting	Average Case	Reasonable Maximum Case	Risk-Contributing Chemicals[b]	Average Case	Reasonable Maximum Case	Risk-Contributing Chemicals[b]
Lower	Drinking Water Wells	Current Resident	Ingestion	ND	ND	NA	ND	ND	NA
			Inhalation (Showering)	ND	ND	NA	ND	ND	NA
			Dermal (Showering)	ND	ND	NA	ND	ND	NA

[a] The estimated risks are for a future residential setting over a lifetime. There is no current domestic water use of the upper aquifer. Additive risk equals the sum of the ingestion, inhalation, and dermal risks.

[b] Value in parentheses is the percent contribution to the total pathway risk estimate, for reasonable maximum exposure conditions. A value is listed when the excess lifetime cancer risk exceeds 1×10^{6} or when the HI exceeds 0.5.

ND = No applicable chemicals detected.

NA = Not applicable.

corridor, and golf course beaver pond subareas to 1 x 10^{-4} at the lower bluff subarea. Arsenic contributed 88 percent of the risk for ingestion in the lower bluff subarea.

The RME additive risks exceeded an HI of 1.0 and equaled an excess lifetime cancer risk of 1 x 10^{-4} at the lower bluff subarea. For all other subareas, the additive risks were less than the criteria. The ingestion route provided most of the additive risk.

Arsenic is a contributor to the calculated risk values at the lower bluff area. Background levels of metals were not subtracted from the risk calculations. The maximum concentration for arsenic in the lower bluff area was 0.0054 mg/L. In comparison, well MW02 in the upgradient subarea, which had an arsenic concentration of 0.0018 mg/L, would have an estimated excess lifetime cancer risk of 4 x 10^{-5} and a hazard quotient of 0.2. Consequently, at least 40 percent of the excess lifetime cancer risk at the lower bluff area probably results from background levels of arsenic. The organic contaminants contribute approximately 10^{-6} to 10^{-5} to the RME excess lifetime cancer risk for future residents exposed to upper aquifer groundwater in all subareas of OU 5.

The risk estimates produced for the upper aquifer are for a future residential scenario over a lifetime. This is a highly conservative scenario. It is very unlikely that the upper aquifer at OU 5 will ever be used for domestic purposes because of low yield and the availability of municipal or military water supplies from other sources.

No contaminants of concern above background levels were detected in the lower aquifer.

Groundwater Risks from Individual Wells: The estimated noncancer and cancer risks (RME only) for individual monitoring well samples for ingestion, inhalation, and dermal absorption are shown in Table 6-13. Figure 6-1 shows the additive risks. The risks are based on only one sampling event per well.

Table 6-13

Summary of Risk Estimates for Individual Monitoring Wells

			Noncancer Effects		Cancer Effects	
Study Subarea	Well ID No.[a]	Exposure Setting[b]	Noncancer Hazard Index: Reasonable Maximum Case	Risk-Contributing Chemicals[c]	Excess Lifetime Cancer Risk: Reasonable Maximum Case	Risk-Contributing Chemicals[c]
Upgradient	OU5MW02	Ingestion	ND	NA	$7x10^{-7}$	NA
		Inhalation	ND	NA	$3x10^{-6}$	TCE (100%)
		Dermal Contact	ND	NA	$3x10^{-8}$	NA
		Additive Risks	ND	NA	$4x10^{-6}$	NA
	OU5MW03	Ingestion	0.3	NA	$3x10^{-7}$	NA
		Inhalation	ND	NA	ND	NA
		Dermal Contact	0.0001	NA	$2x10^{-10}$	NA
		Additive Risks	0.3	NA	$3x10^{-7}$	NA
	OU5MW04	Ingestion	0.4	NA	$3x10^{-7}$	NA
		Inhalation	ND	NA	ND	NA
		Dermal Contact	0.0002	NA	$2x10^{-10}$	NA
		Additive Risks	0.4	NA	$3x10^{-7}$	NA
	OU5MW06	Ingestion	0.01	NA	$9x10^{-6}$	TCE (78%) TPH Gas (20%)
		Inhalation	0.005	NA	$3x10^{-5}$	TCE (100%)
		Dermal Contact	0.00007	NA	$3x10^{-7}$	NA
		Additive Risks	0.02	NA	$4x10^{-5}$	NA

Table 6-13

(Continued)

Study Subarea	Well ID No.^{a}	Exposure Setting^{b}	Noncancer Effects		Cancer Effects	
			Noncancer Hazard Index: Reasonable Maximum Case	Risk-Contributing Chemicals^{c}	Excess Lifetime Cancer Risk: Reasonable Maximum Case	Risk-Contributing Chemicals^{c}
	OU5MW07	Ingestion	ND	NA	$2x10^{-5}$	1,1,2,2-Tetrachloroethane (91%) TCE (9%)
Upgradient	OU5MW07	Inhalation	ND	NA	$7x10^{-6}$	TCE (100%)
		Dermal Contact	ND	NA	$6x10^{-7}$	NA
		Additive Risks	ND	NA	$3x10^{-5}$	NA
Waste Paint Tank	OU5MW11	Ingestion	0.03	NA	$3x10^{-6}$	Bis(2-ethylhexyl)-phthalate (100%)
		Inhalation	0.0005	NA	ND	NA
		Dermal Contact	0.00005	NA	$2x10^{-9}$	NA
		Additive Risks	0.03	NA	$3x10^{-6}$	NA
Pipeline Corridor	SP1-02	Ingestion	0.5	Manganese (88%) Vanadium (5%) Barium (3%)	$4x10^{-6}$	TCE (100%)
		Inhalation	ND	NA	$2x10^{-5}$	TCE (100%)
		Dermal Contact	0.001	NA	$2x10^{-7}$	NA
		Additive Risks	0.5	NA	$2x10^{-5}$	NA
	SP2/6-05	Ingestion	0.2	NA	ND	NA
		Inhalation	ND	NA	ND	NA

Table 6-13

(Continued)

Study Subarea	Well ID No.^{a}	Exposure Setting^b	Noncancer Effects: Noncancer Hazard Index: Reasonable Maximum Case	Noncancer Effects: Risk-Contributing Chemicals^c	Cancer Effects: Excess Lifetime Cancer Risk: Reasonable Maximum Case	Cancer Effects: Risk-Contributing Chemicals^c
		Dermal Contact	0.0001	NA	ND	NA
		Additive Risks	0.2	NA	ND	NA
Lower Bluff	SP1-01	Ingestion	3	Manganese (40%) TFH diesel (32%) Arsenic (16%)	1x10^{-4}	Arsenic (88%) TFH gas (10%) Benzene (2%)
		Inhalation	0.05	NA	1x10^{-5}	Benzene (100%)
		Dermal Contact	0.009	NA	5x10^{-7}	NA
		Additive Risks	3	NA	1x10^{-4}	NA
	OU5MW16A	Ingestion	0.9	Manganese (62%) Arsenic (23%) Barium (7%)	6x10^{-5}	Arsenic (90%) TFH gas (8%) Benzene (8%)
		Inhalation	0.01	NA	5x10^{-6}	Benzene (100%)
		Dermal Contact	0.002	NA	2x10^{-7}	NA
		Additive Risks	0.9	NA	7x10^{-5}	NA
	OU5MW15	Ingestion	0.2	NA	2x10^{-5}	Arsenic (94%) TFH gas (5%)
		Inhalation	0.0007	NA	ND	NA
		Dermal Contact	0.0004	NA	5x10^{-6}	NA
		Additive Risks	0.2	NA	2x10^{-5}	NA

Table 6-13

(Continued)

Study Subarea	Well ID No.[a]	Exposure Setting[b]	Noncancer Effects: Noncancer Hazard Index: Reasonable Maximum Case	Noncancer Effects: Risk-Contributing Chemicals[c]	Cancer Effects: Excess Lifetime Cancer Risk: Reasonable Maximum Case	Cancer Effects: Risk-Contributing Chemicals[c]
Post Road Corridor	OU5MW13	Ingestion	0.3	NA	$5x10^{-6}$	TFH gas (96%) Benzene (4%)
		Inhalation	ND	NA	$8x10^{-7}$	NA
		Dermal Contact	0.0001	NA	$1x10^{-8}$	NA
		Additive Risks	0.3	NA	$6x10^{-6}$	NA
	OU5MW09	Ingestion	0.6	TFH diesel (100%)	$2x10^{-7}$	NA
		Inhalation	ND	NA	ND	NA
		Dermal Contact	0.0003	NA	$8x10^{-11}$	NA
		Additive Risks	0.6	NA	2x10-7	NA
Golf Course Beaver Pond	GW4A	Ingestion	0.2	NA	$6x10^{-6}$	TFH gas (90%) TCE (6%) Benzene (5%)
		Inhalation	ND	NA	$2x10^{-6}$	TCE (53%) Benzene (47%)
		Dermal Contact	0.00007	NA	$3x10^{-8}$	NA
		Additive Risks	0.2	NA	$8x10^{-6}$	NA

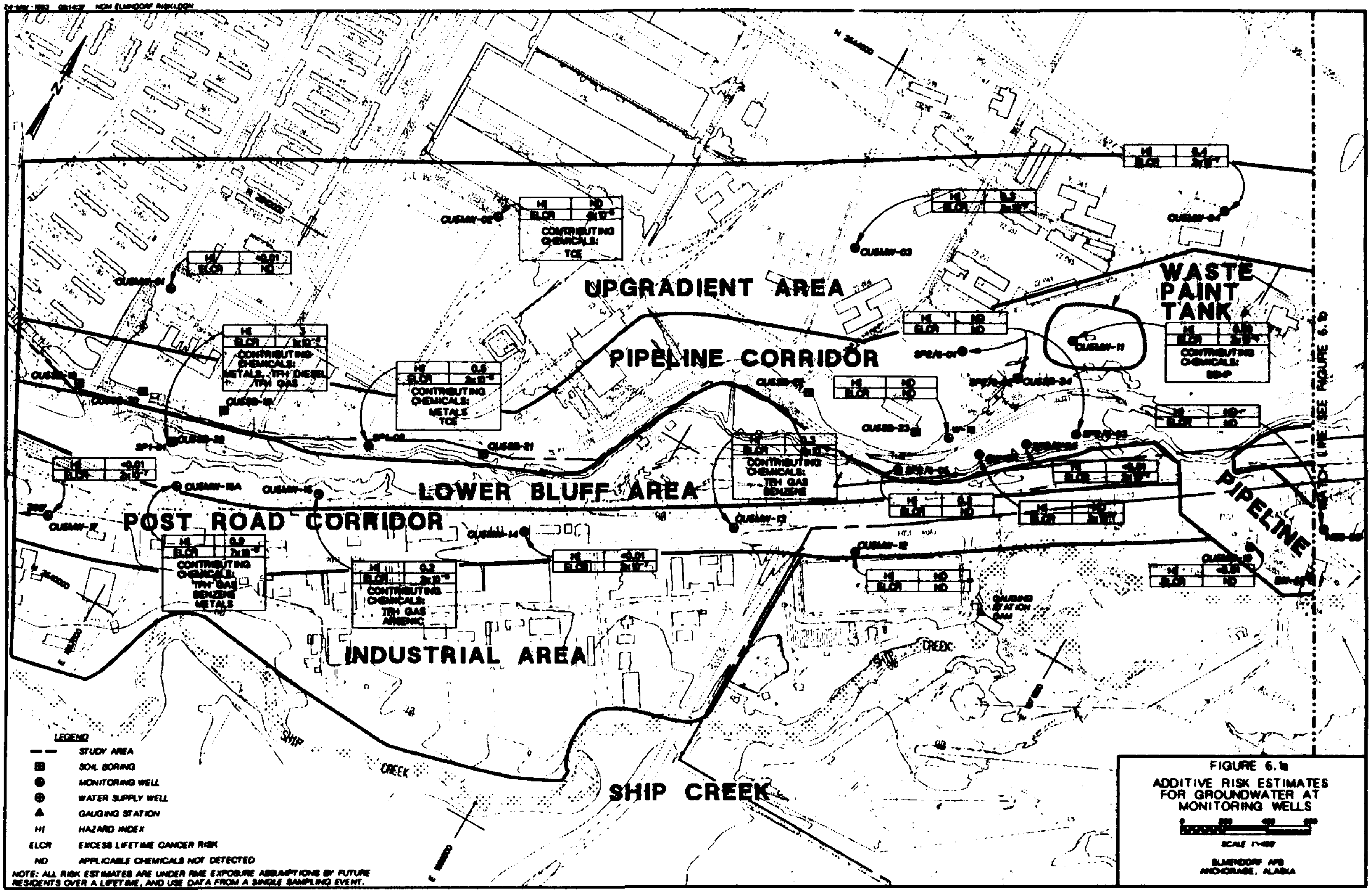
[a] Monitoring wells with both an additive HI of less than 0.01 and an additive excess lifetime cancer risk of less than 10^{-6} are not shown in this table. Risk estimates for all wells are found in Appendix P.

[b] Additive risk equals the sum of the ingestion, inhalation, and dermal risks.

[c] Value in parentheses is the percent contribution to the total pathway risk estimate, for reasonable maximum exposure conditions. A value is listed when the excess lifetime cancer risk exceeds $1x10^{-6}$ or when the HI exceeds 0.5. The estimated risks are for a future residential setting over a lifetime.

NA = No applicable chemicals detected.

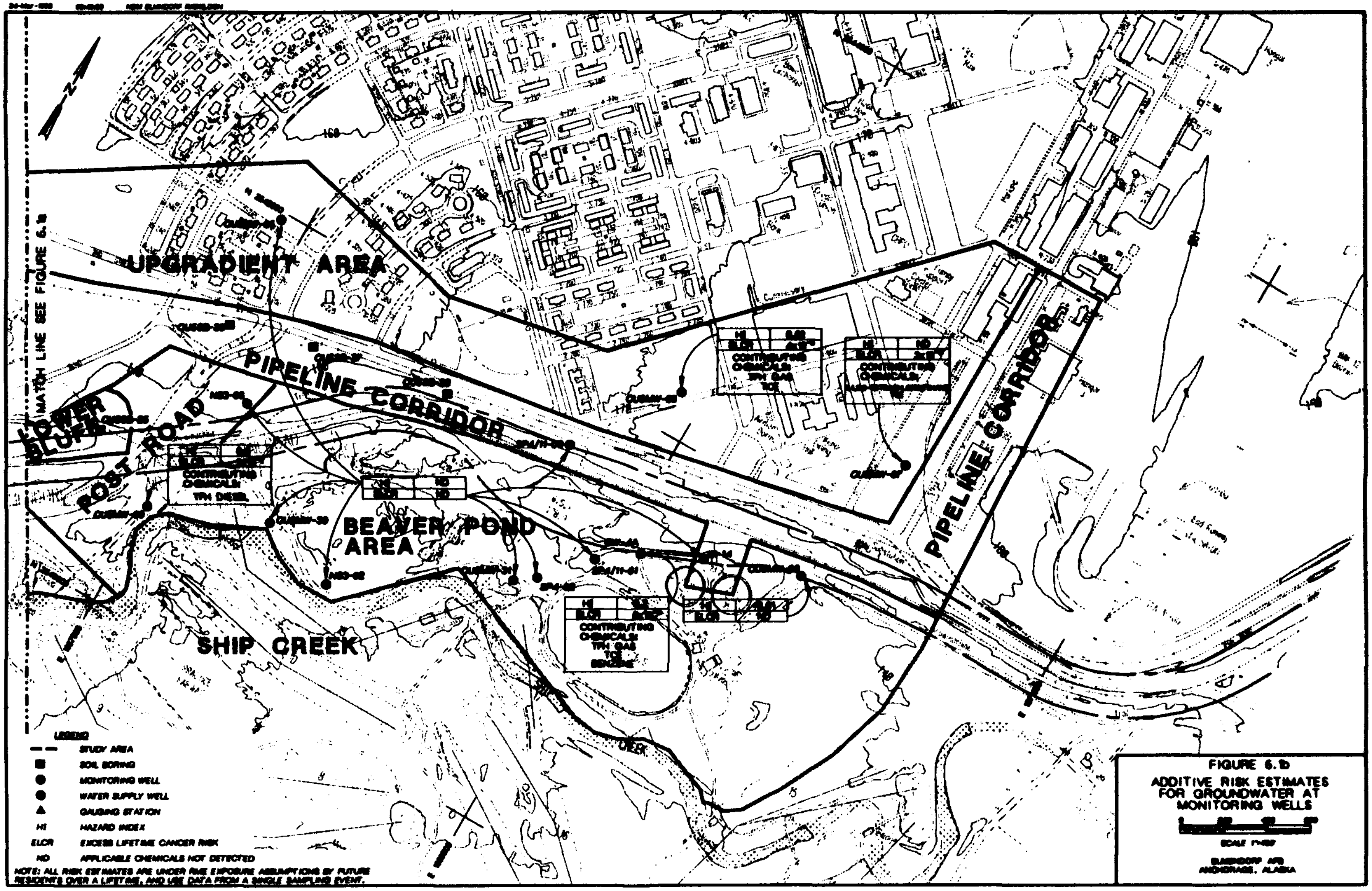
ND = Not applicable per footnotes a and b.



NOTE: ALL RISK ESTIMATES ARE UNDER RME EXPOSURE ASSUMPTIONS BY FUTURE RESIDENTS OVER A LIFETIME, AND USE DATA FROM A SINGLE SAMPLING EVENT.

FIGURE 6.1a

ADDITIVE RISK ESTIMATES FOR GROUNDWATER AT MONITORING WELLS



NOTE: ALL RISK ESTIMATES ARE UNDER RME EXPOSURE ASSUMPTIONS BY FUTURE RESIDENTS OVER A LIFETIME, AND USE DATA FROM A SINGLE SAMPLING EVENT.

FIGURE 6.1b

ADDITIVE RISK ESTIMATES FOR GROUNDWATER AT MONITORING WELLS

ELMENDORF AFB
ANCHORAGE, ALASKA

The only individual well to have an HI greater than 1.0 is SP101 in the lower bluff subarea. The excess lifetime cancer risk for well SP101 is 1 x 10^{-4}. All other wells have excess lifetime cancer risks of less than 1 x 10^{-4}.

Inhalation (Air) Exposure Pathways

Noncancer and excess lifetime cancer risks for dust inhalation are estimated under future residential exposure over a lifetime, and are shown in Table 6-14. The risk estimates were generated using very conservative assumptions. The actual risks are probably much less for the reasons discussed in the following paragraphs.

Upper bound dust concentrations are first estimated using maximum sitewide surface soil concentrations, assuming a PM_{10} equivalent to the federal annual standard of 50 $\mu g/m^3$. The federal standard is very conservative, because local PM_{10} measurements for the MOA show a mean of annual averages from 1986 through 1990 of 22.9 $\mu g/m^3$, and a range of 17.1 to 31.3 $\mu g/m^3$ over the 5 years[a]. Consequently, the upper bound risk may be less than 60 percent of the estimated value using the federal annual standard and is recalculated using 30 $\mu g/m^3$. It is also highly unlikely that the measured PM_{10} would entirely come from OU 5 sources; instead it likely is contributed to by other regional sources such as glacial flour and road dust.

Currently residents live only in the upgradient subareas. The sitewide surface soil concentrations that contributed to the inhalation risk came from the lower bluff subarea, which is not occupied by residences and, for reasons previously enumerated under the soil and groundwater pathways, is unlikely ever to be a residential area.

The risk estimates in Table 6-14 are based on an exposure duration of 275 days per year in the average case and 350 days per year in the RME and maximum screen

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[a] PM_{10} data obtained from Mr. Lawrence Taylor, Department of Human Health and Services; MOA data are from recording station at 7th Avenue and C Street, Anchorage, Alaska.

Table 6-14

Summary of Risk Estimates for Dust Inhalation[a]

Study Area	Exposure Setting	Particulate Concentration[b] ($\mu g/m^3$)	Noncancer Hazard Index	Risk-Contributing Chemicals[c]	Excess Lifetime Cancer Risk	Risk-Contributing Chemicals[c]
OU 5 (all subareas)	Future Residential	50	2 MAX 1 RME 0.7 AVE	Chromium (86%) Manganese (7%) Barium (6%)	$4x10^{-5}$ MAX $2x10^{-5}$ RME $2x10^{-5}$ AVE	Chromium (91%) Arsenic (9%)
		30	1 MAX 0.6 RME 0.4 AVE		$2x10^{-5}$ MAX $1x10^{-5}$ RME $9x10^{-6}$ AVE	

[a] Sitewide concentrations in surface soil samples (0-2-ft depth) were used to estimate dust concentrations. The estimated risks are for a future residential setting over a lifetime.

Exposure cases: MAX = maximum concentrations used to estimate risks as screening approach
RME = reasonable maximum exposure case
AVE = average case

[b] Particulate concentration: $50 \mu g/m^3$ = federal annual PM_{10} standard
$30 \mu g/m^3$ = Municipality of Anchorage average annual PM_{10} data

[c] Value in parenthesis is the percent contribution to the the total RME pathway risk estimate.

cases. The soils at OU 5 are frozen and covered by snow for half of the year, however. Such winter conditions would limit the wind transport of soil particles from OU 5. (Most of the winter airborne dust in the MOA comes from sanded roadways and exposed glacial outwashes.) To account for the snow cover, the RME risk estimates may be multiplied by 0.5 and the average case estimates by 0.7.

The dust inhalation risk estimates can also be put in perspective by examining the chemicals and samples contributing to the risk estimates. Chromium VI and barium contribute 86% and 6%, respectively, to the RME HI for noncarcinogens. Arsenic and chromium VI contribute 9% and 91%, respectively, to the excess lifetime cancer risk estimate. The samples were analyzed for total metals which does not distinguish between the forms of chromium (VI and III); however, the higher toxicity values of chromium VI are used in generating the risk values. Chromium III is the most stable and commonly found ionic form in the environment (McGrath and Smith, 1990); so it is unlikely that chromium VI would constitute a significant amount of the total chromium content.

The two samples that generated the maximum metal risk were SL25S12A (barium and arsenic) and SL27S24N (chromium). Both sampling locations are in the lower bluff subarea in a very wet and vegetated area. Moisture contents for the two samples were 84 percent and 37 percent, respectively. Sample SL27S24 was also collected from the 12- to 24-inch depth. The samples are not likely to contribute to dust production because of their high soil moisture content, vegetative cover, and depth.

Sediment and Surface Water Exposure Pathways

Risks are quantified for current and future recreational users of the surface water bodies in OU 5. Assumed exposures for incidental ingestion are quantified for children only because adults are not likely to play in the ponds, and Ship Creek did not show any significant contamination. Maximum sediment and surface water concentrations from OU 5 are used to estimate the upper bound concentrations to eliminate exposure to sediment and surface water as a pathway of concern. No background metals data were available for sediment or surface water; consequently, site concentrations were not screened against background levels. The risk estimates are shown in Table 6-15.

No HI values exceed 1.0. The highest excess lifetime cancer risk is for recreational exposure to sediments of 1 x 10^{-6}. The assumptions used in this pathway are highly conservative. The estimated maximum risks are for a child playing (swimming or wading) directly in surface water at OU 5 and coming in contact with the sediments. It is assumed that a child is exposed for 1 hour per day for 26 days per year over a 5-year period. During the course of the field effort for the RI, only two children were observed rafting on the ponds and two were observed collecting golf balls from Ship Creek.

6.1.6 Uncertainties and Assumptions

6.1.6.1 Uncertainty Factors

Risk assessment as a scientific activity is subject to uncertainty, both with risk assessment in general and regarding an understanding of the site or site-specific uncertainties. This assessment is subject to uncertainty pertaining to:

- Sampling and analysis;
- Fate and transport estimation;
- Exposure estimation; and
- Toxicological data.

Uncertainties associated with sampling and analysis include the inherent variability (standard error) in the analysis, representativeness of the samples, sampling errors, and heterogeneity of the sample matrix. While the QA/QC program used in the RI

Table 6-15

Summary of Risk Screening Estimates for Sediments and Surface Water[a]

Media	Exposed Individual (current and future)	Exposure Setting[b]	Noncancer Effects		Cancer Effects	
			Noncancer Hazard Index	Risk-Contributing Chemicals[c]	Excess Lifetime Cancer Risk	Risk-Contributing Chemicals[c]
Sediments	Recreational (child)	Incidental ingestion	0.3	NA	1×10^{-6}	Metals (84%) PCB (13%) PAHs (3%)
		Dermal absorption	0.5	TPH diesel (91%)	8×10^{-7}	NA
		Additive Risk	0.8	NA	2×10^{-6}	NA
Surface Water	Recreational (child)	Incidental ingestion	<0.01	NA	8×10^{-8}	NA
		Dermal absorption	<0.01	NA	3×10^{-8}	NA
		Additive Risk	<0.01	NA	1×10^{-7}	NA

[a] As a screening approach, sitewide maximum detected concentrations were used to estimate risks. Exposure assumptions are shown in Table 6-9. The estimated risks are for a child playing (swimming or wading) directly in surface water at OU 5 and coming in contact with sediments. It is assumed that a child is exposed for 1 hour per day for 26 days per year over a 5-year period.

[b] Inhalation of vapors from surface water is discussed in text. Additive risk equals the sum of the ingestion and dermal risks.

[c] Value in parentheses is the percent contribution to the total pathway risk estimate. A value is listed only when the excess lifetime cancer risk exceeds 1×10^{-6} or when the Hazard Index exceeds 0.5.

NA = Not applicable.

serves to reduce these errors, it cannot eliminate all errors associated with sampling and analysis.

This assessment made simplifying assumptions about the environmental fate and transport of the site contaminants; specifically, that no contaminant loss or transformation occurred. The choice of data to represent exposure point concentrations is an additional source of potential error.

The estimation of exposure required numerous assumptions to describe potential exposure situations. There are a number of uncertainties regarding likelihood of exposure, frequency of contact with contaminated media, concentration of contaminants at exposure points, and time period of exposure. These tend to simplify and approximate actual site conditions.

The toxicological database is also a source of uncertainty. The EPA outlined some of the sources of uncertainties in its *Guidelines for Carcinogen Risk Assessment* (1986a). They include extrapolation from high to low doses and from animals to humans; species, gender, age, and strain differences in uptake, metabolism, organ distribution, and target site susceptibility; and human population variability with respect to diet, environment, activity patterns, and cultural factors.

Uncertainty in the risk assessment is a function of the "state-of-the-practice" of risk assessment in general and also a function of the uncertainty specific to OU 5 in particular. Table 6-16 lists general uncertainty factors in risk assessment.

6.1.6.2 Assumptions

The major assumptions used in this assessment are:

- Contaminant concentrations remain constant over the exposure period;

Table 6-16

Uncertainty Factors in the Human Health Risk Evaluation for OU 5

Uncertainty Factor	Effect of Uncertainty	Comment
Use of cancer slope factors	May overestimate risk of developing cancer.	Slope factors are upper 95th percent confidence limits derived from the linearized multistage model. Considered unlikely to underestimate true risk.
Risks within an exposure route assumed to be additive	May overestimate or underestimate risk.	Does not account for synergism or antagonism.
Critical toxicity values derived mainly from animal studies	May overestimate or underestimate risk.	Extrapolation from animal to humans may incorporate errors due to differences in pharmacokinetics, pharmacodynamics, and population variability.
Critical toxicity values derived mainly from high dose exposures, most exposures are at low doses	May overestimate or underestimate risk.	Assumes linearity at low doses.
Critical toxicity values in general	May overestimate or underestimate risk.	Not all values represent the same degree of certainty. All are subject to change as new evidence becomes available.
Pharmacokinetics	May overestimate or underestimate risk.	Assumption that pharmacokinetics and pharmacodynamics are equivalent across species.
Not all chemicals of concern have RfDs or SFs	May underestimate risk.	Health risks of exposure to such chemicals cannot be quantified.
Exposures to chemicals in ambient air not directly measured but were calculated from soil concentrations	May overestimate risk for soils.	Sampling and analysis of ambient air was not conducted.
Exposure Assumptions (Tables 6.6 - 6.9)	May overestimate or underestimate risk.	Assumptions regarding ingestion rates, exposure durations and frequencies, body weight, etc., may not be accurate.
Exposures assumed constant	May overestimate or underestimate risk.	Does not account for environmental fate, transport, or dilution.
Limited scope of chemical analysis	May underestimate risk.	Metals in groundwater were not analyzed in some subareas.
Some soil results reported as wet weight instead of dry weight values.	May underestimate risk.	Part of the soil sample results were reported as wet weight. Both wet and dry weight results were used in risk estimates.

- Exposure remains constant over time;
- Selected intake rates and population characteristics (for example, weight, life span, and activities) are representative for the potentially exposed population; and
- All intake of contaminants is from the site-related exposure media and not from other sources (no relative source contribution).

6.1.7 Summary and Comparison to EPA Bench Marks

The baseline risk assessment is an evaluation of the potential public health risks posed by the pipelines and other identified sources at OU 5 under the no-action (no remedial action) alternative. Risks are evaluated under current and potential future site conditions. Current uses are residential for upgradient subarea surface soil and the lower groundwater aquifer, no current use for the upper aquifer (hence, no risk), trench worker for subsurface soils, and recreational for sediments and surface water. Future uses are assumed to be residential for surface soil and groundwater evaluations, trench worker for subsurface soils, and recreational for sediments and surface water.

Contaminants of potential concern are identified by evaluating the toxicities, concentrations, and frequencies of detection of the chemicals during the RI. The major contaminants of concern are TFH gas, TFH diesel, JP-4, benzene, 1,1,2,2-tetrachloroethane, TCE, and metals. For the purpose of this risk assessment, contaminant concentrations are assumed to remain constant during the duration of the assumed exposures.

The major exposure pathways for OU 5 are identified. Those pathways that have at least some likelihood of occurring under current or potential future site conditions include the following:

- Exposure of current (upgradient subarea) and future (all other subareas) residents to contaminated surface soil through direct contact (incidental ingestion and dermal absorption) and inhalation of dusts;

- Exposure of current and future short-term workers to contaminated subsurface soil through direct contact (dermal absorption and incidental ingestion) and inhalation of vapors from the soil;
- Exposure of current (nearby) and future residents to contaminated lower aquifer groundwater through ingestion, inhalation (showering), and dermal contact (showering);
- Exposure of future residents to contaminated upper aquifer groundwater through ingestion, inhalation (showering), and dermal absorption (showering);
- Exposure of current and future recreationists (children) to contaminated sediment through ingestion and dermal absorption;
- Exposure of current and future recreationists (children) to contaminated surface water through ingestion, dermal absorption, and inhalation of volatiles from the surface water; and
- Exposure of recreationists through consumption of locally caught fish in Ship Creek.

Risk estimates are developed for these assumed exposure scenarios, and the results are summarized in Tables 6-10 through 6-15 and 6-17. The risks summarized in those tables are based on maximum concentrations screening for subsurface soil, surface water, sediment, and some surface soil, and on average case and RME scenarios developed for groundwater and some surface soil. No quantitative estimates of exposure by fish consumption were made because no significant contamination in Ship Creek was found.

Several pathways listed in Table 6-17 used a maximum concentration screening approach to eliminate pathways of low risk to human health. Consequently, the risk estimates listed for the surface soil, subsurface soil, surface water, and sediment are highly conservative, and the actual risks are probably much less. In most cases, one exposure route (usually ingestion) within a pathway contributed to an estimated risk that was an order of magnitude (10x) higher than the other exposure routes. Consequently, additivity did not increase the overall risk for a given pathway.

Table 6-17

Summary of Human Health Risk Assessment

Pathway	Exposed Population	Exposure Case[a]	Exposure Route	Summary of Risk Assessment Results
Surface Soil	Residents (future) over a lifetime	Maximum concentration screening for all subareas; average and reasonable maximum for lower bluff subarea	Ingestion	HIs (RME) <1.0; ELCR (RME) 7 x 10^{-5} at lower bluff subarea; ELCR (AVE) 4 x 10^{-6} at lower bluff subarea
			Inhalation	See Air Pathway
			Dermal	HIs <1.0; ELCR (RME) 9 x 10^{-6} at lower bluff subarea; ELCR (AVE) 4 x 10^{-8} at lower bluff subarea
		Additive Risks		HI (RME) <1.0; ELCR (RME) 8 x 10^{-5} at lower bluff subarea; ELCR (AVE) 4 x 10^{-6} at lower bluff subarea
Subsurface Soil	Trench worker (current/future) who spends 24 days per year for 5 years in trenches at OU 5	Maximum concentration screening	Ingestion	HIs <1.0; ELCR <10^{-6}
		Risk-based concentration screening of individual chemicals	Inhalation	Concentrations of chemicals less than target risk levels for an HI of 1.0 and ELCR of 10^{-6}
		Maximum concentration screening	Dermal	HIs <1.0; ELCR <10^{-6}
		Additive Risks		HIs <1.0; ELCR <10^{-6}
Groundwater	Residents (current/future—lower aquifer; future—upper aquifer) over a lifetime	Average and reasonable maximum exposure	Ingestion	**Lower Aquifer:** No contaminants of concern above background. **Upper Aquifer:** HI (RME) exceeds 1.0 and ELCR (RME) risk equals 10^{-4} at lower bluff subarea. Well SP101 is contributing to the risk. The risk is largely due to metals that may be background levels. ELCR (RME) equal to or less than 10^{-5} for other subareas.
			Inhalation (showering)	**Lower Aquifer:** No volatile compounds detected. **Upper Aquifer:** HIs <1.0; ELCR (RME) between 10^{-5} and 10^{-6} for upgradient, pipeline corridor, lower bluff, and golf course beaver pond subareas.

Table 6-17

(Continued)

Pathway	Exposed Population	Exposure Case[a]	Exposure Route	Summary of Risk Assessment Results
Groundwater (cont.)			Dermal (showering)	**Lower Aquifer:** No contaminants of concern. **Upper Aquifer:** HIs <1.0; ELCR (RME) $<10^{-6}$.
		Additive Risks		**Lower Aquifer:** No contaminants of concern. **Upper Aquifer:** HI (RME) exceeds 1.0 and ELCR (RME) risk equals 10^{-4} at lower bluff subareas.
Surface Water	Recreationists (current/future) — a child exposed for 1 hour per day for 26 days over 5 years	Maximum concentration screening	Ingestion	HI $= 1.0$; ELCR $<10^{-6}$
			Inhalation	See Air Pathway
			Dermal	HI <1.0; ELCR $<10^{-6}$
			Fish Ingestion	No chemical concentration data in fish tissues are available. No significant contamination in Ship Creek.
		Additive Risks		HI <1.0; ELCR $<10^{-6}$
Sediments	Recreationists (current/future) — a child exposed for 1 hour per day for 26 days over 5 years	Maximum concentration screening	Ingestion	HI <1.0; ELCR equals 10^{-6}
			Dermal	HI <1.0; ELCR 10^{-6}
		Additive Risks		HI <1.0; ELCR 2×10^{-6}
Air	Residents (future) over a lifetime	Average and reasonable maximum exposure	Inhalation—dust from surface soils	HI (RME) $= 1.0$; ELCR (RME) 2×10^{-5} using very conservative assumptions. Risks due to OU 5 sources probably much less. See Section 6.1.5.3.
			Inhalation—volatilization from surface water	Qualitative assessment of pathway determined risk to be very low. See text. See Section 6.1.4.2.

[a] Where the exposure case used the maximum concentration as a screening approach, the risk estimates are highly conservative and the actual risks are probably much less. Additive risks equal the sum of the exposure route risks within a pathway.

HI = Hazard Index.
ELCR = Excess Lifetime Cancer Risk.
RME = Reasonable Maximum Exposure.

For exposures to carcinogenic substances, EPA has determined that "acceptable exposure levels are generally concentrations that represent an excess upper bound (RME) lifetime cancer risk to an individual of between 10^{-4} to 10^{-6} using information of the relationship between dose and response." For noncarcinogens, "acceptable exposure levels shall represent concentrations to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime . . ." (EPA, 1989b). In other words, exposures to noncarcinogens cannot exceed RfD intake levels. EPA has more recently clarified the role of risk assessment in supporting risk management decisions (1991c). When the cumulative carcinogenic site risk to an individual based on the reasonable maximum exposure for both current and future land use is less than 10^{-4}, and the noncarcinogenic HI is less than 1, action is generally not warranted unless environmental impacts exist. However, MCLs and other applicable or relevant and appropriate requirements (ARARs) are also to be considered. For the State of Alaska, a policy stating what risk levels generally do not warrant remediation has not been established by ADEC, and may be different from the EPA position.

For the individual exposure pathways in this assessment (under RME assumptions), the only environmental medium containing contaminant concentrations that generate noncancer HI values exceeding 1, or total excess lifetime cancer risks greater than 1 x 10^{-4}, is the upper aquifer groundwater over a lifetime at the lower bluff subarea. In this scenario, future exposure of residents through ingestion of groundwater over a lifetime is assumed. The estimated risks for ingestion of upper aquifer groundwater in the lower bluff subarea are largely due to metals (arsenic and manganese). The risk assessment is based on only one round of sampling. Additional sampling may show that the arsenic levels are due to background levels. The arsenic levels (maximum 0.0054 mg/L) in the upper aquifer groundwater at OU 5 are less than the federal and Alaska state drinking water standards of 0.05 mg/L.

Organic contaminants contribute a total of 10^{-6} to 10^{-5} RME excess lifetime cancer risks for future residents through ingestion, inhalation of volatiles, and dermal contact over a lifetime of exposure to upper aquifer groundwater at all subareas of OU 5. Those organic contaminants contributing to the risks include TFH gas, TFH diesel, benzene, and TCE. All but the TCE may be the result of old pipeline leaks at OU 5. However, the sources of TCE in the upper aquifer groundwater appear to be upgradient of the OU 5 study area. Although excess lifetime cancer risks calculated for organic contaminants do not exceed 10^{-4}, both benzene and TCE levels in the upper aquifer groundwater do exceed federal and Alaska state drinking water standards of 5 mg/L.

A future residential scenario for the upper aquifer groundwater is highly conservative. The upper aquifer at OU 5 is unlikely to be used for domestic purposes because of low yield and the availability of other piped water supplies from the MOA. The upper aquifer is not currently being used at OU 5. No risks were identified for use of lower aquifer groundwater.

The risk estimates in this assessment are based on a no-action scenario at OU 5 and they could be mitigated through future remedial action at the sources and study subareas.

6.2 Ecological Evaluation

This baseline ecological evaluation addresses the potential risks to ecological receptors from the contaminants in OU 5.

This evaluation is based on the following major assumptions:

- No remedial actions will be taken;
- The media of primary concern are soils within 1 foot of the ground surface, sediment, and surface water;
- For the purpose of risk assessment, future chemical concentrations will not change over time;

- Observed concentrations of petroleum and metal contaminants at points of exposure were assumed to be 100 percent bioavailable; and

- Future land uses will be similar to current uses.[b]

This ecological evaluation is based on the data collected during the remedial investigation, which are presented in earlier sections of this report. The following sections are the most relevant:

- **Sections 2.1 and 2.2** describe procedures used in the field investigations (including aquatic and terrestrial ecological surveys) and chemical analyses.

- **Section 3.6** discusses the ecological characteristics of aquatic and terrestrial communities in OU 5.

- **Sections 4.4, 4.5, and 4.6** provide information on nature and extent of contamination where aquatic and terrestrial receptors were surveyed.

- **Section 5.0** describes the conceptual model, including sources, characteristics, release mechanisms, environmental fate, and transport pathways for contaminants in OU 5.

Other sections also provide information concerning the site characteristics and the nature and extent of contamination that was considered in evaluation of ecological risks.

The baseline ecological evaluation was performed in accordance with the following guidance documents:

- *Risk Assessment Guidance for Superfund: Volume II, Environmental Evaluation Manual* (EPA, 1989c);

- *Supplemental Guidance for Superfund Risk Assessments in Region 10* (EPA, 199d);

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[b] This assumption is based on a telephone conversation with Allen Richmond, natural resource planner at Elmendorf AFB, on December 1, 1992.

- *Handbook to Support the Installation Restoration Program (IRP) Statements of Work: Volume I—Remedial Investigation/Feasibility Studies (RI/FS)* (USAF, 1991); and
- *Framework for Ecological Risk Assessment* (EPA, 1992b).

This section is organized to present the evaluations for aquatic resources and for terrestrial resources separately, although some findings from the aquatic surveys are used in evaluating risks to semi-aquatic wildlife. Within the sections for aquatic and terrestrial resources, the following topics are included:

- **Selection of Site Contaminants** screens contaminants identified in Section 4 to determine which ones should be considered further in the ecological risk assessment.
- **Exposure Assessment** evaluates the pathways by which exposures can occur and estimates the magnitude of actual or potential ecological exposures and the frequency and duration of these exposures.
- **Toxicity Assessment** presents toxicity information available on chemicals of concern to determine their potential to cause adverse effects in aquatic or terrestrial ecological receptors.
- **Risk Characterization** integrates the exposure and toxicity assessments to estimate the likelihood of impacts to ecological receptors from exposure to OU 5 chemicals of potential concern.
- **Conclusions and Limitations** summarizes the basic conclusions of the environmental evaluation and the limitations or uncertainties associated with the data and methodology.

6.2.1 Aquatic Resources

Aquatic habitats and fauna were described in Section 3.6.1. The study areas of greatest concern are ponds and drainages along the foot of the lower bluff, the golf course beaver pond, and Ship Creek. These areas include beaver ponds, wetland ponds, and drainage ditches channeling OU 5 runoff to Ship Creek as shown on Figure 4-10. The nature and extent of contamination in these aquatic habitats were described in Sections 4.4 and 4.5.

Assessment endpoints (the environmental values to be protected) for aquatic receptors include the following:

- Integrity of aquatic habitats in OU 5;
- No impacts of environmental contaminants in OU 5 on aquatic species;
- Compliance with federal and state applicable or relevant and appropriate requirements (ARARs); and
- No exceeding of toxicity levels based on existing scientific literature.

Measurement endpoints include the following:

- General habitat conditions, including aquatic bed plants and fauna within OU 5, as assessed through qualitative and quantitative surveys;
- Benthic macroinvertebrate species diversity and density;
- EPT Index;
- Evidence of impaired ecosystem health, as indicated by the absence of aquatic plant life;
- Contaminant impacts on fish and invertebrates from laboratory toxicity testing;
- Comparisons of observed concentrations to documented effect levels; and
- Comparison of observations and contaminant concentrations to ARARs.

6.2.1.1 Selection of Site Contaminants

Surface Water

To assess the potential for adverse effects on aquatic organisms, surface water contaminant concentrations in Ship Creek, the ponds, and drainage ditches, are compared with federal Ambient Water Quality Criteria (AWQC) (EPA, 1986d) for aquatic life protection, and LOAELs (45 FR 79318). Alaska Water Quality Standards (WQS) (ADEC, 1991) are also considered for chemical elements (zinc) when more stringent than federal standards. The AWQC, Alaska WQS, and LOAEL values used for this assessment are presented in Table 6-18. Site comparisons to AWQC are presented in Tables 6-19 through 6-25, which list the concentrations detected in surface water samples. These tables show the maximum concentration of the potential contaminants detected for the two sample events. Also, as indicated on the figures, the federal AWQC for zinc is 106 μg/L, and the Alaska WQS is a more stringent 47 μg/L.

While AWQC for aquatic life protection currently exist for some PAHs (for example, naphthalene, fluoranthene, and phenanthrene; see Table 6-18), no criteria are available for other PAHs detected at OU 5. In lieu of this information, the criterion value for naphthalene is used as a surrogate for anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and pyrene (Table 6-26). In general, toxicity of relatively soluble PAHs to aquatic organisms increases with increasing molecular weight, to a point where low water solubility becomes limiting and the acute toxicity of high molecular weight PAHs is reduced (Eisler, 1987b). Table 6-26 summarizes the available freshwater and marine aquatic toxicity information for these chemicals. Based on these comparisons, the detection of each of the PAHs found in OU 5 surface water are well below acute or chronic criteria and LOAELs for the protection of aquatic life and, therefore, will not be evaluated in the risk characterization.

The BTEX grouping of chemical contaminants was detected in the surface water in a bluff pond (SW08) at concentrations that exceed the Alaska WQS of 10 μg/L for

Table 6-18

Ambient Water Quality Criteria for Aquatic Life Protection
(µg/L)

Chemical	Acute Criterion[a]	Chronic Criterion[a]
Aluminum	750 (13)	87 (13)
Antimony	/p/88 (12)	/p/30 (12)
Arsenic (III)	360 (4)	190 (4)
Arsenic (V)	850 (4)[b]	48 (4)[b]
Benzene	5,300 (2)[b]	–
Bis(2-ethylhexyl)phthalate	400 (11)[c]	360 (11)
Bromomethane	11,000[f]	–
Cadmium	3.9 (4)[d]	1.1 (4)[d]
Copper	18 (4)[d]	12 (4)[d]
1,1-dichloroethane	118,000 (2)[b]	20,000 (2)[b]
1,2-dichloroethane	118,000 (2)[b]	20,000 (2)[b]
Trans-1,2-dichloroethene	118,000 (2)[b]	20,000 (2)[b]
Ethylbenzene	32,000 (2)[b]	–
Fluoranthene	3,980 (2)[b]	–
Iron	–	1,000 (1)
Lead	82 (4)[d]	3.2 (4)[d]
Mercury (inorganic)	2.4 (4)	0.012 (4)
Naphthalene	2,300 (2)[b]	620 (2)[d]
Nickel	1,418 (6)[d]	158 (6)[d]
Phenanthrene	/p/30 (12)	/p/6.3 (12)
Selenium	20 (8)	5 (8)
Silver	0.92 (11)	0.12 (11)
1,1,2,2-tetrachloroethane	–	2,400 (2)[b]
Toluene	17,500 (2)[b]	–
1,1,1-trichloroethane	18,000 (2)[b]	–
Trichloroethylene	45,000 (2)[b]	21,900 (2)[b]
Zinc	117 (7)[d]	106 (7)[d]

[a] *Ambient Water Quality Criteria for Protection of Freshwater Aquatic Life*. The acute criterion reflects a 1-hour average not to be exceeded more than once every 3 years on average. Chronic criterion reflects a 4-day average concentration not to be exceeded more than once in 3 years on the average.

[b] Not enough data were available to derive a numerical national water quality criterion for aquatic life protection for these chemicals. Values reflect lowest reported effects levels. From 45 FR 79318, November 28, 1980.

[c] Not directly based on measured toxicity – See Document (11).

[d] Criterion is dependent on the hardness of the water. Assumed hardness = 100 mg/L

[e] Criterion is dependent on the pH of the water. The assumed pH is 7.8.

[f] Lowest reported effect level for halomethane.

[g] Lowest observed effect level.

Sources:
(1) From "Quality Criteria for Water" (Red Book), U.S. EPA July 1976
(2) From 45 FR 79318, November 28, 1980.
(3) From 49 FR 5831, February 15, 1984.
(4) From 50 FR 30784, July 29, 1985.
(5) From 51 FR 22978, June 24, 1986.
(6) From 51 FR 43665, December 3, 1986.
(7) From 52 FR 6213, March 2, 1987.
(8) From 53 FR 177, January 5, 1988.
(9) From 53 FR 19028, May 26, 1988.
(10) From 53 FR 33177, August 30, 1988.
(11) From 55 FR 19986, May 14, 1990.
(12) Proposed criteria /p/ (EPA May 1, 1991, Water Quality Criteria Summary).
(13) EPA 440/5-86-008, Ambient Water Quality for Aluminum, 1988.

Table 6-19

Beaver Pond (SSW13) Surface Water Compared to Ambient Water Quality Criteria for Aquatic Life Protection

Chemical	Maximum Concentration[d] (µg/L)	Acute Criterion (µg/L)	Chronic Criterion (µg/L)
Barium	53	--	1,000
Beryllium	0.61	130[a]	5.3[a]
Copper	21.9	32[b]	20[b]
Iron	39.2	--	1,000
Lead	0.7	185[b]	7.2[b]
Nickel	11.1	2,441[b]	271[b]
Zinc	58.9	202[b]	183[b]/46[c]
Hardness (mg/L)	188		

[a] Not enough data were available to derive a numerical national water quality criteria for aquatic life protection for these chemicals. Values reflect lowest reported effect levels. From 45 FR 79318. November 28, 1980.

[b] Criterion is calculated based on measured water hardness.

[c] Criterion from Alaska Water Quality Standards.

[d] Maximum quantity detected in one sampling event.

Table 6-20

Golf Course Beaver Pond (5SW04-05) Surface Water Compared to Ambient Water Quality Criteria for Aquatic Life Protection

Chemical	Maximum Concentration[d] (µg/L)		Acute Criterion (µg/L)	Chronic Criterion (µg/L)
	5SW04	5SW05		
1,1,2,2-Tetrachloroethane	4.3	1.2	--	2,400[a]
Aluminum	--	249	750	87
Arsenic (tri)	1.4	1.2	360	190
Arsenic (pent)	1.4	1.2	850	48
Barium	17.8	26.5	--	1,000
Benzene	0.6	--	5,300[a]	--
Copper	--	4.7	33[b]	21[b]
Iron	440	2,720	--	1,000
Lead	--	4.7	191[b]	7.5[b]
Thallium	0.8	--	1,400	40[a]
Toluene	0.7	--	17,500[a]	--
Trichloroethylene	6.6	2.9	45,000[a]	21,900[a]
Zinc	4.5	39.9	207[b]	188[b]/47[c]
Hardness (mg/L)	196	215		

[a] Not enough data were available to derive a numerical national water quality criteria for aquatic life protection for these chemicals. Values reflect lowest reported effect levels. From 45 FR 79318. November 28, 1980.

[b] Criterion is based on the measured hardness of the water (196 mg/L).

[c] Criterion from Alaska Water Quality Standards.

[d] Maximum concentration detected from two sampling events.

Table 6-21

Wetland Pond (5SW06) Surface Water Compared to Ambient Water Quality Criteria for Aquatic Life Protection

Chemical	Maximum Concentration[b] (µg/L)	Acute Criterion (µg/L)	Chronic Criterion (µg/L)
Aluminum	25.6	750	87
Arsenic (tri)	1.4	360	190
Arsenic (pent)	1.4	850[a]	48[a]
Barium	50.8	--	1,000
Iron	3,000	--	1,000
Toluene	2.7	17,500[a]	--
Hardness (mg/L)	283	--	--

[a] Not enough data were available to derive a numerical national water quality criteria for aquatic life protection for these chemicals. Values reflect lowest reported effect levels. From 45 FR 79318. November 28, 1980.

[b] Maximum concentration detected in one sampling event.

Table 6-22

Snowmelt Pond (5SW07) Surface Water Compared to Ambient Water Quality Criteria for Aquatic Life Protection

Chemical	Maximum Concentration[d] (µg/L)	Acute Criterion (µg/L)	Chronic Criterion (µg/L)
1,2-Dichloroethane	2.6	118,000	20,000
Aluminum	329	750	87
Arsenic (tri)	3	360	190
Arsenic (pent)	3	850[a]	48[a]
Barium	200	--	1,000
Iron	1,220	--	1,000
Lead	2.6	264[b]	10[b]
Trans-1,2-dichloroethene	1.9	11,600	--
Trichloroethylene	1.4	45,000	21,900
Zinc	5.6	256[b]	230[b]/47[c]
Hardness (mg/L)	252		

[a] Not enough data were available to derive a numerical national water quality criteria for aquatic life protection for these chemicals. Values reflect lowest reported effect levels. From 45 FR 79318. November 28, 1980.

[b] Criterion is calculated based on the measured water hardness.

[c] Criterion from Alaska Water Quality Standards.

[d] Maximum quantity detected in one sampling event.

Table 6-23

Bluff Pond (5SW08) Surface Water Compared to Ambient Water Quality Criteria for Aquatic Life Protection

Chemical	Maximum Concentration[f] (µg/L)	Acute Criterion (µg/L)	Chronic Criterion (µg/L)
1,1-Dichloroethane	2.3	118,000[a]	20,000[a]
4-Methylphenol	7	–[e]	–[e]
Aluminum	1,190	750	87
Arsenic (tri)	3.5	360	190
Arsenic (pent)	3.5	850[b]	48[b]
Barium	123	–	1,000
Benzene	1.5	5,300[b]	–
Bromomethane	1.3	–[e]	–[e]
Copper	7.2	48[c]	29[c]
Ethylbenzene	12	32,000[b]	–
Iron	6,270	–	1,000
JP-4	770	–[e]	–[e]
Lead	14.8	82[c]	12[c]
Naphthalene	1	2,300[b]	620[b]
TFH-Gas	400	–[e]	–[e]
Toluene	27	17,500[b]	–
Xylene	19	–	–
Zinc	36.9	289[c]	262[c]/47[d]
Hardness (mg/L)	291	–	–

[a] LOEL for 1,2-dichloroethane. No criterion for 1,1-dichloroethane.

[b] Not enough data were available to derive a numerical national water quality criteria for aquatic life protection for these chemicals. Values reflect lowest reported effect levels. From 45 FR 79318. November 24, 1980.

[c] Criterion is calculated based on the measured water hardness.

[d] Criterion from Alaska Water Quality Standards.

[e] Total hydrocarbons in the water column shall not exceed 15 µg/L, or 0.01 times the lowest measured continuous flow 96-hour LC_{50} for life stages of the most sensitive, biologically important species in a particular location, whichever concentration is lower. Total aromatic hydrocarbons in the water column shall not exceed 10 µg/L, or 0.01 times the lowest measured continuous flow 96-hour LC_{50} for life stages of the most sensitive, biologically important species in a particular location, whichever concentration is lower. Concentrations of hydrocarbons, animal fats, or vegetable oils in the sediment shall not cause deleterious effects to aquatic life; shall not cause a film, sheen, or discoloration on the surface or floor of the water body or adjoining shorelines. Alaska WQS 1991.

[f] Maximum quantity detected in one sampling event.

Table 6-24

Drainage Ditch (5SW09 and 5SW10) Surface Water Compared to Ambient Water Quality Criteria for Aquatic Life Protection

Chemical	Maximum Concentration[e] (µg/L)		Acute Criterion (µg/L)	Chronic Criterion (µg/L)
	5SW09	5SW10		
1,1,1-Trichloroethane	1.8	1.9	--	9,400[a]
Arsenic (tri)	--	0.7	360	190
Arsenic (pent)	--	0.7	850[b]	48[b]
Barium	17	20.8	--	1,000
Beryllium	0.62	0.61	130[b]	5.3[b]
Cadmium	1.4	--	3.9[c]	1.1[c]
Copper	--	1.5	18[c]	12[c]
Iron	127	36.2	--	1,000
Nickel	8.2	9.7	1,418[c]	158[c]
Zinc	13.6	3.9	117	106/47[d]

[a] LOEL for 1,2-trichloroethane. No criterion for 1,1,1-trichloroethane.

[b] Not enough data were available to derive a numerical national water quality criteria for aquatic life protection for these chemicals. Values reflect lowest reported effect levels. From 45 FR 79318. November 28, 1980.

[c] Criterion is dependent on the hardness of the water. Assumed hardness = 100 mg/L.

[d] Criterion from Alaska Water Quality Standards.

[e] Maximum quantity detected in one sampling event.

Table 6-25

Ship Creek Surface Water Compared to Ambient Water Quality Criteria for Aquatic Life Protection

Chemical	Maximum Concentration[d] (µg/L)				Acute Criterion (µg/L)	Chronic Criterion (µg/L)
	5SW01	5SW02	5SW03	5SW11		
Aluminum	380	569	315	–	750	87
Antimony	–	–	–	15	/p/88[e]	/p/30[e]
Arsenic (tri)	2.1	–	0.7	–	360	190
Arsenic (pent)	2.1	–	0.7	–	850[a]	48[a]
Barium	9.7	11.2	16.2	72.1	–	1,000
Beryllium	–	–	–	0.61	130[a]	5.3[a]
Copper	1.7	9.8	1.7	–	7.5[b]	5.4(6.1)[b]
Iron	585	863	562	161	–	1,000
Lead	–	1.7	0.7	–	25[b]	0.99(1.2)[b]
Selenium	0.56	0.54	–	–	20	5
Zinc	–	13.3	–	4.2	55[b]	50[b]/47[c]
Hardness (mg/L)	41	46	76	–		

[a] Not enough data were available to derive a numerical national water quality criteria for aquatic life protection for these chemicals. Values reflect lowest reported effect levels. From 45 FR 79318. November 24, 1980.

[b] Criterion is calculated based on a hardness of 41 µg/L. Criteria based on a hardness of 46 µg/L are in parentheses.

[c] Criterion from Alaska Water Quality Standards.

[d] Maximum concentration detected from two sampling events for 5SW01, 5SW02, 5SW03, and one sampling event for 5SW11.

[e] /p/ = Proposed criteria as of May 1, 1991, EPA Water Quality Criteria Summary.

Table 6-26

Aquatic Toxicity of Polycyclic Aromatic Hydrocarbons

PAH Compound	Species	Duration of Exposure	Effect[a]	Dose	Reference[b]
Anthracene[c]	Pink salmon fry (*Oncorhynchus gorbuscha*)	24 hours	LC_{50}	920 μg/L	Neff 1979
Benzo(a)anthracene	Bluegill (*Lepomis macrochirus*)	6 months	LC_{87}	1,000 μg/L	EPA 1980
Benzo(b)fluoranthene[c]	Pink salmon fry (*Oncorhynchus gorbuscha*)	24 hours	LC_{50}	920 μg/L	Neff 1979
Benzo(k)fluoranthene[c]	Pink salmon fry (*Oncorhynchus gorbuscha*)	24 hours	LC_{50}	920 μg/L	Neff 1979
Benzo(a)pyrene	Sandworm (*Neanthes arenceodentata*)	96 hours	LC_{50}	>1,000 μg/L	Neff 1979
Chrysene	Sandworm (*Neanthes arenceodentata*)	96 hours	LC_{50}	>1,000 μg/L	Neff 1979
Fluoranthene	Sandworm (*Neanthes arenceodentata*)	96 hours	LC_{50}	500 μg/L	Neff 1979
Naphthalene	Copepod (*Eurytemora affinis*)	10 days	LC_{50}	50 μg/L	Neff 1979
	Pink salmon fry (*Oncorhynchus gorbuscha*)	24 hours	LC_{50}	920 μg/L	Neff 1979
	Grass shrimp (*Palaemonetes pugio*)	96 hours	LC_{50}	2,400 μg/L	Neff 1979
	Sheephead minnow (*Cyprinodon variegatus*)	24 hours	LC_{50}	2,400 μg/L	Neff 1979
	Brown shrimp (*Penaeus aztecus*)	24 hours	LC_{50}	2,500 μg/L	Neff 1979
	Amphipod (*Elasmopus pectenicrus*)	96 hours	LC_{50}	2,680 μg/L	Neff 1979
	Coho salmon fry (*Oncorhynchus kisutch*)	96 hours	LC_{50}	3,200 μg/L	Neff 1985
	Sandworm (*Neanthes arenceodentata*)	96 hours	LC_{50}	3,800 μg/L	Neff 1979
	Mosquitofish (*Gambusia affinis*)	96 hours	LC_{50}	150,000 μg/L	Neff 1979
2-Methylnaphthalene	Grass shrimp (*Palaemonetes pugio*)	96 hours	LC_{50}	1,100 μg/L	Neff 1985
	Sheephead minnow (*Cyprinodon variegatus*)	24 hours	LC_{50}	2,000 μg/L	Neff 1979

Table 6-26

(Continued)

PAH Compound	Species	Duration of Exposure	Effect[a]	Dose	Reference[b]
Phenanthrene	Grass shrimp (*Palaemonetes pugio*)	24 hours	LC$_{50}$	370 μg/L	Neff 1979
	Sandworm (*Neanthes arenceodentata*)	96 hours	LC$_{50}$	600 μg/L	EPA 1980
Pyrene[c]	Pink salmon fry (*Oncorhynchus gorbuscha*)	24 hours	LC$_{50}$	920 μg/L	Neff 1979

[a] LC=lethal concentration; subscript indicates percent of test population.

[b] As referenced in Eisler 1987b.

[c] Toxicity of naphthalene used as surrogate for anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and pyrene.

total aromatic hydrocarbons and, therefore, will be evaluated in the risk characterization section.

Fuel hydrocarbons detected in the surface water include JP-4 and TFH-gas. In certain instances, the total aromatic hydrocarbons in surface water exceeds Alaska WQS of 10 μg/L. In these instances, fuel hydrocarbons in surface water will be evaluated further in the risk characterization.

The semivolatile compound 4-methylphenol (p-cresol) was detected in one surface water sample (SW08) at 7 μg/L, which is below the 24 hour LC_{50} (lethal concentration of 50% of test population) of 4000 μg/L for trout embryos, and will not be evaluated further in the risk characterization.

Metals found in the surface water can be compared to AWQC, and to background surface water concentrations in Ship Creek. The aquatic toxicity of some metals (such as aluminum, cadmium, copper, lead, nickel, and zinc) depends on the hardness of the surface water. Since the hardness of the OU 5 ponds and Ship Creek varies (41 to 291 mg/L, as calcium carbonate), the toxicity of metals will vary. Tables 6-19 through 6-25 list the AWQC for metals based on the actual hardness.

In general, in the beaver pond (SW13) at seep SL29, acute and chronic criteria were exceeded for copper, and zinc exceeds chronic criteria based on Alaska WQS (Table 6-19). For surface waters in the golf course beaver pond and the snowmelt pond, aluminum and iron exceeded chronic criteria (Tables 6-20 and 6-22). Surface waters in the wetland pond exceeded the chronic criterion for iron (Table 6-21). Bluff pond acute and chronic criteria were exceeded for aluminum, while only chronic criteria were exceeded for iron and lead (Table 6-23). Chronic criteria were exceeded in the drainage ditch surface waters for cadmium (Table 6-24). Chronic criteria were also exceeded for aluminum in Ship Creek (Table 6-25).

Overall, inorganic elements that exceeded available AWQC include aluminum, cadmium, copper, iron, lead, and zinc. These elements will be considered further in the toxicity assessment. Other inorganic elements such as calcium, magnesium, manganese, potassium, and sodium are macro- or micronutrients or nontoxic elements (Reimer, 1984). Because these elements are considered harmless and generally nontoxic, they will not be evaluated further in the risk assessment.

Sediments

Sediment concentrations of concern for OU 5 were derived using the AWQC and an equilibrium partitioning approach for those organic compounds detected in the sediment. This approach is consistent with that used by EPA in the development of sediment quality criteria. A basic assumption is that exposure occurs primarily to the dissolved fraction of chemical. By knowing what concentration of a nonpolar chemical is protective in surface water, the protective concentration in sediment can be estimated by knowing the chemical-specific partition coefficient for organic carbon to water (K_{oc}), and the organic carbon content of the sediment. This approach is conservative in that it assumes surface water concentrations are in equilibrium with sediment concentrations, such as in the ponds and wetlands, although an unlikely occurrence in a moving stream such as Ship Creek. The equation (EPA, 1988d) used for the derivation is as follows:

$$C_{sed} = K_{oc} \times AWQC \times 10^{-3} kg/g$$

where:

C_{sed} = sediment concentration of concern ($\mu g/g$ organic carbon)

K_{oc} = partition coefficient for organic carbon to water

AWQC = protective surface water concentration ($\mu g/L$)

$10^{-3} kg/g$ = unit conversion

The sediment concentration of concern expressed in terms of micrograms of chemical per gram of organic carbon, can be normalized to the particular sediment of concern by multiplying with the organic content (OC) of the sediment as follows:

$$\text{Sediment concentration of concern (as } \mu\text{g/kg sediment)} = C_{sed} \times \text{OC (as g/kg)}$$

The default organic carbon content of the OU 5 sediments is assumed to be 3.0% (30 g/kg)[e].

The sediment concentrations of concern for PAHs and other organic compounds detected in sediment during the RI are given in Table 6-27. The comparison of sediment concentrations detected at OU 5 with the derived concentrations of concern is discussed in the risk characterization section.

Because no reliable approaches currently exist for predicting surface water concentrations of metals and other inorganic compounds from sediment information, no sediment levels of concern for inorganic elements are derived using this approach. Instead, surface water concentrations measured during the RI are assumed to be indicative of ecological exposures to metals.

Table 6-28 provides a summary of the site contaminants that were selected for further evaluation in the risk assessment for aquatic resources. Phenol in sediments was not included because the one reported concentration (72 ppb at 5SE09) was an estimated level well below the detection limit of 420 ppb.

6.2.1.2 Exposure Assessment

An exposure pathway describes how a contaminant may move from its source to a receptor (a potentially exposed organism). A complete exposure pathway has five

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[e] Based on best judgment of TOC content of pond sediment.

Table 6-27

Toxicity of Sediments to Aquatic Organisms

Chemical	Toxicity (µg/L)	Endpoint	Estimated Chronic Toxicity[h] (µg/L)	KOC (ml/g)	Sediment Level of Concern[i] (µg/kg)	Maximum Concentrations Detected in OU 5 Sediment (µg/kg)
Anthracene	620[a]	AWQC	620	4.45	82.8	230
Benzo(a)anthracene	1,000[b]	LC87	10	1,380,000	414,000	59
Benzo(a)pyrene	620[a]	AWQC	620	5,500,000	102,300,000	91
Benzo(b)fluoranthene	620[a]	AWQC	620	550,000	10,230,000	58
Benzo(k)fluoranthene	620[a]	AWQC	620	550,000	10,230,000	63
Bis(2-ethylhexyl)phthalate	3.0[f]	AWQC	3.0	31,600	2,844	240
Chrysene	620[a]	AWQC	620	200,000	3,720,000	85
Ethylbenzene	32,000[c]	AWQC	320	1,100	10,560	930
2-Methylnaphthalene	620[a]	AWQC	620	933	17,400	100
4-Methylphenol	2,560[d]	AWQC	2,560	500	38,400	160
Aroclor-PCB-1260	0.014	AWQC	0.014	530,000	223	1600
Pyrene	620[a]	AWQC	620	38,000	706,800	150
Phenanthrene	6.3[g]	AWQC	6.3	14,000	2,646	270
Toluene	17,500[c]	AWQC	175	300	1,575	520
Xylenes, Total	13,500[e]	LC50	135	240	972	6200

[a] No value was available. AWQC for naphthalene was used.
[b] Eisler 1987b.
[c] Acute AWQC was used.
[d] No value was available. AWQC for phenol was used.
[e] Verschueren K. 1983. *Handbook of Environmental Data of Organic Chemicals*.
[f] Generic AWQC for phthalate esters.
[g] Proposed criterion.
[h] Chronic AWQC was used where available. If only acute endpoint was available, a safety factor of 100 was applied.
[i] An organic carbon of 3% was assumed in these calculations.

Table 6-28

Summary of Data Sources and Contaminants in Aquatic Media Selected for Further Evaluations

Data Source	Contaminants Selected
Surface water (Tables 6-19 through 6-25)	Fuel hydrocarbons, PAHs, semivolatiles, BTEX, aluminum, cadmium, copper, iron, lead, and zinc
Sediment (Table 6-27)	PCB (Aroclor 1260), anthracene, fuel hydrocarbons, and xylenes (total)

primary elements (EPA, 1992a):

- A chemical source;
- A mechanism for release;
- An environmental medium;
- An exposure point (receptor location); and
- A feasible route of exposure (for example, dermal contact/absorption).

Contaminant sources, release mechanisms, and migration pathways have been presented in Sections 4 and 5. Potential exposure points, exposure routes, and receptors are evaluated on a site-specific basis. An exposure pathway is complete if there is a reasonable likelihood that a receptor may take in contaminants through contact with contaminated media. No exposure (and thus no risk) exists unless the exposure pathway is complete.

The possible current and future exposure pathways for OU 5, based on a current understanding of the site, are presented on Figure 5-4 for potential exposure pathways for ecological receptors. The potentially complete exposure pathways to aquatic receptors selected for assessment are discussed in the following sections.

Surface Water and Near Surface Groundwater Exposure Pathways

Aquatic plant and/or animal exposures to surface water contaminants can occur through ingestion of water by aquatic organisms, through dermal contact with and absorption of contaminated water, or by direct metabolic uptake through roots or gills. Contaminants have been detected in surface water and shallow unconfined groundwater in the lower bluff area. Shallow groundwater could expose benthic organisms, or discharge into nearby surface water bodies where exposures can occur. In addition, contaminants may migrate to surface water bodies through periodic surficial runoff.

Sediment Exposure Pathways

Aquatic plants are potentially exposed to site contaminants of concern through metabolic uptake if their roots penetrate contaminated sediments. Aquatic animals could be exposed to contaminated sediments through dermal contact and through inadvertent ingestion during normal feeding. The frequency, duration, extent, and route of exposure depend on the particular activity of the receptor and the location of the activity.

Aquatic Receptors. Important aquatic receptors include fish, aquatic invertebrates, and freshwater vegetation inhabiting Ship Creek, the golf course beaver pond, the beaver pond (at seep SL29), and the snowmelt pond. Although the other ponds and drainage ditches support aquatic insect populations, they are not considered to be significant ecological aquatic habitats. The most likely receptors are fish and invertebrates residing in Ship Creek, and more invertebrates in the ponds. Fish were not observed to inhabit the ponds within OU 5, apparently because of the lack of suitable habitat, and not because of toxic effects. It does not appear that the anadromous Pacific salmon species spend appreciable amounts of time as fry or juveniles in the vicinity of the study area, due to the absence of suitable rearing habitat in the OU 5 reach of the river, Also, upstream fish passage is effectively blocked at the Elmendorf AFB hatchery dam. Although salmon eggs and sac-fry in reds could be affected by exposure to OU 5 discharges, no salmon spawning or reds were observed in the OU 5 reach of Ship Creek. Therefore, these migratory species are not considered significant potential receptors at risk from OU 5 contaminants of concern.

Potentially important Ship Creek receptors include the resident gamefish, nongame fish, and invertebrate species using the creek habitats adjacent to the study area. The Elmendorf AFB fish hatchery salmon fry and smolts can also be considered important receptors in the surface water runoff pathway[4]. The fish species observed that use this section of the creek (above the fish hatchery dam) include rainbow trout and slimy sculpin.

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[4] Determined use of Ship Creek water by hatchery from telephone conversation with Daryl Keifer, Elmendorf AFB hatchery manager, on December 11, 1992.

Although not observed, Dolly Varden may also represent a potential receptor. Important resident aquatic invertebrates observed along this section of Ship Creek include taxa from the orders Ephemeroptera (families Baetidae, Ephemerellidae, and Heptageniidae), Plecoptera (families Chloroperlidae, Nemouridae and Perloidae), Trichoptera (families Glossosomatidae, Hydropsychidae, and Limnephilidae), Diptera (family Chironomidae), and class Oligochaeta (Lumbriculidae, Niadidae, and Tubificidae).

In general, pond life, including aquatic bed plants and aquatic invertebrates, are also potential receptors. Invertebrate residents of the golf course beaver pond included Diptera (family Chironomidae) and class Oligochaeta. Organisms from the intolerant order Ephemeroptera (families Baetidae and Heptageniidae) were also noted. The cladoceran *Daphnia* cf. *pulex* was also present in this pond. Macroinvertebrate populations from the wetland pond (MI06) consisted almost exclusively of organisms from the order Diptera (family Chironomidae) and class Oligochaeta (families Lumbriculidae, Niadidae, and Tubificidae). Invertebrates from the snowmelt pond represented class Crustacea (order Cladocera), and order Diptera (families Chironomidae and Culicidae). The bluff pond had an invertebrate assemblage similar to the snowmelt pond, except for the Chironomidae, which were not noted.

6.2.1.3 Toxicity Assessment

The toxicity of chemicals of concern is described in relation to aquatic receptors in this section. Both acute and chronic exposures are considered. Acute exposure is considered only in the absence of chronic criteria.

In order to assess the likelihood of toxicity to surface water life, measured surface water concentrations were compared to AWQC, established by EPA for protection of aquatic life. The Alaska WQS for zinc was considered because it is more stringent than federal standards.

The initial screening of site contaminants (Section 6.2.1.1) and exposure pathways (Section 6.2.1.2) reduced the contaminants of concern to those listed and described in the following.

Contaminants of Concern

- Fuel hydrocarbons
  - TFH gas
  - TFH diesel
  - JP-4
- Other organics
  - PCBs
  - xylene
  - anthracene
- Inorganics
  - aluminum
  - cadmium
  - copper
  - iron
  - lead
  - zinc.

Fuel Hydrocarbons

TFH gas was detected in the surface water and sediments of the bluff pond (SW/SE08), the golf course beaver pond (SE04 and SE05), and the wetland pond (SE06) (Figure 4-10).

TFH diesel was not found in the surface water, but was detected in the sediments of the golf course beaver pond (SE04 and SE05), the wetland pond (SE06), and the bluff pond (SE08).

JP-4 was detected in the surface water of the bluff pond (SW08) and in the sediment of the golf course beaver pond (SE05).

The presence of these hydrocarbons caused films, sheens, and discoloration of the waters of the golf course beaver pond, wetland pond, and bluff pond. Based on this presence, the criteria of the Alaska WQS are exceeded. The discussion of laboratory bioassays later in this section indicates acute and chronic toxicity of sediments in the golf course beaver pond; however, it is not clear if fuel hydrocarbons are the direct cause of the bioassay results.

Other Organics

PCBs (1,600 μg/kg) were detected at a toxic concentration in the snowmelt pond (SE07) sediment sample, above the sediment level of concern of 223 μg/kg (Table 6-27).

Xylene (1,100 μg/kg) was detected in the golf course beaver pond (SE05) above the endpoint (LC_{50}) toxicity value for total xylenes of 972 μg/kg (Table 6-27). It was also detected in the bluff pond (SE08) at 6,200 μg/kg and in the wetland pond (SE06) at 3,700 μg/kg.

Anthracene (230 μg/kg) was detected in the wetland pond above the sediment level of concern of 82.8 μg/kg (Table 6-27).

Inorganics

Aluminum was detected in creek and pond surface waters at concentrations that exceed AWQC. In Ship Creek, aluminum was detected at the reference sample station at 380 μg/L, which exceeds the AWQC of 87 μg/L for chronic exposure. At sample station SW02 (immediately upstream of the fish hatchery), aluminum was detected at 569 μg/L. It appears that if aluminum was indeed toxic at the concentrations reported, creek invertebrate populations, and potentially the hatchery fish stocks, would be at risk from chronic exposure.

Although aluminum occurs at high background levels in Alaskan soils, the nature and toxicity of aluminum concentrations detected in the study area surface waters are uncertain.

Cadmium was detected in the surface water of drainage ditch SW09 at 1.4 μg/L, which exceeds AWQC by only 0.3 μg/L. This ditch is at the downgradient/downstream end of OU 5 and does not pose a risk to important aquatic receptors within OU 5.

Copper was detected in surface water at one pond (SW13) and one Ship Creek sample station (SW02) at concentrations above AWQC. Based on the very slight exceedance of AWQC in the creek (0.3 μg/L above AWQC), it is assumed that aquatic receptors within OU 5 are not at significant risk from copper; however, the copper concentrations will be evaluated during risk characterization.

Iron was detected at concentrations above AWQC of 1000 μg/L in the golf course beaver pond, wetland pond, snowmelt pond, and the bluff pond (see Section 4.4.1). The high concentrations may be associated with the inadvertent sample collection of suspended particulates and iron bacteria associated with near surface groundwater seeps. This assumption is made based on the association of bluff groundwater seeps with high iron concentrations found in the background soils where the seeps occur. From the same surface water sample, the soluble fraction of iron in the bluff pond was detected at a concentration of 309 μg/L, whereas the total iron was detected at 6,270 μg/L. The absence of sufficient dissolved iron concentration information for the ponds makes the resolution of iron toxicity uncertain. Iron will be evaluated further in the risk assessment.

Lead was detected in surface water at one pond (SW08) and one Ship Creek sample station (SW02) at concentrations that exceed AWQC. Lead in the bluff pond (2.4 μg/L above AWQC) may be associated with the suspected disposal of fly ash in or near this pond. The lead in Ship Creek (only 0.5 μg/L above AWQC) may be associated with the incomplete combustion of fuel by-products washed off Post Road into the creek. Lead concentrations will be evaluated in the risk characterization section.

Zinc (58.9 μg/L) was detected in surface water at one pond (SW13) at a concentration that may exceed Alaska WQS (47 μg/L). However, based on the relatively high hardness of the surface water (188 mg/L), it is assumed that important aquatic receptors are not at significant risk from toxic concentrations of zinc.

Laboratory Bioassays

Toxicity test results were presented in Section 4.5.2.4. The results of the acute toxicity tests show that:

- The surface water and sediment samples from Ship Creek and the drainage ditch (SW09), were not acutely toxic to the test species; and
- The sediment from SE04 at the golf course beaver pond was acutely toxic to the test species.

Based on the acute toxicity test screening of selected surface water and sediment samples in the spring, chronic toxicity tests were conducted on surface water and sediment sampled from the golf course beaver pond in the late summer. The chronic toxicity tests were conducted because of the acute toxicity of the sediments at sample station SE04, and because of the strong fuel hydrocarbon odor detected at the opposite end of the pond at SW/SE05. The results of the chronic toxicity tests show that:

- The surface water samples were not chronically toxic to test species.
- Sediment sample SE04 was not chronically toxic to *Hyalella azteca* based on significant difference testing. However, *Hyalella* growth was approximately 41% of the laboratory control weight, indicating that the statistical analyses may be inappropriate for toxicity interpretation.

- Sediment sample SE05 was chronically toxic to *Hyalella azteca*. This sample caused a reduction in *Hyalella* survival, also indicating acute toxicity.

Based on these results, it appears that aquatic receptors are at risk from the concentrations of fuel hydrocarbons and volatiles (total xylenes) detected in the sediment at the golf course beaver pond. Results of the laboratory toxicity testing program are in Section 4.5.

6.2.1.4 Risk Characterization

The aquatic habitats of concern are those near contaminant sources and those ecologically coupled to contaminated areas. Surface water, near surface groundwater, and sediment sampling results have indicated elevated concentrations of contaminants of concern to ecological receptors. The following discussion evaluates the potential risks to aquatic receptors.

Aquatic Exposure Pathway Risks

Beaver Pond (SW/SE13). No organic contaminants were detected, other than an unknown hydrocarbon (8.5 mg/kg) in the sediment. Copper (20.1 µg/L) exceeded AWQC, and zinc (58.9 µg/L) exceeded Alaska WQS, indicating potential toxicity to aquatic animals. No toxicity tests were conducted on surface water and sediments, and no definitive conclusions can be made about risk to aquatic receptors (macroinvertebrates and aquatic bed plants, no fish), because of limited chemical toxicity data. However, aquatic invertebrates (*Daphnia* spp.) were observed in the water column during sampling activities, indicating a favorable environment for the species (see Section 6.2.2 for discussion of potential stress to terrestrial [riparian zone] plants).

Golf Course Beaver Pond (SW/SE04 and SW/SE05). With the exception of surface oil sheens at the northeast end of the pond at SW05, organic and inorganic elements detected in the surface water do not appear to represent risk to aquatic receptors. For instance, free-swimming aquatic insects (*Daphnia spp.*) were observed in this pond, where the iron (2720 μg/L) was detected above chronic criterion. However, as laboratory toxicity test results indicate, sediment toxicity at SE04 may be apparent, since the growth of test species was measured at less than half that of the control specimens. Sediment was chronically toxic to test species at SE05 and resulted in reduced survival.

Based on a comparison of the sediment levels of concern (Table 6-27) to contaminant detections in the pond at SE05, organic contaminants exceed endpoint toxicity values for total xylenes. Additionally, at SE04 and SE05, JP-4, TFH-diesel, and TFH-gas in the sediment are assumed to be at levels adverse to aquatic life protection, although no criteria other than LC_{50} values for fuel hydrocarbons in solution (see Table 6-38 in Terrestrial Assessment) are available.

In general, based on the results of laboratory toxicity tests, detection of total xylenes (1,100 μg/kg) above endpoint toxicity (972 μg/kg), visible oil sheens and odors, fuel hydrocarbon concentrations in the near surface ground water above LC_{50} endpoint values, and the results of qualitative and quantitative benthic macroinvertebrate analysis (RBP I), aquatic receptors (aquatic bed plants and macroinvertebrates, no fish) are clearly at risk in the northeast end of the pond (at SE05), as indicated, in part, by the restricted community structure of midges and aquatic worms. At the southwest end of the pond (SE04), there are indications of stress to aquatic receptors, based on toxicity bioassays and macroinvertebrate data from the RBP I assessment and analysis of quantitative samples. Potential contamination could be from contaminant drift toward the southwest (downstream) end of the pond from the northeast end. However, it may be more likely that the fuel hydrocarbon concentrations in the sediment, which are less than those found at the opposite (northwest/upstream) end of the pond, are the cause for risk to aquatic receptors.

Additionally, aquatic bed plants were not observed during the spring sampling, and were observed to be just budding out of the sediment during the late summer sampling.

Based on the observance of mature aquatic bed plants in a nearby pond (old power plant cooling water pond), it appears that the occurrence of contaminants of concern (fuel hydrocarbons) in the sediment could, in part, be limiting plant growth. Sedimentation of the pond bottom may also be the cause; however, sediment transport and increased turbidity were not observed to occur even during heavy rains. The cause of a reduced growth pattern of aquatic bed plans is not clear but may be from the sediment contaminant load. More investigation would be required to determine the cause.

Wetland Pond (SW/SE06). TFH-gas (110 mg/kg), TFH-diesel (7,400 mg/kg), total xylene (3700 μg/kg), and anthracene (230 μg/kg) were detected in the sediments, and xylene and anthracene exceeded the endpoint toxicity values of 972 μg/kg, and 82.8 μg/kg, respectively, for sediment level of concern. Also, fuel hydrocarbon concentrations in the near surface groundwater (at nearby seeps SL16 and SL17) were detected above LC_{50} endpoint values.

Aquatic receptors at this shallow wetland pond site are limited to aquatic insects and emergent wetland vegetation. Qualitative and quantitative analyses of benthic macroinvertebrates indicate a restricted community structure of midges and aquatic worms, but not as restricted as that noted in the golf course beaver pond site MI05. Still, the benthic community structure represents tolerant taxa that can generally withstand adverse conditions.

Based on these observations, and the absence of organic contaminants downstream (Ship Creek at SW/SE03), it is concluded that risk to aquatic receptors from organic contaminants in this pathway is restricted to this localized wetland pond environment. Downstream aquatic receptors in Ship Creek do not appear to be at risk, because the wetland pond contaminants appear to be bound in the sediment.

Snowmelt Pond (SW/SE07). PAHs were detected in the sediments, but at concentrations well below sediment concentrations of concern. Organic chemical concentrations detected in the near surface groundwater are also below contaminant levels of concern.

PCBs (Aroclor 1260) were detected in the sediments at 1.6 mg/kg, which is above the sediment level of concern of 0.223 mg/kg. PCBs may accumulate in the sediments after surface application or spills. The aquatic receptors in this pond (benthic macroinvertebrates) would appear to be at risk from exposure to PCBs in the sediment from contact with the PCBs, or ingestion of the contaminant. However, the presence of chironomids at the water/ sediment interface would suggest that the contaminant is not biologically available, or the organisms present are highly resistant to the contaminant. Larsson (1984) discusses PCB uptake and bioconcentration by chironomids suggesting that the organisms may be resistant. This article also suggests the importance of these organisms as transporters of the contaminant to higher food chain organisms such as fish, diving ducks, and insectivorous birds (chironomid adults).

Based on the extent of chemical contaminants of concern in this pond, namely PCBs, it does not appear that aquatic receptors other than the benthic macroinvertebrate community are at risk. No fish are present, and the water depth inhibited the observation of aquatic bed plants, if any. A risk to aquatic receptors downstream (Ship Creek downstream of Yakutat Street) could occur if a significant section of the beaver dam collapsed. The sediment (with PCBs) could be picked up by the water rushing out of the pond through the dam breach. The sudden discharge would, in part, follow drainage ditches to Ship Creek and deposit the contaminants in the creek bed where anadromous Pacific salmon have been observed. However, the extent of the PCBs in the local pond sediments, and the long-term integrity of the beaver dam are unclear. A more focused investigation of the pond substrate and PCB contaminant load would be necessary to eliminate the uncertainties of this assessment.

Bluff Pond (SW/SE08). Lead (14.8 μg/L) and TFH-gas (400 μg/L) were detected in the surface water above AWQC and Alaska WQS, respectively. Xylene (6,200 μg/kg) exceeded the sediment level of concern of 972 μg/kg. Fuel hydrocarbons TFH-diesel (1,100 mg/kg) and TFH-gas (700 mg/kg) were also detected at high concentrations in the sediment.

The aquatic receptors at risk in this waterbody are limited to aquatic insects. The invertebrate community associated with the water column were culicids (mosquito pupa) and cladocerans (water fleas) (RBP I qualitative sampling). The cladocerans are routinely used as bioassay organisms. Their presence in the water column would suggest that at least the water itself was not acutely toxic to the organisms. No organisms associated with the sediments were collected.

Based on observation of the flow patterns during light to moderate rain, it appears that contaminant runoff from the bluff pond could be washed out from this pond and flow down the bluff to the drainage ditch at sample station SW09, which in turn flows west to Ship Creek. However, the contaminants could also be rapidly diluted with stormwater runoff before they entered Ship Creek. Therefore, aquatic receptors downgradient/ downstream of this potential contaminant source may be at risk. Further investigations would be necessary to eliminate uncertainties of this assessment.

Drainage Ditches (SW/SE09 and SW/SE10). Cadmium (1.4 μg/L) was detected at sample station SW09 in the surface water at a concentration above the AWQC of 1.1 μg/L (based on assumed hardness of 100 mg/L). However, based on hardness values of a nearby upgradient pond (bluff pond hardness = 291 mg/L), it is suspected, that cadmium in the drainage ditch surface water is not chronically toxic to downstream aquatic receptors.

Phenol was the only organic compound detected in the sediment sample (SE09 at 72 mg/kg). The source of the phenol in the sediments is unclear; it may be runoff from the bluff pond. No significant aquatic receptors are at risk at these locations, although the drainage ditches provide a pathway for contaminant runoff to Ship Creek.

Ship Creek (SW/SE01, 02, 03, 11, and SE12). Lead (1.7 μg/L) and copper (7.8 μg/L) were detected in the surface water slightly above AWQC at SW02. No other organic or inorganic contaminants of concern were detected in the creek surface water or sediments above AWQC, LOAELs, or sediment levels of concern. Lead was not detected in the surface water at the reference site (SW01); however, it was detected at sample station SW02, which receives runoff from Post Road. Because lead has been used as fuel additive, the source may be from background levels caused by the incomplete combustion of fuels from vehicles. The source of the elevated copper concentration at SW02 is not clear. The results of acute toxicity tests and qualitative and quantitative analysis of benthic macroinvertebrate populations indicate that aquatic receptors at this sample station, or Ship Creek in general, are not at risk from OU 5 contaminants of concern.

Based on community diversity, taxa richness, and numerical abundance, benthic macroinvertebrate populations remained relatively constant. The changes in community structure and function were considered more indicative of eutrophication processes and probably were not associated with OU 5 contaminants of concern.

6.2.1.5 Conclusions and Limitations

Aquatic habitats surveyed during the 1992 RI surveys for the ecological risk assessment are similar to those observed during the 1991 Ecological Survey (CH2M Hill, 1992c) and those described by Rothe et al (1983). The conclusions are limited by the level of detail in which the aquatic habitat conditions were surveyed.

Indications of aquatic ecosystem impacts were found in some pond environments, as shown by oil sheens, shoreline oil sludges, fuel odors, the absence or arrested development of aquatic vegetation in several surface water bodies, the reduced communities of benthic macroinvertebrates in the northeast end of the golf course beaver pond (compared to the southwest end of the pond), and the results of laboratory toxicity tests. The apparent absence of any resident fish species in the golf course beaver pond (SW04-05) and snowmelt pond (SW07) may have been caused by contaminants of concern, although it is more likely that these lower bluff beaver ponds have been inaccessible to fish. The causes inhibiting growth of the aquatic plants in the golf course beaver pond could not be determined, but appeared to be something other than oxygen deprivation caused by sedimentation. The appearance of stunted aquatic plant growth may be from the cumulative effects of potential contaminants, or the absence of a sufficient nutrient load (for example, phosphorus and nitrogen) to enhance aquatic plant growth. The data are not adequate to reach definitive conclusions about the causes of limited aquatic plant growth.

The risk characterization indicated that the most likely impacts of contaminants on aquatic ecological receptors in OU 5 would be caused by the following:

- Dermal contact/absorption of fuel hydrocarbons, anthracene, and total xylenes in certain pond sediments to benthic macroinvertebrates; and
- Metabolic uptake/inhibition effects of contaminants of concern in pond sediments to aquatic bed plants and emergent vegetation.

These conclusions are limited by the data (toxicity tests and AWQC), that are not adequate to assess potential risks of a particular contaminant, or multiple contaminants, by multiple exposure routes; and because organisms were not analyzed for potential tissue uptake.

Comparing observations during the aquatic ecological survey and conclusions of risk characterization to ARARs indicates that federal water quality criteria and Alaska WQS for fuel hydrocarbons are not being met in the golf course beaver pond (SW05) and the bluff pond (SW08).

6.2.2 Terrestrial Resources

Terrestrial habitats, vegetation, and fauna were described in Section 3.6.2. Briefly, the areas of greatest concern are between the bluff (located south of Bluff Road and Second Street) and Ship Creek. These areas include a range of wooded to grass and sedge habitats, interspersed with many open water bodies and wetlands, as shown on Figure 3-14. The nature and extent of contamination in these habitats was described in Section 4, and the conceptual model was presented in Section 5.

Assessment endpoints (the environmental values to be protected) for terrestrial receptors include the following:

- Integrity of wildlife habitats in OU 5;
- No significant impacts of environmental contaminants in OU 5 on wildlife species; and
- Compliance with federal and state ARARs.

Measurement endpoints include the following:

- General habitat conditions, including vegetation and animals within OU 5, as assessed through qualitative surveys;
- Evidence of impaired ecosystem health, as shown by plant stress or by actual or potential contaminant impacts on plants and animals through comparisons of observed concentrations to documented effect levels; and
- Comparison of observations and contaminant concentrations to ARARs.

6.2.2.1 Selection of Site Contaminants

Several screening criteria were used to identify which of the contaminants reported at OU 5 are not likely to produce adverse ecological effects and which should be evaluated in more detail. The screening methodologies used conservative assumptions so that potential adverse effects are not likely to be underestimated. These assumptions include:

- 100% of an animal's diet is composed of soil;
- 100% of an animal's diet is from contaminated areas; and
- Selected criteria are generally from studies on the most sensitive species.

Because of these intentional biases, screening-level assessments can be appropriate for identifying unlikely potential impacts and selecting chemicals for further analysis, but cannot be used to show that an impact is likely.

Direct measurements of soil gasses are not available to assess potential inhalation hazards to small mammals (for example, voles and shrews) that live in shallow burrows throughout the bluff area.

Vapors of selected volatile organic chemicals were measured in the soil gas survey as indicators for the locations where soils and groundwater would be analyzed from soil borings and monitoring wells (see Sections 2.1.2 and 4.1). The soil gas sampling was accomplished with on-site analyses that were intended only for screening purposes; the analyses are not considered to be of sufficient quality that they can be used for risk assessment.

It was possible to estimate contaminant concentrations in some other portions of OU 5, however. Concentrations of various contaminants in the vapor phase of an air space in soil were estimated from measurements of contaminant concentrations in soil or groundwater.

Estimates were made for the maximum detected concentrations of contaminants in soils where plant stress was observed (Table 4-20) and in shallow groundwater analyzed during the soil gas survey (Section 4.1). Although the soil gas survey analyses were performed at an on-site laboratory, and the results were intended only for screening purposes, the groundwater analyses are considered to be of sufficient quality for the estimations being made here. The following assumptions were made for both the soil and the groundwater concentrations:

- Equilibrium conditions exist; concentrations of all phases are constant over time;

- Linear relationships exist between the concentrations of contaminants in the three phases; and
- No air exchange occurs with the surface air.

For calculations based on groundwater concentrations, Henry's Law was applied. Henry's constant is the proportionality constant between the liquid phase concentrations. Values for Henry's constants were selected from an on-line database (HSDB, 1992), except that values for the fuel mixtures were obtained from the literature (BEIA, 1989).

For calculations based on soil concentrations, the soil distribution constant was input. The on-line database was the source of the constants for the single compounds. A range of values was available for mixtures; the most conservative numbers (contaminant preferring water and vapor phase to soil phase) were selected (Arthur D. Little, Inc., 1987). Once water concentrations were calculated, Henry's Law was applied. Soil calculations required a value for the organic carbon in soil and a relatively low value, 0.5 percent, was selected.

Estimates for the fuels, gasoline, jet fuel, and diesel were made assuming that the fuels have constant properties (Henry's constant and organic carbon partition coefficient). In fact, these mixtures have compositions that vary depending on the fuel grade, and vary over time as the different fractions migrate and transform. The more volatile fractions will volatilize at a greater rate than the heavier fractions.

The calculated maximum soil vapor concentrations for chemicals measured in groundwater are presented in Table 6-29 and those for chemicals measured in soils from plant stress areas are presented in Table 6-30. In each of these tables, the maximum calculated concentrations are compared to acute and chronic exposure effect levels by inhalation in mammals (insofar as data are available). Except for fuel hydrocarbons, all estimated maximum concentrations in soil vapor are below the exposure effect levels, and only fuel hydrocarbons will be considered further through the inhalation pathway.

Table 6-29

Comparison of Estimated Maximum Soil Vapor Concentrations From Groundwater to Acute and Chronic Exposure Effect Levels by Inhalation in Mammals

Compound	Henry's Constant (atm-m³/mol)	Concentrations in		Exposure Effect Levels (mg/m³)		
		Pore Water (ug/l)	Soil Gas (mg/m³)	Acute	Chronic[b]	References
cis-1,2-dichloroethene	3.37E-03	53	7.30	65,000 (2-hr)	ND	BEIA, 1989
trans-1,2-dichloroethene	6.72E-03	9	2.47	75,000 (2-hr)	ND	BEIA, 1989
1,1,1-Trichloroethane	8.00E-03	2	0.65	73,710 (10-hr)	737	Verschueren, 1983; Prendergast et al, 1967
Trichloroethene	1.03E-02	12	5.05	29,590 (10-hr)	>3,927	Seigel, 1971; BEIA, 1989
Tetrachloroethene	1.49E-02	0.06	0.04	35,256 (4-hr)	ND	BEIA, 1989
Benzene	5.50E-03	82	18	31,836	2,552	BEIA, 1989; NTIS, 1989
Toluene	6.64E-03	170	46	19,981 (8-hr)	ND	NIOSH, 1973
Ethylbenzene	8.44E-03	310	107	17,360 (4-hr)	4,340	Andrews et al, 1981; Hardin et al, 1981; BEIA, 1989
Total xylenes	7.04E-03	630	181	21,700 (4-hr)	3,403	BEIA, 1989; NTIS, 1990
TVHC (C_{4-9})[c]	5.60E-03	510,000	117,000	135,000 (5-min)	1,619[d]	BEIA, 1989; HSDB, 1992; MacFarland et al, 1984
TVHC (C_{10-x})[e]	2.90E-04	11,000	130	?	150[f]	BEIA, 1989; HSDB, 1992

[a] Data from Section 4.1.

[b] Sublethal effects in varying time exposures.

[c] Total volatile hydrocarbons within the range of gasoline hydrocarbons.

[d] No observed adverse effect level calculated as 230 mg/m³ (Dollarhide, 1992).

[e] Total volatile hydrocarbons within the range of diesel hydrocarbons.

[f] Lowest observed adverse effect level, 90-day exposures (Dollarhide, 1992).

ND = not determined

Table 6-30

Comparison of Maximum Estimated Soil Vapor Concentrations From Soils[a] to Acute and Chronic Exposure Effect Levels by Inhalation in Mammals

Compound	Henry's Constant (atm-m³/mol)	Organic Carbon Partition Coeff. (ml/g)	Concentrations in			Exposure Effect Levels (mg/m³)		
			Soil (ug/kg)	Pore Water (ug/l)	Soil Gas (mg/m³)	Acute	Chronic[b]	References
Benzene	5.50E-03	31	14.9	96.13	22	31,836	2,552	BEIA, 1989; NTIS, 1989
Toluene	6.64E-03	95	63.9	134.53	37	19,981 (8-hr)	?	NIOSH, 1973
Ethylbenzene	8.44E-03	250	393	314.40	109	17,360 (4-hr)	4,340	Andrews et al, 1981; Hardin et al, 1981; BEIA, 1989
Total xylenes	7.04E-03	204	8360	8196.08	2360	21,700 (4-hr)	3,403	BEIA, 1989; NTIS, 1990
Gasoline	5.60E-03	65	670,000	2,060,000	472,000	135,000 (5-min)	1,619[c]	BEIA, 1989; HSDB, 1992; MacFarland et al, 1984
Diesel	2.90E-04	962	720,000	150,000	1,780	?	150	Dollarhide, 1992

[a] Data from Section 4.6.1.

[b] Sublethal effects in varying time exposures.

[c] No observed effect level calculated as 230 mg/m³ (Dollarhide, 1992).

High concentrations of PAHs (5,050 µg/kg) were found in soils within 2 feet of the surface at SB29 (Section 4.2). The concentration is adequate to provide a potential risk to exposed terrestrial animals. Risk was established by the comparison of a literature-derived toxicity value for chronic exposure (0.002 mg/kg body weight [bw], Eisler, 1987a) to the observed soil concentration. As a simplifying assumption, it was assumed that 100 percent of the material is benzo(a)pyrene. This is believed to be a conservative assumption because benzo(a)pyrene is considered to be among the most toxic of the PAH chemical group.

A direct comparison of the soil concentration to the toxicity value could not be completed due to inconsistent units. However, the toxicity value as well as the soil concentration can be adjusted to provide comparable values for use in assessing risk. Toxicity values such as LOAEL, NOAEL, and LD_{50} values are reported in units of mg/kg bw/day for the organism of study, typically a rat or mouse. To compare the derived toxicity value to the observed soil concentrations, the toxicity value must be adjusted to represent a total dose. This is accomplished by removing the kg bw factor by multiplying the toxicity value by the body weight of the organism of study in kilograms. Lewis (1992) has compiled estimates of average body weights for species of animals used for toxicity testing. The average body weight for a mouse is 25 g (or 0.025 kg); based on these numbers, the toxicity value (NOAEL, LOAEL, or LD_{50}) can be adjusted to derive a total dose.

Assuming the exposed organism ingests 100% soil in its daily diet, an exposure does was derived from the soil concentration by converting the concentration to mg chemical/mg soil (equal to 0.00000505 mg PAH/mg soil) and then multiplying by the organism's ingestion rate. Lewis (1992) reported the average ingestion rate of food by a mouse to be 3 gm/day, or 3000 mg.

To assess the potential risk posed to terrestrial organisms exposed to chemicals in the soil, the literature-derived toxicity value was adjusted to derive a total dose estimate, assuming 100 percent soil ingestion. The resulting dose correlative to toxicity is 0.05 µg/day

(0.002 mg/kg bw/day × 0.025 kg bw = 0.00005 mg/day or 0.05 μg/day). Assuming a mouse would ingest 3000 mg of the contaminated soil, the mouse would ingest a total dose of 15.15 μg PAH per day. This exceeds the toxicity dose of 0.05 μg/day, which correlates to the incidence of tumors in mice. Therefore, the potential for risk may exist and PAHs have been retained for further assessment.

Metals and other inorganics found in soils within the areas below the bluff where plant stress was observed (Section 4.6) can be compared to background soils from elsewhere on Elmendorf AFB. These elements were measured in alluvial and moraine soils in a background soil sampling program, as described in Section 4.2 and in the *Basewide Background Sampling Report* (CH2M Hill, 1992a). If individual on-site values are greater than the upper tolerance limits calculated from the background soils data, it is extremely unlikely that they are part of the background population. The OU 5 soils from below the bluff also were compared to the interim Canadian environmental quality criteria for contaminated sites (CCME, 1991) as a screening procedure. These comparisons to Elmendorf AFB background soils and Canadian remediation criteria are shown in Table 6-31. The Canadian remediation criteria are intended for generic use and do not address site-specific conditions, but they are considered generally protective of human and environmental health (CCME, 1991). The criteria presented in Table 6-31 are those for agricultural uses of soils and serve as benchmarks to evaluate the need for further investigation or remediation with respect to such use. For risk screening purposes, these criteria are considered suitable for evaluating potential accumulation or adverse effects in plants growing in OU 5 habitats. The following elements were found at elevated concentrations in comparison to background soils or the interim remediation criteria: arsenic, barium, beryllium, boron, cadmium, calcium, chromium, copper, lead, manganese, mercury, molybdenum, selenium, silver, sodium, and zinc.

To further screen these elements, the maximum detected concentrations were compared to maximum tolerable dietary levels of minerals for domestic animals (NAS, 1980; Table 6-32). The maximum tolerable level was defined as "that dietary level that, when fed

Table 6-31

Comparison of Maximum Detected Concentrations (mg/kg) for Inorganic Elements in Soils from OU 5 with Elmendorf AFB Background Soils and Canadian Interim Remediation Criteria

Element	Maximum Detected[a]		Elmendorf AFB Background Soils[b]		Remediation Criteria[c]
	2" - 12"	12" - 36"	0" - 6"	6" - 36"	
Aluminum	18,400	19,700	25,000	23,800	--
Antimony	15.0	8.9	?	?	20
Arsenic	28.2	8.7	13.1	9.60	20
Barium	3,650	1,430	154	171	750
Beryllium	1.3	1.1	0.62	0.55	4
Boron	33.2	37.2	--	--	2
Cadmium	3.1	1.8	1.95	1.90	3
Calcium	35,300	20,400	7,318	7,151	--
Chromium	39.0	64.3	34.3	45.3	750
Cobalt	12.5	13.9	12.6	14.3	40
Copper	38.0	32.0	24.8	28.3	150
Iron	37,800	34,600	32,700	32,000	--
Lead	87.2	22.3	11.1	7.00	375
Magnesium	8,960	9,810	6,610	10,100	--
Manganese	10,700[d]	7,860	738	742	--
Mercury	0.30	0.31	0.15	0.22	0.8
Molybdenum	24.8	3.4	--	--	5
Nickel	36.3	54.9	31.7	44.5	150
Potassium	908	865	685	630	--
Selenium	1.1	3.1	0.51	0.29	2
Silver	22.0	1.5	1.60	1.20	20
Sodium	1,430	929	381	317	--
Thallium	0.87	0.59	?	?	1
Vanadium	66.4	81.1	83.1	76.6	200
Zinc	159	86.4	77.7	62.9	600

[a] Data from Section 4.6.

[b] Values shown are upper tolerance limits for the 99th percentile with a 95 percent confidence level (CH2M HILL 1992a).

[c] Values shown are interim remediation criteria for agricultural uses of soils (CCME, 1991).

[d] Excluding a value of 199,000 mg/kg, where the 12" to 24" depth sample contained 7860 mg/kg manganese.

Table 6-32

Comparison of Maximum Detected Concentrations (mg/kg) for Inorganic Elements in Soils from OU 5 that Exceeded Elmendorf AFB Background Soils or Canadian Interim Remediation Criteria with Maximum Tolerable Dietary Levels for Domestic Animals

Element	Maximum Detected[a]	Tolerable Level[b]
Arsenic	28.2	50
Barium	3,650	(20)[c,d]
Beryllium	1.3	--
Boron	37.2	150
Cadmium	3.1	0.5
Calcium	35,300	12,000
Chromium	64.3	1,000
Copper	38.0	25
Iron	37,800	500
Lead	87.2	30
Magnesium	9,810	(3,000)[d]
Manganese	10,700[e]	(400)[d]
Mercury	0.31	2
Molybdenum	24.8	10
Nickel	54.9	50
Potassium	908	(20,000)[d]
Selenium	3.1	2
Silver	22.0	100
Sodium	1,430	20,000
Vanadium	81.1	10
Zinc	159	300

[a] Data from Section 4.6.

[b] Lowest maximum concentrations among cattle, sheep, poultry, and rabbits are shown (NAS 1980).

[c] As soluble salts of high bioavailability. Higher levels of less soluble forms found in natural substances can be tolerated.

[d] Value derived by interspecific extrapolation.

[e] Excluding a value of 199,000 mg/kg, where the 12-inch to 24-inch depth sample contained 7,860 mg/kg manganese.

for a limited period, will not impair animal performance and should not produce unsafe residues in human food derived from the animal." Many factors (such as age and physiological status of the animal, its nutritional status, levels of various other dietary components, duration and route of exposure, and biological availability of the compound) influence the level at which an element causes an adverse effect. The endpoints assessed in the review by the National Academy of Sciences (NAS, 1980) varied widely by element, animal species, and individual study, so they reflect many different possible biological effects of excessive dietary levels. Examples include effects on growth rate, biochemical or morphological lesions, mortality, and bioaccumulation of the element in animal tissues. The domestic species included cattle, sheep, poultry, and rabbits, which are considered as surrogates for ecological receptors such as moose, beavers, voles, and birds found in OU 5. This screening approach assumed that the animals ate only soil; thus, for the elements with maximum detected concentrations below the tolerable level, those elements should not be toxic to animals. The following elements were retained through this screening process: barium, beryllium, cadmium, calcium, copper, iron, lead, magnesium, manganese, nickel, selenium, and vanadium. These elements will be considered in relation to possible ingestion by animals and their potential for causing adverse effects through that exposure pathway. Relationships between soil chemistry parameters measured in soils supporting plants that showed signs of stress (Section 4.6.1.1) also will be evaluated further.

As an additional screening for site contaminants, concentrations of inorganic elements in plants from OU 5 (see Section 4.6) were compared to maximum tolerable levels of dietary minerals for domestic animals (NAS, 1980; Table 6-33). The following elements exceeded the maximum tolerable dietary levels in one or more plant samples: cadmium, calcium, iron, lead, magnesium, manganese, and potassium. These elements will be considered further in the risk assessment.

Although selenium was reported at 3.2 mg/kg (which exceeds the 2.0 mg/kg tolerable level), this concentration was the limit of detection and selenium concentrations are

Table 6-33

Comparison of Maximum Detected Concentrations (mg/kg) for Inorganic Elements in Plants from OU 5 with Maximum Tolerable Dietary Levels for Domestic Animals

Element	Maximum Detected[a]	Tolerable Level[b]
Arsenic	3.2[c]	50
Boron	65.2	150
Cadmium	0.58	0.5
Calcium	28,100	12,000
Chromium	1.6	1,000
Cobalt	6.9	10
Copper	11.2	25
Iron	1,370	500
Lead	47.6	30
Magnesium	6,570	3,000
Manganese	484	(400)[d]
Molybdenum	3.9	10
Nickel	6.5	50
Potassium	26,600	20,000
Selenium	3.2[c]	2
Sodium	1,750	20,000
Zinc	95.8	300

[a] Data from Section 4.6.

[b] Lowest maximum concentration among cattle, sheep, poultry, and rabbits is shown (NAS 1980).

[c] Limit of detection.

[d] Value derived by interspecific extrapolation.

not expected to reach that level on the basis of selenium concentrations and pH in soils at this area.

Concentrations of inorganic elements in plants from OU 5 also were compared to several criteria to evaluate their status as being present at background, deficient, or toxic levels in the plants (Table 6-34). These evaluation levels have been developed by Bodek et al (1988) and by Kabata-Pendias and Pendias (1992) to summarize available information for a wide range of plant species and environmental conditions. Thus, the range of concentrations found in plants from OU 5 should be expected to fall within the background levels. The following elements either exceed background/normal levels, excessive/toxic levels, or tolerable levels for agronomic crops in one or more plant samples: arsenic (although the detection limit was higher than the minimum value for the excessive level), cobalt, iron, lead,manganese, nickel, and selenium (where the detection limit exceeded the background level for plants). Some plant samples had boron, copper, or zinc concentrations in the range where deficiencies could occur.

Seeps and surface water (Section 4.4) as well as shallow groundwater that may discharge to the surface (Sections 4.1 and 4.3) are potential sources of exposure for semi-aquatic wildlife within OU 5. Concentrations of contaminants in these waters were compared to water quality criteria and to no observed adverse effect levels in the previous section (6.2.1) in relation to aquatic resources.

Table 6-35 provides a summary of the site contaminants that were selected for further evaluation in the risk assessment for terrestrial resources.

6.2.2.2 Exposure Assessment

Exposure pathways for ecological receptors were described generally in Section 5; these pathways are summarized on Figure 5-4. The potentially complete exposure pathways to primary terrestrial receptors selected for assessment are listed in Table 6-36.

Table 6-34

Comparison of Detected Concentrations (mg/kg) for Inorganic Elements in Plants from OU 5 With Various Evaluation Levels

Element	Range of Concentrations Detected[b]	Evaluation Levels[a]			
		Background/Normal	Deficient[c]	Excessive/Toxic	Tolerable[d]
Arsenic	3.2 - 3.2[e]	0.01 - 1.7	--	3 - 20	-
Boron	3.7 - 65.2	10 - 200	5 - 30	50 - 200	100
Cadmium	0.20 - 0.58	0.05 - 0.8	--	5 - 30[f]	3
Calcium	4,080 - 28,100	--	--	--	--
Chromium	0.40 - 1.6	0.01 - 1	--	5 - 30	2
Cobalt	0.30 - 6.9	0.02 - 1	--	15 - 50	5
Copper	2.6 - 11.2	4 - 30	2 - 5	20 - 100	50
Iron	131 - 1,370	3 - 300	--	--	--
Lead	3.3 - 47.6	0.1 - 10	--	30 - 300	10
Magnesium	1,060 - 6,570	--	--	--	--
Manganese	42.5 - 484	15 - 300	10 - 30	300 - 2,000	300
Molybdenum	0.40 - 3.9	0.2 - 5	0.1 - 0.3	10 - 100	--
Nickel	1.7 - 6.5	0.1 - 5	--	10 - 100	50
Potassium	4,980 - 26,600	--	--	--	--
Selenium	3.2 - 3.2[e]	0.01 - 2	--	5 - 100	--
Sodium	190 - 1,750	--	--	--	--
Zinc	8.4 - 95.8	8 - 150	10 - 20	100 - 400[g]	300

[a] From Bodek et al. (1988) and Kabata-Pendias and Pendias (1992); dashes indicate values are not given.
[b] Data from Section 4.6.
[c] If less than stated concentration for these essential elements.
[d] In agronomic crops (see Kabata-Pendias and Pendias 1992).
[e] Limit of detection
[f] Given as 5 - 700 mg/kg by Bodek et al. (1988).
[g] Given as >300 - 1,500 mg/kg by Bodek et al. (1988).

Table 6-35

Summary of Data Sources and Contaminants Selected for Further Evaluations

Data Source	Contaminants Selected
Estimated soil vapor concentrations (Tables 6-29, 6-30)	Fuel hydrocarbons
Soil inorganics analyses (Tables 6-31, 6-32)	Arsenic, barium, beryllium, boron, cadmium, calcium, copper, lead, manganese, mercury, molybdenum, selenium, silver, and sodium
Plant tissue analyses (Table 6-33)	Cadmium, iron, lead, and manganese
(Table 6.34)	Arsenic, cobalt, iron, lead, manganese, nickel, and selenium (potentially excessive) Boron, copper, and zinc (potentially deficient)
Surface water and near-surface groundwater (Section 6.2.1)	Fuel hydrocarbons, PAHs, semivolatiles, BTEX, aluminum, copper, iron, lead, and zinc

Table 6-36

Potentially Complete Exposure Pathways to Primary Terrestrial Receptors Selected for Assessment

Exposure Points	Exposure Routes	Receptors	Contaminants	Assessment Medium
On-site soils	Ingestion/metabolic uptake	Voles, shrews	PAHs, fuel hydrocarbons, inorganics	Soils
Animal burrows	Inhalation	Voles, shrews	Fuel hydrocarbons	Soil gas
Surface water bodies	Ingestion/metabolic uptake	Beavers, ducks, wood frogs	Organics, inorganics	Surface water
	Dermal contact/ absorption	Beavers, ducks, wood frogs	Fuel hydrocarbons, inorganics	Surface water
Seeps/wetlands	Metabolic uptake/ inhibition	Plants, beavers, voles, ducks, wood frogs	Fuel hydrocarbons, other organics, inorganics	Soils, surface water, shallow groundwater, plants

This table also lists the contaminants of concern and the medium in which they were measured. The only secondary terrestrial receptors for which potential exposure concentrations were measured are herbivorous mammals (for example, beavers and voles) that may feed on vegetation at various locations where plants were collected for analysis. These exposure routes are discussed in the following paragraphs for the four principal exposure points (on-site soils, animal burrows, surface water bodies, and seeps/wetlands). Exposure point concentrations for each of the pathways have been presented in earlier sections (especially Section 4 and in portions of Section 6.2).

On-Site Soils

Terrestrial animals that ingest soils either through grooming or in association with feeding could be exposed to contaminants present in the soil. Examples of chemicals detected at elevated levels in the soil include PAHs, fuel hydrocarbons, and inorganic elements. The exposures of terrestrial ecological receptors to inorganic elements in soils could occur at dry sites as well as the seeps and wetlands where plant stress was observed (and elevated concentrations were found in soils).

Animal Burrows

Inhalation. Voles and shrews could be exposed to volatile hydrocarbon vapors if they live in the vicinity of contaminated areas. These small mammals live in runways (that is, pathways through vegetation) and shallow burrows that do not normally extend more than a few inches below ground surface[e]. Throughout OU 5 where elevated concentrations of fuel hydrocarbons were found in near-surface soils (Sections 4.2 and 4.6.1) or shallow groundwater (Section 4.1) there is a likelihood that soil vapor concentrations in animal burrows could reach exposure effect levels (as described in Section 6.2.2.1).

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[e] This information was obtained in a telephone conversation with Allen Richmond, natural resource planner at Elmendorf AFB, on December 1, 1992.

Although no vapor concentrations were measured in animal burrows, the concentrations of gasoline and diesel at both SL04 and SL16 were estimated to exceed the acutely toxic level.

Dermal contact and incidental ingestion of soil by voles and shrews may also be important intake routes. However, available data do not enable reasonably accurate estimation of the risk of adverse effects to small mammals through this pathway.

Surface Water Bodies

Ingestion/Metabolic Uptake. Semi-aquatic species such as beavers, ducks, and wood frogs are the most likely wildlife receptors for exposure through ingestion and metabolic uptake of contaminants found in surface waters, although most wildlife in OU 5 could be exposed through this route. For assessment of this pathway, the protection of aquatic organisms (see Section 6.2.1) is considered to be protective also for semi-aquatic species. It is also not clear to what extent waterborne contaminants in OU 5 may cause effects to terrestrial species through ingestion from surface water bodies or what level of bioconcentration of contaminants could occur there. Hence, this pathway will not be assessed in further detail.

Dermal Contact/Absorption. Beavers, ducks, and wood frogs also are the wildlife species that are most likely to be exposed through contact with fuel hydrocarbons found in surface water bodies. Floating petroleum products, which were observed in greatest abundance in the large beaver pond at SL22, SL23, and SL24, could be contacted by these species during their use of the pond. Beavers, muskrats, ducks, shorebirds, and frogs were observed at that pond where they could be exposed to oil sheens. These species and aquatic plants also could be exposed through contact with dissolved hydrocarbons in the water.

Seeps/Wetlands

Metabolic Uptake/Inhibition. Plants, beavers, voles, ducks, wood frogs, and other terrestrial receptors are potentially exposed to fuel hydrocarbons, other organics, and inorganics in the soils, surface water, and shallow groundwater found at the seeps and wetlands. Those constituents and media, as well as inorganics found in plants, were analyzed during the RI sampling for assessment of potential effects on ecological receptors. In this exposure pathway, chemical concentrations in plants and the soils they were growing in are used for assessment of potential direct effects on plants.

Secondary Terrestrial Receptors

Animals that may feed on plants with elevated concentrations of various inorganic elements could be exposed through ingestion (Figure 5-4). This pathway is presumed to be potentially complete, although food habitats of the herbivorous mammals in OU 5 were not studied.

Predatory birds and mammals that feed on food-chain organisms containing elevated concentrations of contaminants may also be exposed through ingestion. However, larger mammals (including predatory species such as otter, fox, coyote, and bear) are wide-ranging and were not surveyed during the qualitative surveys that were conducted, although the presence of bear scat in OU 5 was noted. The affected areas of OU 5 are a small portion of the home range for the larger predatory mammals known to occur there. This is also true for predatory birds. Insufficient data are available to model exposure of those animals (such as home range, diet, and dietary contaminant concentrations) in a meaningful way, and obtaining that information was beyond the scope of the Phase 1 risk assessment. However, based on the available data, this exposure pathway for larger predators does not appear to be significant because exposure would be very limited.

There also are enough uncertainties about the food-chain availability of contaminants of concern for smaller predators, such as shrews, to limit the usefulness of modeling this exposure pathway. Some inorganics (such as lead) identified as contaminants of concern (Section 6.2.2.1) may bioaccumulate in food chains of predators to moderate levels, but concentrations of those elements in soils were not greatly elevated above background levels. The degree of food-chain bioaccumulation for those elements varies widely because of site-specific conditions (see also Section 6.2.2.3). Therefore, food-chain bioaccumulation of some inorganics could cause exposure to predators having limited home ranges within OU 5, but the significance of this pathway is uncertain. It should be noted that organochlorines (persistent pesticides and PCBs), which tend to bioaccumulate readily in food-chain organisms, were not identified as contaminants of concern for terrestrial receptors.

Frequency and Duration of Exposure

It is assumed that resident species of terrestrial animals (for example, beavers, voles, shrews, wood frogs) and plants may be continuously exposed to the contaminants in their habitats. Migratory species that nest within OU 5 habitats (such as ducks) may be exposed to site contaminants throughout their seasonal residence (about half of the year, but nesting and early development periods are when birds are most sensitive); other migratory species are not included in the assessment.

Voles and shrews generally live at or near the soil surface, using shallow burrows, logs, and surface runways through vegetation as shelter (Ingles, 1965; Whitaker, 1980). Their burrows in soils such as those below the bluff in OU 5 are usually less than 1 foot below the surface[f]. Semi-aquatic species such as beavers, muskrats, ducks, shorebirds, and wood frogs spend much of their time in contact with surface waters. Because these are air-breathing animals, they are frequently at the water's surface where they

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[f] This information was obtained in a telephone conversation with Allen Richmond, natural resource planner at Elmendorf AFB, on December 1, 1992.

could be exposed to chemicals such as fuel hydrocarbons that form a surface sheen. In addition, frog tadpoles live in the water column and frequently contact and/or ingest materials associated with sediments. Ducks and shorebirds also depend on benthic (sediment-associated) invertebrates as food resources, so they could be affected directly by contaminants the invertebrates have accumulated, or indirectly by reduced food resources if contaminants are toxic to the invertebrates.

6.2.2.3 Toxicity Assessment

The toxicity of chemicals of concern identified for OU 5 is described in relation to terrestrial receptors in this section. Both acute and chronic exposures are considered. The relative importance of these types of exposure varies by chemical and receptor population. Except for acute exposure to floating petroleum hydrocarbons (oil sheens), the chronic exposures are considered more significant and are the primary focus for assessment. The initial screening of site contaminants (Section 6.2.2.1) and pathways (Section 6.2.2.2) reduced the contaminants of concern to those described in the following sections. Because some inorganics were excluded through one screening but not others, general information is presented about the toxicity of most inorganics considered in the assessment.

Fuel Hydrocarbons

Vapors of fuel hydrocarbons can be toxic to animals that inhale them. Dollarhide (1992) calculated a NOAEL of 230 mg/m^3 for continuous exposure using the results of the chronic inhalation study for unleaded gasoline (that tested rats and mice), reported by MacFarland et al (1984). Continuous exposures of dogs, rats, or mice to diesel or jet fuels produced a range of sublethal effects (Dollarhide, 1992). Based on results of subchronic inhalation studies using female mice, a LOAEL of 150 mg/m^3 was identified for JP-5. Similarly, LOAELs of 500 mg/m^3 and 50 mg/m^3 were identified for JP-4 and marine diesel fuel, respectively. However, the effects of chronic exposure of voles or shrews to fuel hydrocarbon vapors occurring at various locations within OU 5 have not been tested.

A comparison of the PAH concentration in soil at SB29 (5050 $\mu g/kg$) to the chronic oral dose causing tumors in mice (0.002 mg/kg bw/day) (Eisler, 1987a) was presented in Section 6.2.2.1. Because of differences in units, these values cannot be compared directly, and the LOAEL (as PAH concentration that causes effects) must be calculated. The PAH concentration equates to 0.00000505 mg PAH/mg soil. If a mouse (the test animal on which the toxicity value is based) eats 3000 mg of food per day (Lewis, 1992), and, as a "worst-case" conservative assumption the mouse eats only soil, it would ingest a dose of 0.01515 mg PAH/day. Assuming that a mouse weighs 0.025 kg (Lewis, 1992), its ingestion dosage would equal 0.606 mg/kg bw day (calculated as 0.01515 mg/day divided by 0.025kg). The LOAEL soil PAH concentration, therefore, can be calculated as 0.0167 mg/kg, based on:

$$5.050\ mg/kg \times \frac{0.002\ mg/kg\ bw/day}{0.606\ mg/kg\ bw/day}$$

Thus, even if the mouse's diet (or that of a similarly sensitive small mammal such as a vole) contained only a trace of the soil, ingestion of this soil on a continuing basis could be toxic.

Albers (1991) reviewed the effects of oil on plants and animals, and several other authors have reported findings that help to assess the toxicity of fuel hydrocarbons to terrestrial receptors. Those effects that are most relevant to OU 5 potential exposures are summarized in the following paragraphs.

Mammals. Mammals that rely primarily on fur for insulation are the most likely to die after contact with spilled oil (Albers, 1991). Oiled fur becomes matted and loses its ability to trap air or water. Skin and eye irritation and interference with normal swimming can also occur. No reports of effects on moose or black bears were found in the literature, but those species rely on their fur for insulation.

Oil ingested in large quantities can kill polar bears (*Ursus maritimus*), but seals (Otariide and Phocidae) and cetaceans are more resistant to toxic effects because renal clearance is rapid and they can metabolize petroleum (Albers, 1991). Ingested oil can cause gastrointestinal tract hemorrhaging in the European otter (*Lutra lutra*), renal failure in the polar bear, liver toxicity in laboratory mice, and blood disorders in the polar bear and laboratory rats and mice. Inhalation of evaporating oil is a potential respiratory problem for mammals near or in contact with large quantities of fresh oil.

Documentation of the effects of oil spills on non-marine mammals is limited (Albers, 1991). Large numbers of muskrats were killed by a spill of bunker C fuel oil on the St. Lawrence River. Giant kangaroo rats (*Dipodomys ingens*) in California were found dead after being oiled, beaver and muskrats were killed by an aviation kerosene spill in a Virginia river, and rice rats (*Oryzomys palustris*) in a laboratory experiment died after swimming through oil-covered water.

Because of its small size and abundance in tidal wetlands, rice rats were chosen as subjects for studying the possible effects of crude oil spills on marsh mammals by Wolfe and Esher (1981). Two types of crude oil (Texas and Empire) were applied to the water surface at two concentrations. Application rates were 200 and 20 ml of oil to the surface of the water in the tanks (200 and 20 ml/m^2). Tests were begun at about 4 pm and concluded at about 8 am. All experimental and control animals, in individual cages with food and water, were placed in an environmental chamber at 5.0°C. Survival and body temperature were checked at 3, 6, and 24 hours. Both concentrations of the two oils significantly inhibited water crossings per night. The comparison of number swimming or not swimming was not different with either concentration of Texas Crude, but was different with both concentrations of Empire Crude. Both oils at high concentrations produced a significant mortality within 3 hours. The effects of the low concentrations were not significant. Mortality was probably due to loss of insulation rather than direct toxic effects. This study demonstrates an effect on swimming behavior and on survival. It can be inferred that an oil slick washing into a tidal wetland would adversely affect populations of rice rats and other semiaquatic mammalian inhabitants such as muskrat, nutria (*Myocastor coypus*), mink (*Mustela vison*), and otter (*Lutra canadensis*). Data indicate that mortality would be high for individuals swimming through oil slicks, especially during the colder months.

Birds. Birds can be affected by petroleum through external oiling, ingestion, egg oiling, and habitat changes (Albers, 1991). External oiling disrupts feather structure and causes matting of feathers and eye irritation. Mortality often results from hypothermia and drowning. Birds that spend much of their time in the water are the most vulnerable to surface oil.

Petroleum can be ingested through feather preening, drinking, consumption of contaminated food, and inhalation of fumes from evaporating oil (Albers, 1991). Ingestion of oil is seldom lethal, but it can cause many debilitating sublethal effects that promote mortality from other causes, including starvation, disease, and predators. Effects include inflammation and hemorrhaging of the digestive tract, pneumonia, organ damage, red blood cell damage, hormonal imbalance, intoxication, inhibited reproduction, retarded growth in young, and abnormal parental behavior (Fry and Lowenstine, 1982, 1985; Albers, 1991). Bird embryos are very sensitive to petroleum. Contaminated nest material and oiled plumage are mechanisms for transferring oil to the shell surface. Small quantities of some types of oil are sufficient to cause death, particularly during the early stages of incubation.

Petroleum spilled in avian habitats can have immediate and long-term indirect effects on the birds (Albers, 1991). Fumes from evaporating oil, a shortage of food, and cleanup activities can reduce use of an affected area, but long-term effects are more difficult to document.

Unweathered crude and refined oils are known to be very toxic to the embryos of aquatic birds but the toxicity of weathered petroleum is not as well established (Albers and Gay, 1982). The toxicity of Prudhoe Bay crude oil and No. 2 fuel oil to embryos of mallard ducks decreased only after 3 weeks and 2 weeks of weathering on a large container of fresh water. Although 10 microliters (μL) of 4-week-old Libyan crude oil caused a significant increase in mortality among embryos of tricolored herons (*Egretta tricolor*), the same amount of fresh oil did not cause a significant increase in mortality. However, embryos of laughing gulls (*Larus atricilla*) were not significantly affected by 10 μL of 4- or 8-week-old weathered Libyan crude oil or by 10 μL of fresh oil. Crude oil (10 μL) recovered from the water surface near the IXTOC-I oil spill site in the Gulf of Mexico did not significantly reduce the survival of mallard embryos by day 18 of incubation.

External exposure and ingestion of oil by birds can cause short-term and long-term reproductive problems. Small amounts of weathered crude oil (0.1-2 mL) on breast feathers of seabirds can reduce the number of eggs laid, lower the number of hatching eggs, and reduce breeding success. Lower breeding success decreased the number of birds returning to the nesting area and disrupted pair bonds, which caused lower reproductive success in the years following external exposure to crude oil (Fry et al, 1985; 1986). Japanese quail, Canada geese, and chickens, fed 0.2 g, 2 g, and 0.5 g of bunker C oil respectively, laid fewer eggs, had fewer eggs hatch, and laid eggs with abnormal yolks (Grau et al, 1977).

Bird embryos are most sensitive to toxic compounds in petroleum during the first 10 days of incubation (Albers and Gay, 1982). Six of 7 groups of 50 mallard eggs were treated with either 1, 5, or 20 μL of unweathered aviation kerosene or 1, 5, or 20 μL of aviation kerosene collected by cleanup crews 2 to 5 days after the Manassas, Virginia, spill. The seventh group was an untreated control. Both substances were applied to the surface of the egg near the air cell end by microliter syringe. The 20 μL treatments consisted of four 5 μL applications.

Egg hatching success of the control group was not significantly different from that of any of the groups treated with unweathered or weathered aviation kerosene (Albers and Gay, 1982). Hatching success was not dose-related for either substance. No significant differences among groups were found for the developmental ages of dead embryos; means varied from 19.1 to 21.6 days. These results mean that the eggs of waterfowl nesting near the spill site were probably not endangered by plumage transfer of small amounts of partially weathered kerosene to the eggs.

The lack of any toxic effect of aviation kerosene on duck embryos is probably attributable to the absence of high molecular weight aromatic hydrocarbons that are present in crude and fuel oils (Albers and Gay, 1982). Tricyclic and higher aromatic hydrocarbons, alone or in combination with other aromatic hydrocarbons, can cause significant amounts of mortality in duck embryos. Tetracyclic and higher aromatic hydrocarbons were responsible for reduced growth and other physiological changes in herring gull (*Larus argentatus*) chicks and increased corticosterone and thyroxine levels in herring gull and black guillemot (*Cepphus grylle*) chicks. Consequently, further weathering of the residual aviation kerosene probably would not alter the demonstrated effect of the 2- to 5-day-old sample.

Amphibians. Mortality rates in bullfrogs (*Rana catesbeiana*) were most severe in tadpoles that were in the late stages of development when exposed to oil. Sensitivity to oil of wood frogs and the spotted salamander (*Ambystoma maculatum*) was similar to two species of fish (Albers, 1991).

Bullfrogs occupy a central position in the freshwater aquatic food web (McGrath and Alexander, 1979). They are dependent on water throughout their life cycle. Laboratory experiments were conducted to determine the effects of exposure to oil on bullfrog tadpoles. The concentrations of Bunker C (#6) fuel oil used in the experimental jars ranged from 0.13, 0.36, and 10 percent by volume, measured by the total volume per jar of 2.4 liters. Duration of exposure time varied from 96 to 120 hours.

Initially, all tadpoles were observed either to rest on the bottom or to swim actively in apparent feeding motions, both of which are normal behavior activities for tadpoles in the wild (McGrath and Alexander, 1979). However, within a period of approximately 7.5 hours, 72.8 percent of the total number of animals exposed to oil, regardless of the concentration, began to float on the surface. Sensitivity to oil was related to the developmental stages of the tadpole. Animals that had reached the XXVI stage of development were less tolerant of the oil, as seen by a significantly higher mortality rate. All animals, regardless of the developmental stage or concentration of oil, experienced a floating response frequently accompanied by a swollen heart-shaped appearance and lethargy. Lungs of these swollen animals were grossly inflated and occupied a larger-than-normal portion of the body cavity.

Short-term lethality tests were conducted with five (waste oil, No. 1 fuel oil, No. 2 fuel oil, mixed blend sweet crude oil, Lloydminister crude oil) oils and four freshwater species by Hedtke and Puglisi (1982). The oils were tested as floating layers, emulsions, and as the water-soluble fraction of 10 percent oil-water mixtures, in static and flow-through tests. The organisms tested were the American flagfish (*Jordanella floridae*), the fathead minnow (*Pimephales promelas*), and larvae of the wood frog and spotted salamander. LC_{50} values were quite variable depending on a number of influencing factors, including the species tested, the type of oil, differences between batches of the same oil, the form of the oil when added to the test system, the type of test, duration of exposure, and the oil-water contact time. Results of these tests are presented in Table 6-37.

Criteria and Standards. The following criteria and standards apply to the toxicity assessment for fuel hydrocarbons in surface water within OU 5.

Federal water quality criteria for aquatic life (EPA, 1986d) are as follows:

- 0.01 of the lowest continuous flow 96-hour LC_{50} to several important freshwater and marine species, each having a demonstrated high susceptibility to oils and petrochemicals;
- Levels of oils or petrochemicals in the sediment which cause deleterious effects to the biota should not be allowed; and
- Surface waters shall be virtually free from floating nonpetroleum oils of vegetable or animal origin, as well as petroleum-derived oils.

Table 6-37

LC_{50} Values for Five Oils and Four Species in Static and Flow-Through Tests

Type of Oil	Condition of Oil When Added	Type of Test	Species Tested	LC_{50} in μL Toxicant Solution/L water		
				24 hours	96 hours	8 days
Used Crankcase	Water-soluble fraction[a]	Static	A. flagfish	52,500	36,200	16,800
		Flow-through	A. flagfish	45,500	9,500	
		Flow-through	Fathead minnow	20,200	16,600	16,600
	Emulsion	Static	A. flagfish		485	
		Flow-through	A. flagfish	200	82.7	82.7
	Floating layer	Static	Fathead minnow	>40,000	12,000	6,200
			Wood frog	>20,000	1,500	
No. 2 fuel, Sample A	Water-soluble fraction	Static	A. flagfish	>100%[b]	>100%	>100%
		Static	Fathead minnow	>100%	>100%	>100%
		Static	Wood frog	>100%	413,000	
	Emulsion	Static	Wood Frog	>62.5	>26.4	
		Flow-through	Wood frog	>70.5	4.9	3.4
		Flow-through	A. flagfish	>81.5	60.5	
		Flow-through	Fathead minnow	>72.6	38.6	34.5
		Flow-through	Spotted salamander	>86.4	>86.4	>86.4
No. 2 fuel, Sample A (cont.)	Floating layer	Static	Fathead minnow	>160,000	>160,000	>160,000
			Wood frog	>80,000	<5,000	
No. 2 fuel, Sample B	Floating layer	Static	Fathead minnow	>80,000	48,300	
No. 1 fuel	Emulsion	Flow-through	Fathead minnow	201	56.7	
		Flow-through	Wood frog	>60.6	45.8	23.1
Mixed-blend sweet crude	Water-soluble fraction	Static	Wood frog	>250,000	>250,000	>250,000
	Emulsion	Static	Wood frog	9.51	78.0	78.0
		Flow-through	Wood frog	56.9	28.2	25.0
		Flow-through	Fathead minnow	12.4	<8.4	<8.4
	Floating layer	Static	Wood frog	21,600	<2,500	
Lloydminister crude	Floating layer	Static	Wood frog	>40,000	6,300	

[a] Water-soluble fraction of 10 percent oil-water mixture.
[b] No mortality in 100 percent solution of water-soluble fraction.
Source: Hedtke and Puglisi 1982.

Alaska water quality standards (18 AAC 70) for Class (1)(C) waters to protect aquatic life and wildlife are:

- Total hydrocarbons in the water column shall not exceed 15 μg/L, or 0.01 times the lowest measured continuous flow 96-hour LC_{50} for life stages of the most sensitive, biologically important species in a particular location, whichever concentration is less.
- Total aromatic hydrocarbons in the water column shall not exceed 10 μg/L, or 0.01 times the lowest measured continuous flow 96-hour LC_{50} for life stages of the most sensitive, biologically important species in a particular location, whichever concentration is less.
- Concentrations of hydrocarbons, animal fats, or vegetable oils in the sediment shall not cause deleterious effects to aquatic life; shall not cause a film, sheen, or discoloration on the surface or floor of the water body or adjoining shorelines.
- Sediment loads shall not cause adverse effects on aquatic animal or plant life, their reproduction, or habitat.

Other Organics

Animals. Limited information is available on the toxicity of PAHs to mammals, birds, and amphibians (Eisler, 1987b). Information on PAH toxicity to mammals deals primarily with carcinogenic or mutagenic effects. Chronic oral exposures of mice to benzo(a)pyrene caused stomach tumors at doses as low as 50 mg/kg in the diet. Also, application of some PAHs to mouse skin has produced skin tumors. Immunosuppression has been noted in mice exposed to certain PAHs. Acute oral LD_{50} values for benzo(a)pyrene, phenanthrene, naphthalene, and fluoranthene are reported to be 50, 700, 1780, and 2000 mg/kg body weight, respectively, in rodents. Subchronic studies involving mouse oral exposure to benzo(a)pyrene were used to derive a NOAEL of 125 mg/kg body weight/day and a LOAEL of 250 mg/kg body weight/day for both fluoranthene and pyrene (EPA, 1988e). Similarly, a NOAEL of 10 mg/kg body weight/day and a LOAEL of 40 mg/kg body weight/day were derived for phenanthrene from acute studies (Mackenzie and

Angevine, 1981). PAHs generally do not biomagnify in food chains despite being highly lipid soluble because they are rapidly metabolized (Eisler, 1987b).

Chronic feeding studies with mallards fed diets containing 4,000 mg/kg PAHs showed few signs of toxicity, such as elevated liver weight and increased blood flow to the liver (Eisler, 1987b). Other data suggest that some PAHs, particularly 7,12-dimethylbenz(a)anthracene and benzo(a)pyrene, can cause embryotoxicity when applied in microliter quantities externally to mallard eggs.

Most data available on the toxicity of PAHs to amphibians focus on carcinogenic effects (Eisler, 1987b). Implantation of 1.5 mg of benzo(a)pyrene crystals into the abdominal cavities of immature and adult South African clawed toads resulted in lymphoid tumors, but young toads were less likely to develop tumors than adults. Hepatic tumors were induced in tiger salamanders (*Ambystoma tigrinum*) by intraperitoneal injection of perylene. High incidence of cancer and abnormal metabolite ratios were also observed in tiger salamanders exposed to high concentrations of PAHs (Power et al, 1989). Naphthalene was shown to cause decreased swimming in clawed toads after 6 hours of exposure to 1.7 to 2.3 mg/L, neurotoxic effects at 0.5 to 3 mg/L water, and loss of pigment at 3.7 mg/L (Edmisten and Bantle, 1982). The 96-hour LC_{50} for clawed toads is reported as 2.1 mg/L.

Plants. Plants absorb PAHs through their roots and translocate them to elongating shoots and other plant tissues even though PAHs are lipid soluble (Eisler, 1987b). There is no evidence that plants concentrate PAHs above the levels of their surroundings and PAH-induced toxic effects are rare. The fate of PAHs within plants is largely unknown, as are the implications of toxicity to herbivorous wildlife. Uptake rates of PAHs are dependent upon concentration, water solubility, soil type and whether the PAH is in vapor or particulate form. Plants tend to absorb lower molecular weight PAHs more readily than high molecular weight PAHs.

Inorganics

Animals. The toxicity of the inorganic elements found in soils, sediments, and surface water at OU 5 has been reviewed in relation to their effects on mammals, birds, and amphibians by various authors (see Romanoff, 1972; Luckey and Venugopal, 1977; Underwood, 1977; Venugopal and Luckey, 1978; Friberg et al, 1979; Eisler, 1985a, 1985b, 1986, 1987a, 1988a, 1988b; and Scheuhammer, 1987).

A number of inorganic elements are essential in small amounts for animal nutrition because they are an integral part of at least one enzyme (Underwood, 1977; Clarkson, 1979; Robbins, 1983). Examples include arsenic, calcium, chromium, copper, iron, magnesium, manganese, potassium, sodium, and zinc, among those measured at OU 5. The animal body has developed a variety of homeostatic mechanisms with regard to these essential macro and trace elements, so they are less likely to produce toxic effects at elevated concentrations than are the non-essential elements such as cadmium and lead. Nevertheless, some essential elements can overwhelm or circumvent those control mechanisms to produce toxic effects in wild birds and mammals (for example, selenium; see Ohlendorf, 1989).

The toxicity of many elements is greatly influenced by the chemical state in which they occur in the animals' food, water, or air. Therefore, total concentrations of these elements in water, soil, or air are not generally good indicators of potentially toxic exposure; concentrations in the food are usually the most important. However, because potentially toxic trace elements occur in many different forms, even the total concentration of some elements in the diet may not be a good predictor of toxicity.

The toxicity of inorganic elements in the diet varies so widely that it is not practical to list specific concentrations that cause adverse effects under conditions of acute or chronic exposure. Furthermore, the reported concentrations in sediments/soils or surface water cannot reasonably be extrapolated to the concentrations that might occur in foods of birds and mammals living in OU 5; only the concentrations measured in plants are useful for this purpose. The following general summary of the relative toxicity of inorganic elements is based primarily on reviews by Romanoff (1972), Underwood (1977), Luckey and Venugopal (1977), Venugopal and Luckey (1978), Friberg et al (1979), Gough et al (1979), Sax (1984), Eisler (1985a, 1985b, 1986, 1987a, 1988a, 1988b), and Scheuhammer (1987). The various elements are divided into bond valence groups as depicted on the periodic table of elements.

Group I. Potassium and sodium are essential macroelements that are considered to be harmless and generally nontoxic. Copper is an essential trace metal that stimulates growth when moderately high levels (about 100 times the dietary allowances) are fed to mammals, even though it is highly toxic to aquatic organisms. Observed LD_{50} values for laboratory rats include 140 mg/kg body weight (copper chloride), 29 mg/kg body weight (cupric perchlorate), 940 mg/kg body weight (cupric nitrate) and 960 mg/kg body weight (copper sulfate) in the diet (Venugopal and Luckey. 1978). The maximum chronic tolerated level in grazing animal diets is 25 to 300 mg/kg (Bodek et al, 1988). Based on subchronic laboratory studies, a NOAEL of 12.5 mg Cu/kg body weight/day and a LOAEL of 4.2 mg Cu/kg body weight/day were derived for rats (Murphy et al, 1981; Massie and Aiello ,1984.) Silver is a nonessential metal that is moderately toxic but poorly absorbed from the gut when ingested.

Group II. Magnesium and calcium also are essential macroelements for animals, and barium is stimulatory but not essential. All three are considered relatively nontoxic at physiologic levels but definitely toxic at higher levels. Reported LD_{50} values for laboratory animals exposed orally to barium include 54 mg/kg body weight (barium chloride-mouse), 150 mg/kg body weight (barium chloride-rats), and 175 mg/kg body weight (barium silicofluoride-rat) (Venugopal and Luckey, 1978). Lifetime exposure of rats and mice to 5 mg/L barium in drinking water (approximately 0.25 mg/kg/day for rats and 0.825 mg/kg/day for mice) resulted in no adverse effects (Schroeder and Mitchener, 1975a, 1975b). Beryllium, cadmium, and mercury are nonessential elements that are stimulatory at very low doses but become highly toxic at relatively low levels. Beryllium and mercury are more toxic than other metals in this group. However, gastrointestinal absorption of soluble beryllium salts in mammals is poor and depends on the ingested dose. There are few reports of beryllium toxicity following oral exposure. In a study using rats, a NOAEL of 0.54 mg/kg body weight/day and a LOAEL of 0.85 mg/kg body weight/day were reported for chronic oral exposure to beryllium (Schroeder and Mitchener, 1975a and b). Homeostatic mechanisms maintain normal levels of magnesium and calcium, and to a certain extent barium and strontium, but beryllium and cadmium are not controlled by homeostasis. Cadmium toxicity to mammals varies widely and is influenced by external factors. Cadmium exposure can cause derangement in carbohydrate and mineral metabolism in renal, hepatic, testicular, and prostate functions and disturbs the integrity of the central nervous system (Venugopal and Luckey, 1978). Various LD_{50} values reported for laboratory animal exposed orally to cadmium salts include: 88 mg/kg body weight (cadmium chloride-rat), 150 mg/kg body weight (cadmium fluoride-guinea pig), and 660 mg/kg body weight (cadmium succinate-rat). Chronic ingestion of cadmium at low levels by rats, rabbits, lambs, pigs, and calves results in diminished growth and feed consumption (Nomiyama et al, 1973; Doyle et al, 1974; and Cousins et al, 1973). Using laboratory rats, a NOAEL of 0.004 mg/kg body weight/day and a LOAEL of 0.014 mg/kg body weight/day were derived for oral exposure to cadmium (Kopp, 1982). Barium, beryllium, cadmium, and mercury are retained in the tissues, and the body levels of these metals increase with age. Zinc is an essential trace metal that is relatively nontoxic because of efficient homeostatic mechanisms that maintain a proper balance within the body. Reported LD_{50} values for laboratory animals exposed to zinc salts orally include: 45.7 mg/kg body weight (zinc phosphide-rat), 250 mg/kg body weight (zinc chloride-guinea pigs), and 350 mg/kg body weight (zinc chloride-mice and rats) (Venugopal and Luckey, 1978). A subchronic NOAEL of 98.3 mg/kg body weight/day was reported for rats orally exposed to zinc in their feed (Drinker et al, 1927). Similarly, a chronic LOAEL of 38 mg/kg body weight/day was derived for mice exposed to zinc in drinking water (Aughey et al, 1977).

Group III. No Group III metals are known to be an essential element in animal nutrition. Intestinal absorption of aluminum is generally very poor and its toxicity is low in comparison to that of many other metals. Thallium is potentially toxic when administered orally, but behaves like potassium in its metabolism. There apparently are no homeostatic mechanisms to control the levels of Group III metals in animals.

Group IV. Lead is a nonessential metal that is readily absorbed from the digestive tract. Organic lead compounds are more toxic than are inorganic salts, because of their greater lipid solubility, stability in biological fluids, and penetration into tissues such as brain and lodgement in the central nervous system. Soluble lead salts are more toxic than insoluble salts, and rabbits and guinea pigs are more susceptible to lead poisoning than rats and mice (Venugopal and Luckey, 1978). Reported oral LD_{50} toxicity values for laboratory animals include: 100 mg/kg body weight (lead arsenate-rat), 125 mg/kg body weight (lead arsenate-rabbit), 2,000 mg/kg body weight (lead chloride-guinea pig), and 3,000 mg/kg body weight (lead lactate-guinea pig). A chronic NOAEL of 0.45 mg/kg body weight/day and LOAEL of 2.8 mg/kg body weight/day have been reported for rats (Perry et al, 1988; Azar et al, 1973). Adverse effects on aquatic biota have been reported at waterborne lead concentrations of 1 to 5 μg/L. Lead salts are only toxic to birds at a high dietary dose (100 mg/kg or more), with most experiments conducted on chickens and other gallinaceous birds (WHO, 1989). Exposure of quail from hatching through reproductive age resulted in effects on egg production at dietary levels of 10 mg/kg.

Group V. Arsenic, antimony, and vanadium are nonessential, potentially toxic elements. In general, inorganic arsenic compounds are more toxic than organic arsenic compounds, and trivalent compounds (in the form of soluble arsenite) are far more toxic than pentavalent compounds (arsenates). Arsenic is a teratogen and carcinogen that produces death and malformations in many species of mammals. Reported oral LD_{50} values for rats and mice include: 8 mg/kg body weight (arsenic pentoxide-rat), 14 mg/kg body weight (potassium arsenite-rat), 43 mg/kg body weight (arsenic trioxide-mouse), 143 mg/kg body weight (arsenic trioxide-rat), and 794 mg/kg body weight (calcium arsenate-mouse) (Venugopal and Luckey, 1978; Eisler, 1988a). In chronic studies with dogs, a NOAEL of 1.2 mg/kg body weight/day and a LOAEL of 6.4 mg/kg body weight/day were reported for ingestion of arsenic in drinking water (Byron et al, 1967). Antimony salts are inherently toxic, but they are relatively insoluble and less toxic than antimony metal. Acute vanadium exposure to animals affects the central nervous system, lungs and kidneys (Klaassen et al, 1986). Acute studies of laboratory animals have shown that inhalation of vanadium in dust results in respiratory depression, whereas subacute studies have suggested that the liver, bone marrow, and adrenal glands may also be affected. In chronic studies in which rats were exposed to vanadium in drinking water, a NOAEL of 0.7 mg/kg body weight/day and LOAEL of 2.8 mg/kg body weight/day were reported (Schroeder et al, 1970; Kowalski, 1988).

Group VI. Chromium and selenium are essential trace elements for animals, but both are toxic at high doses. Hexavalent chromium is the most biologically active form, although little is known about the properties of organochromium compounds, water-soluble species, or their interactions in complex mixtures. However, in mammals hexavalent chromium is chemically reduced in the acid fluid of the stomach. A NOAEL of 0.46 mg/kg body weight/day has been reported for rats chronically exposed to chromium in the diet, however no LOAEL was reported (Schroeder et al, 1965). Chromium concentrations are usually highest in the lowest trophic levels, and no biomagnification has been observed in food chains. Selenium is more toxic than chromium and the difference between essential dietary levels and toxic levels is narrow. Selenium is teratogenic and has significant toxic effects on reproduction and calcification. Excretory mechanisms exist for maintaining tissue levels of both chromium and selenium, but they are limited in their ability at high dietary concentrations.

Group VII. Manganese salts appear to be the least toxic of the essential metals. An efficient homeostatic mechanism prevents manganese accumulation in tissues, and toxic effects of manganese are not clearly manifested. In one study, a NOAEL of 290 mg/kg body weight/day and a LOAEL of 930 mg/kg body weight/day were reported for rats exposed chronically to manganese in the diet (Hejtmancik et al, 1987a, 1987b).

Group VIII. Iron is an essential metal that is generally considered to be of very low toxicity to animals. Reported oral LD_{50} values for iron exposure to laboratory animals include: 900 mg/kg body weight (ferric chloride-rat), 984 mg/kg body weight (ferrous chloride-rat), 1,170 mg/kg body weight (ferrous sulfate-mouse), 1,480 mg/kg body weight (ferrous sulfate-rat), and 3,250 mg/kg body weight (ferric nitrate-rat) (Venogopal and Luckey, 1978). Nickel is presumed to be an essential element but its metabolic functions are less known than those for iron. Nickel is relatively nontoxic, ranking with iron, cobalt, copper, chromium, and zinc. A NOAEL of 5 mg/kg body weight/day and LOAEL of 50 mg/kg body weight/day were reported for rats chronically exposed to nickel in the diet (Ambrose et al, 1976). Cobalt is an essential metal that has a potential for toxicity if excessive amounts are ingested (Klaassen et al, 1986). In a subchronic study, a NOAEL of 0.05 mg/kg body weight/day and a LOAEL of 0.5 mg/kg body weight/day were reported for rats orally exposed to cobalt (Krasovskii and Fridlyand, 1971).

Amphibians. Additional information is summarized here for amphibians because the kinds of exposures that are typically tested are more applicable to toxicity assessment.

Metals are toxic to amphibians and readily accumulate in body tissues (Power et al, 1989). Metal concentrations present in tissues are often much greater then environmental levels, and can be bioaccumulated in the food chain. Amphibians are most sensitive to the toxic effects of metals while still in the egg. The larval form is slightly less sensitive followed by the adult which is the most resistant.

In an acute study, *Gastrophryne carolinensis* eggs exposed to arsenic from fertilization to 4 days posthatch exhibited a 96 hour LC_{50} of 0.04 mg/L (Power et al, 1989).

Cadmium affects the development and survival of amphibians (Power et al, 1989). Leopard frog (*Rana pipiens*) eggs which were exposed to 2.5 mg/L of cadmium showed no further development. Exposure to lower concentrations greatly decreased survival. Exposure of the salamander *Notophthalmus viridescens* to 2.0 to 6.75 mg/L of cadmium for 51 days resulted in retarded limb regeneration at the lower concentrations and mortality at the higher concentrations. Limb regeneration in those that survived was retarded and numerous abnormalities were present. A 96 hour LC_{50} of 0.04 mg/L was reported for *G. carolinensis* eggs exposed to cadmium from fertilization to 4 days posthatch.

Chromium residues measured in field collected *R. esculenta* frogs showed that residue levels were much lower in the neometamorphosed frogs than in tadpoles (Power et al, 1989). The decrease in residue levels was due to the change in diet. Tadpoles were primarily herbivorous, whereas the adults were insectivorous. Acute studies with *G. carolinensis* eggs resulted in a 96 hour LC_{50} of 0.03 mg/L.

Cobalt alters epithelial cell membrane permeability by combining with sulfhydryl groups within the membrane (Power et al, 1989). An acute 96 hour LC_{50} for *G. carolinensis* eggs exposed from fertilization to 4 days posthatch was reported as 0.05 mg/L.

Copper is often present in acid mine drainage (Power et al, 1989). Acute 96 hour LC_{50} values reported for different amphibians include: 0.32 mg/L for *Bufo melanosticus* tadpoles, 5.04 and 5.38 mg/L for 1 week old and 4 week old *Microhyla ornata*, respectively, and 0.04 mg/L for *G. carolinensis*.

Lead has a number of toxic effects in amphibians (Power et al, 1989). Lead has been shown to bind to melanin present in amphibian skin. Toads with darker skin (more melanin) accumulated significantly more lead than toads with light colored skin (less melanin). Lead also inhibits hematopoietic tissues resulting in a reduction in the number of red and white blood cells, causes discoloration of the liver, and affects vision. Acute 96 hour LC_{50} for *G. carolinensis* has been reported as 0.04 mg/L.

Manganese alters the sodium permeability in membranes and may decrease metabolic rates (Power et al, 1989). *G. carolinensis* eggs exposed to manganese from fertilization to 4 days posthatch were reported to have a 96 hour LC_{50} of 1.42 mg/L.

Nickel has been shown to affect myelinated nerves by slowing down the kinetics of the potassium system (Power et al, 1989). Decreased metabolic rates in frogs located near metallurgic worksites have also been reported. An acute 96 hour LC_{50} of 0.05 mg/L has been reported for *G. carolinensis* exposed from fertilization to 4 days posthatch.

Selenium is an essential trace element, but can be toxic at higher concentrations (Power et al, 1989). Exposure of *Xenopus laevis* embryos to low concentrations of selenium had increased survival rates compared to controls not exposed to selenium. At increased concentrations of 2.0 mg/L and higher, decreased survival rates were observed. Survivors from the higher concentrations exhibited numerous abnormalities. [illegible] treated with selenium exhibited spine curvatures, tail flexures, and malformed heads. Tadpoles treated with selenium exhibited epithelial blisters, abdominal edema, degeneration of muscle cells, erratic swimming, and sluggishness. *G. carolinensis* eggs were much more sensitive to selenium than *X. laevis* with a 96 hour LC_{50} of 0.09 mg/L.

Zinc exerts its toxic effects on the nervous system and on epithelial cells (Power et al, 1989). Zinc slows the kinetics of the potassium system in myelinated nerves and alters sodium and potassium kinetics across cell membranes. *Bufo boreas* tadpoles were much more resistant to zinc than *G. carolinensis* eggs. Exposure of *B. boreas* to 0.1 mg/L for 61 days resulted in no mortality, whereas *G. carolinensis* had a 96 hour LC_{50} of 0.01 mg/L.

Plants. The ratio of manganese to iron affects the uptake and translocation of iron in a plant. Iron is translocated in greater concentrations from the root to the shoots and leaves as the concentration of manganese increases (Ghosh et al, 1987). However, with an excess of manganese, iron deficiency may occur in the protoplasm (Erkama, 1950).

Manganese can compete with iron for uptake and/or translocation causing iron deficiency and chlorosis in addition to its own toxicity (Hue et al, 1988). Also, the biological activity of iron can be affected by the concentration of manganese and of cobalt. Iron is reduced from Fe^{3+} to Fe^{2+}, the biologically active form. This reduction takes place in the roots as well as in the leaves (Poschentieder et al, 1991). A high manganese to iron ratio can inhibit the reduction of iron. Thus, it is possible to have high concentrations of iron in the leaves, yet the leaves can be chlorotic because the iron is biologically unavailable.

In all pairings of affected and nonaffected plant soil samples from OU 5 but one, SL19S12A and SL19S12N (that is, SL19 soil from 2 to 12 inches deep), the concentration of manganese was higher for affected plant soil samples than nonaffected plant soil samples. In all cases, the iron to manganese ratio was higher in the nonaffected plant soil samples than in the affected ones. The foliage analysis shows that in 9 out of 13 foliar analyses, affected plants had higher concentrations of manganese than did nonaffected plants.

Cobalt also can affect the biological activity of iron. Cobalt competes with iron, and as the concentration of cobalt increases, the concentration of iron in chlorophyll decreases (Blaylock et al, 1985). Looking at the relationship of cobalt in affected and nonaffected plant soil samples, there is a slight trend of higher concentrations of cobalt in affected plant soil samples than in nonaffected soil samples. However, this trend is so slight that it probably is not significant.

The chlorosis appears to be due to iron deficiency and may be caused by competition from other metals, possibly manganese. Toxicity from other metals such as manganese may be working in combination with iron deficiency. Iron levels can be similar in affected and nonaffected plants because of the ratio of biologically active to biologically nonactive iron.

A summary of relevant information regarding bioaccumulation of metals in common species present or representative of vegetation at Elmendorf AFB is presented in

Table 6-38. Where data for a plant's response to multiple elements of concern are available, the data are presented by species. Where a range of doses and responses were reported, the minimum and maximum doses and responses are reported. In most cases, the response generally varies in proportion to the applied dosage.

In general, plants exposed to elevated concentrations of metals in soils will take up some fraction of the metals into stem and leaf tissues. In fireweed, willow and horsetail, about half of the applied cadmium dose was taken up by the plant. When horsetail was exposed to low doses of cadmium, there seemed to be some biomagnification, while about half of a high dosage was retained. In contrast, the grasses *Agropogon* and *Avena* appear to accumulate levels greater than the metal concentrations of the soils at low levels, but take up much lower fractions of the soil concentrations when exposed to high doses.

Grasses exposed to manganese in the soil appear to readily take up or even biomagnify this element when exposed to moderate or high levels. In general, both copper and lead do not appear to accumulate readily in stems and leaves when plants are exposed to moderate or high levels of soil concentrations.

6.2.2.4 Risk Characterization

Risks of adverse effects were characterized by comparing maximum observed concentrations of the selected contaminants of ecological concern (Table 6-36) to assessment levels that were judged most appropriate. The assessment levels included ecological effects concentrations, background concentrations, or interim remediation criteria that were presented in Section 6.2.2.1. The ecological quotients along with the ecological endpoints and assessment criteria are presented in Table 6-39.

The ecological quotients for PAHs in soils (302), estimated gasoline vapors in soils (291), estimated diesel vapors in soils (11.9), boron in soils (18.6), and manganese in soils (10.5) were highest, meaning that they may represent the greatest risks to ecological

Table 6-38

UTAB Database Information on Bioaccumulation of Heavy Metals by Plants

Common Name	Scientific Name	Element	Dose (mg/kg)	Uptake (mg/kg, dry weight)
Fireweed	*Epilobium angustifolium*	Cadmium	0.270	0.140
Willow	*Salix cinerea*	Cadmium	0.230	0.170
Horsetail	*Equisetum arvense*	Cadmium	0.08 6.9-15.4 543	0.170 1-2.6 259
Wheatgrass	*Agropogon* sp.	Cadmium Lead Manganese	0.2 0.5 10	0.6 0.9 26
	Agrostis capillaris	Cadmium Lead	2.3 420	1.2 97
Bent-grass	*Agrostis stolonifera*	Cadmium Copper	0.8 15	0.63 10.9
	Agrostis tenuis	Copper Cadmium	40 25-250	5 15-140
Wild Oat	*Avena* sp.	Cadmium	0.01-.13 5.9-15	0.09-0.22 0.38-2.0
Smooth Brome	*Bromus inermis*	Cadmium Copper Lead Manganese	0.08 1.2 0.6 8.9	0.03 1.0 0.7 51
Bermuda Grass	*Cynodon dactylon*	Cadmium Copper Lead Manganese	3.28-8.96 12-106 98-194 225-632	7.89-27.81 9.41-78.28 21-41 55-144
Perennial Ryegrass	*Lolium perenne*	Cadmium Copper Lead	11.3-27.5 72-195 290	4.2-6.5 13-41 8
	Poa annua	Cadmium Copper Lead	2.3 750 420	1.1 41 31
	Poa pratensis	Cadmium Copper	1.0 6.0	2.23 11.3

Source: Uptake/accumulation, translocation, adhesion, and biotransformation (UTAB) database, University of Oklahoma (1992)

Table 6-39

Ecological Quotients Comparing Observed Contaminant Concentrations in OU 5 to Assessment Levels[a]

Chemical	Medium (units)	Concentrations		Quotient[b]	Ecological Receptor	Assessment Endpoint
		Observed	Assessment			
PAHs	Soil (mg/kg)	5,050	0.0167	302	Mammals	LOAEL[c]
Gasoline	Soil gas (mg/m³)	472,000[e]	1,619	291	Mammals	Chronic, sublethal effects
Diesel	Soil gas (mg/m³)	1,780[e]	150	11.9	Mammals	Chronic, sublethal effects
Arsenic	Soil (mg/kg)	28	20	1.4	Vegetation	Adverse effects/ accumulation
Barium	Soil (mg/kg)	3,650	750	4.9	Vegetation	Adverse effects/ accumulation
Boron	Soil (mg/kg)	37.2	2	18.6	Vegetation	Adverse effects/ accumulation
Cadmium	Soil (mg/kg)	3.1	3.0	1.0	Vegetation	Adverse effects/ accumulation
Calcium	Soil (mg/kg)	35,300	8,881	4.0	None	Background level
Copper	Soil (mg/kg)	38	32	1.2	None	Background level
Lead	Soil (mg/kg)	87	13	6.7	None	Background level
Manganese	Soil (mg/kg)	10,700[d]	1,016	10.5	None	background level
Molybdenum	Soil (mg/kg)	24.8	5	5.0	Vegetation	Adverse effects/ accumulation
Selenium	Soil (mg/kg)	3.1	2.0	1.6	Vegetation	Adverse effects/ accumulation
Silver	Soil (mg/kg)	22.0	20	1.1	Vegetation	Adverse effects/ accumulation
Sodium	Soil (mg/kg)	1,430	498	2.9	None	Background level
Cadmium	Plant tissues (mg/kg)	0.58	0.5	1.2	Herbivores	Tolerable dietary level
Cobalt	Plant tissues (mg/kg)	6.9	5	1.4	Vegetation	Tolerable tissue level

Table 6-39

(Continued)

Chemical	Medium (units)	Concentrations		Quotient[b]	Ecological Receptor	Assessment Endpoint
		Observed	Assessment			
Iron	Plant tissues (mg/kg)	1,370	500	2.7	Herbivores	Tolerable dietary level
Lead	Plant tissues (mg/kg)	48	30	1.6	Vegetation	Excessive/toxic tissue level
Manganese	Plant tissues (mg/kg)	484	300	1.6	Vegetation	Tolerable tissue level

[a] Including ecological effects concentrations, background concentrations, or interim remediation criteria, as judged most appropriate; see earlier text and tables in Section 6.2.2.

[b] Calculated as observed concentration divided by assessment concentration.

[c] Maximum estimated value.

[d] Excluding a value of 199,000 mg/kg in 2-inch to 12-inch soil where the 12-inch to 24-inch depth sample contained 7,860 mg/kg manganese.

[e] Lowest observed adverse effect level.

receptors. However, the area contaminated with PAHs appears to be small, seemingly limited to the vicinity of SB29, a soil boring location near SL05. Fuel hydrocarbons are more widely distributed and present risks to terrestrial animals through inhalation exposures in animal burrows, contamination of bottom sediments in the golf course beaver pond (and perhaps elsewhere), and formation of surface sheens at seeps, wetlands, and the golf course beaver pond. These sheens may affect semiaquatic mammals, birds, and frogs using the pond. Those animals could be affected directly by contacting the oil, and bird egg hatching success may be reduced by transfer of oil on the birds' feathers from the pond surface to shells of eggs being incubated. However, it is unknown whether fuel hydrocarbons caused reproductive impairment of ducks, gulls, and sandpipers because eggshells were not visibly contaminated.

It is also unknown whether the scarcity of aquatic vegetation in the golf course beaver pond (compared to others such as the one at SL29) is caused by fuel hydrocarbon contamination of sediment in the pond.

The elevated soil manganese concentrations seem to be the most likely cause of plant stress observed at various OU 5 locations.

Ecological quotients in the range between 5 and 10 included lead and molybdenum in soils from the plant stress sampling sites (Table 6-39). Other ecological quotients for contaminants of concern were between 1 and 5. Contaminants with quotients below 1 were not considered to be of ecological concern and are not listed in the table.

6.2.2.5 Conclusions and Limitations

General habitat conditions in areas surveyed during the qualitative surveys in 1992 are similar to those described in earlier studies. These studies included ecological surveys by Rothe et al (1983), and observations of fuel hydrocarbon contamination in areas below the bluff (summarized in Section 1 of this report). These conclusions are limited by the level of detail with which the general habitat conditions were surveyed. This ecological risk assessment is being conducted using a phased approach, as described in the Site Management Plan (CH2M Hill, 1992d). The intent was to determine whether ecological risk can be characterized at the end of one field season on the basis of qualitative surveys and limited ecological sampling.

There was evidence of impaired ecosystem health, as shown by plant stress and possibly by reduced egg hatching success in semi-aquatic birds that nested in the vicinity of several surface water bodies. Causes of the plant stress could not be identified definitively, but they appeared to be some factor other than fuel hydrocarbons. The most likely cause seemed to be mineral imbalances related to elevated manganese, and potentially cobalt, phosphorus, and pH in areas where plants showed signs of stress. The plants exhibited symptoms of iron deficiency (interveinal chlorosis), although they contained high concentrations of iron. Detailed biochemical analyses and bioassays were not performed, so the conclusions are limited to general associations of observed effects that are similar to effects described in the literature. Bird nests were marked when they were found during general surveys near the wetlands/surface water bodies. The number of nests was not adequate to determine causes of nesting failure, but the surveys accomplished their intended purpose (to characterize ecological receptors in OU 5 and screen for possible ecological effects).

The risk characterization indicated that the most likely impacts of contaminants on terrestrial ecological receptors in OU 5 would be caused by (1) inhalation exposure of small mammals to fuel hydrocarbon vapors when the animals were in their burrows, (2) dermal contact/absorption of fuel hydrocarbons by semiaquatic mammals, birds, and wood frogs in the golf course beaver pond (or elsewhere when surface sheens are present), and (3) metabolic uptake/inhibition effects of inorganics by plants near seeps and wetlands where plants exhibited signs of stress. Limitations of these conclusions are that (1) soil vapor concentrations were not always measured or estimated within the top foot of soil where small mammal burrows occur (concentrations were estimated from soils or groundwater, sometimes at depths of a few feet, but the shallow soils from plant stress areas [Tables 4-20, 6-29, and 6-30] were well above the effects levels for mammals), (2) although surface sheens of fuel hydrocarbons were observed on the beaver pond, animals were not seen in direct contact with the sheens and soiling of eggshells was not observed, and (3) the analyses of soils and stressed plants were conduced as an exploratory survey and the data are not adequate to reach definitive conclusions about the causes of stress.

A seemingly small area having a high concentration of PAHs was found through sampling in the lower bluff area (SB29, near SL05). The areal extent of this contamination is not known and the composition of the PAHs is not known.

Comparing observations during the terrestrial ecological survey and conclusions of the risk characterization to ARARs indicates that federal water quality criteria and Alaska WQS for fuel hydrocarbons are not being met in the golf course beaver pond.

Small resident predatory mammals, such as shrews, could be exposed to elevated dietary levels of some inorganic elements, such as lead, that may bioaccumulate in their prey. However, the risks associated with that exposure pathway could not be determined because dietary composition and contaminant concentrations in prey were not measured. Available data were also considered inadequate for modeling this exposure.

Potential effects of animals' exposure to multiple contaminants or to various contaminants through more than one exposure pathway were not assessed because of data limitations. These effects were evaluated, however, for inorganics in relation to plants, as described in earlier parts of this section. Multiple exposures for animals could be of concern if potential interactive effects are identified for contaminants of ecological concern.

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7.0 REMEDIAL INVESTIGATION SUMMARY AND RECOMMENDATIONS

The results of the remedial investigation (RI) of Operable Unit (OU) 5 indicate areas of soil, sediment, groundwater, and surface water contamination. To determine which media and which contaminants need to be remediated, the RI results were compared to potential Applicable or Relevant and Appropriate Requirements (ARARs), human health risks posed by the contaminants, and ecological risks. The comparison with these three criteria determined:

- Which contaminants exceeded the criteria. These became the contaminants of concern (COCs).
- The concentrations of the COCs that may require remediation.
- Which media may require remediation.
- The migration pathways affected.

These four factors — COCs, concentrations, media, and migration pathways — in turn form the basis of the Feasibility Study (FS). The most important factors are the identification of COCs and the concentrations of COCs that may require remediation. In this report, the concentrations above which COCs must be remediated are referred to as interim remediation goals, because, while they are based on regulatory requirements and site data, they are not the negotiated clean-up levels for OU 5.

The following focused studies were performed after the RI was completed:

- A polychlorinated biphenyls (PCBs) study in the snowmelt pond;
- A stream gaging effort in Ship Creek; and
- A natural attenuation study at the Beaver Pond.

The findings of these studies are presented in this section. The results were considered in the identification of media and compounds to be addressed in the FS.

The interim remediation goals, the comparison of RI results to those goals, and recommendations for areas that need no further action or that will be evaluated in the FS, are described below.

7.1 Interim Remediation Goals

The interim remediation goals for OU 5, presented in Table 7-1, form the basis for summarizing the RI results and identifying areas, media, and contaminants that are addressed in the FS. These goals set action levels based on three criteria types:

- Potential Applicable or Relevant and Appropriate Requirements (ARARs) — These are specific federal and state contaminant-specific action levels that are found in laws and regulations. They also include related guidance documents (i.e., "To Be Considered" [TBC]), which are established by regulatory agencies but are not found in regulations. A detailed presentation of potential ARARs is found in Appendix N, Potential ARARs Identification.
- Human Health Risk — This criterion is based on a site-specific health risk assessment (HRA) which measures carcinogenic and noncarcinogenic risk, following United States Environmental Protection Agency (U.S. EPA) guidelines.
- Ecological Risks — These are risks or potential impacts to ecological receptors that are not covered by specific ARARs or the HRA.

Any of the criteria may be the basis for identifying a specific geographical area, medium, and/or COC for further study in the FS. Contaminated areas that are not identified as areas of concern according to the above criteria and the RI results can be pursued as "no further action" sites. These goals are described as "interim" because they are solely for the purpose of designating areas in OU 5 that might reasonably require remediation. Per Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) guidance,

Table 7-1

Interim Remediation Goals

Medium	Potential Contaminant of Concern	Interim Remediation Goal		Rationale/Comments
		Goal	Reference	
Soil (includes sediments)	TFH - diesel	200 mg/kg	ACM	The ACM, a TBC, specifies a procedure to calculate these goals on a site-specific basis. For all areas of concern at OU 5, the indicated goals were calculated.
	TFH - gasoline	100 mg/kg	ACM	
	Benzene	0.5 mg/kg	ACM	
	BTEX	15 mg/kg	ACM	
	All potential COCs (i.e., PCBs, PAHs, TFHs, VOCs, and inorganics [except arsenic]) at a specific location	Total carcinogenic risk of 1 x 10^{-6}	EPA Risk Assessment Guidelines for Superfund	Upper value of 1 x 10^{-4} to 1 x 10^{-6} EPA acceptable carcinogenic risk range.
		Total noncarcinogenic Hazard Index of 1	EPA Risk Assessment Guidelines for Superfund	EPA acceptable noncarcinogenic risk value
	PCBs	1,900 µg/kg (if TOC equals 10%) 190 µg/kg (if TOC equals 1%)	PCB SQCs	EPA recommends that SQCs be considered in establishing remediation goals for sediments. The goal is proportional to the TOC concentration as indicated.
	Arsenic	9–13 mg/kg	Average surface soil background levels at EAFB	Arsenic can result in a high level of risk, even at background levels. Remediation to below background levels is unreasonable; therefore, arsenic would only be a COC if background levels are exceeded.

Table 7-1

(Continued)

Medium	Potential Contaminant of Concern	Interim Remediation Goal		Rationale/Comments
		Goal	Reference	
Water (surface and groundwater)	Benzene	5 µg/L	MCLs (federal and Alaska)	MCLs are enforceable ARARs under the Safe Drinking Water Act.
	TCE	5 µg/L		
	Toluene	1,000 µg/L		
	bis(2-Ethyl hexyl-phthalate)	6 µg/L		
	Ethyl benzene	700 µg/L		
	Xylenes (total)	10,000 µg/L		
	Copper	1,300 µg/L		
	Arsenic	50 µg/L		
	Lead	15 µg/L		
	Total hydrocarbons	10 µg/L	ASWQ standards	ASWQ states that level is lesser of 10 µg/L or 0.01 times the lowest measured 96 hour LC50 for most sensitive species at the particular location. Level is 15 µg/L for species not designated by the state as "most sensitive." 10 µg/L is selected as the conservative value.
	Hydrocarbons, oil, and grease	Not cause visible sheens or discoloration	ASWQ standards	Sheens must be from COCs and not natural sources.
	All potential COCs (i.e., PCBs, PAHs, TFHs, VOCs, and inorganics [except arsenic]) at a specific location	Total carcinogenic risk of < 1 x 10^{-6}	EPA Risk Assessment Guidelines for Superfund	Upper value of 1 x 10^{-4} to 1 x 10^{-6} EPA acceptable carcinogenic risk range.

Table 7-1

(Continued)

Medium	Potential Contaminant of Concern	Interim Remediation Goal		Rationale/Comments
		Goal	Reference	
Water (cont.)		Total noncarcinogenic Hazard Index of < 1	EPA Risk Assessment Guidelines for Superfund	EPA acceptable noncarcinogenic risk range
	PCBs	0.014 μg/L	NAWQC	This goal is more conservative than the MCLs.

TPH = Total fuel hydrocarbons
ACM = Alaska Cleanup Matrix for non-UST soils
ASWQ = Alaska Surface Water Quality Standards
MCL = Maximum concentration level
TBC = To be considered
COC = Contaminant of concern
TCE = Trichloroethylene
PAH = Polycyclic aromatic hydrocarbons
VOC = Volatile organic compounds
PCE = Tetrachloroethylene
BTEX = Sum of benzene, toluene, ethylbenzene and xylene
PCB = Polychlorinated biphenyls
NAWQC = National Ambient Water Quality Criteria
SQC = Sediment Quality Criteria
TOC = Total organic carbon

final remediation goals should be based on both ARARs and risk, and are negotiated between the facility and the agencies on a site-specific basis.

7.2 General Conceptual Model for OU 5

The conceptual model identifies the contaminant migration pathways in OU 5. Identification of pathways provides a basis for evaluating the potential for exposure of human and ecological receptors to contaminants detected in the OU. The model is used to identify areas addressed in the FS. Figure 7-1 shows a schematic of the migration routes of contaminants toward receptors. Routes of migration include runoff, seeps, and groundwater flow.

Current land use within Elmendorf AFB, but downgradient of the pipeline sources, includes industrial and recreational use. The downgradient area also serves as a major access route to Elmendorf AFB. Land use between Elmendorf AFB and lower Ship Creek includes railroad, industrial, and fisheries activities. Water use varies by the source of the water. Only the lower groundwater aquifer is used as a source of drinking water. Recreational users may come in contact with the surface water. Surface water from Ship Creek is used for irrigation of the golf course, for cooling water at the power plant, and for hatchery operations. Ecological receptors include terrestrial and aquatic communities.

Operable Unit 5 covers an area over 7,000 feet long and over 1,200 feet wide. The OU is geographically diverse, ranging from a steep bluff to a broad flat area in the western part of the OU to a more gently sloping bluff leading to wetland areas in the eastern part of OU 5. The central part of the OU is a transitional area with a bluff and some surface water features. (The snowmelt pond and a fish hatchery are located in this area.) The Installation Restoration Program (IRP) sites located within OU 5 can be roughly grouped into western, central, and eastern areas. Because of the geographic setting and grouping of sites, the conceptual site model of OU 5 has been divided into these three geographical areas, shown in Figure 7-2.

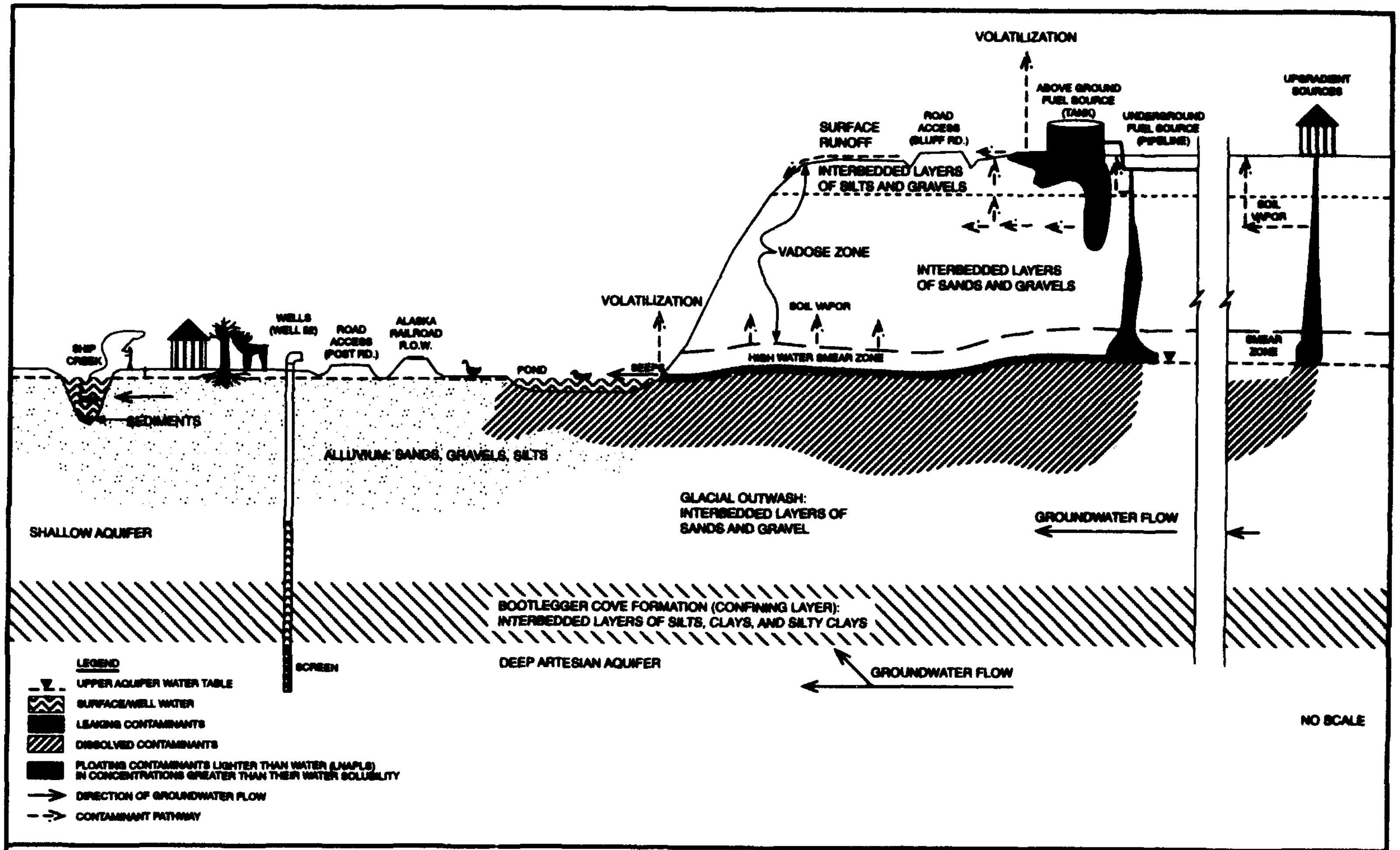


Figure 7-1. Conceptual Model Illustration
Elmendorf AFB, Anchorage, Alaska

ELMF71.FH9 - VMS 10/6/95 SAC

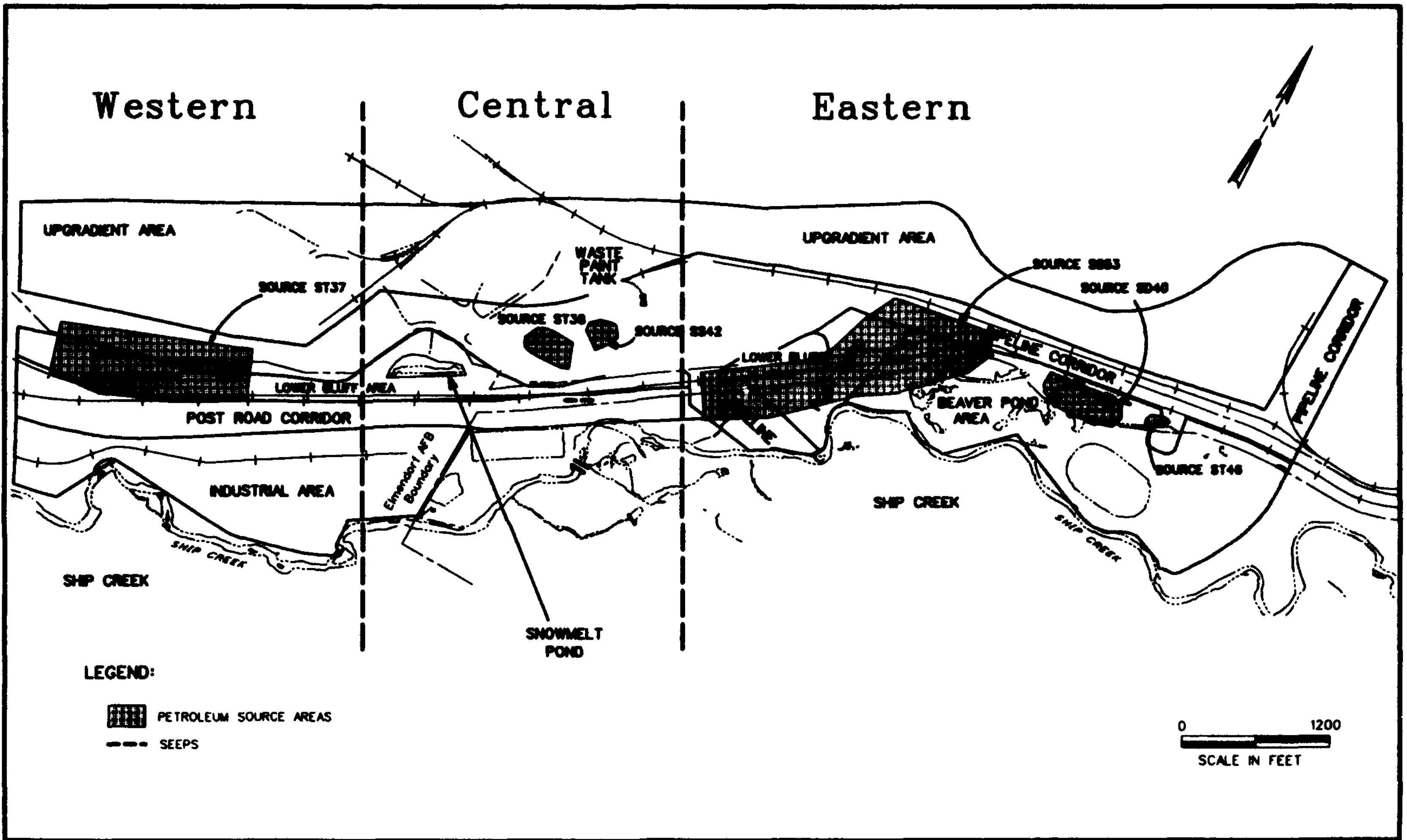


Figure 7-2. Source Areas and Geographic Subdivisions of OU 5

ELMS OU5SNO VRL SAC

The most likely sources of contamination appear to be three fuel pipelines and the associated fuel distribution system located at the top of the bluff. This system includes storage tanks, valve pits, truck filling stands, and abandoned and active fuel lines. Subsurface leaks in the fuel lines and surface spills were reported in the past at ST37, ST38, SS42, ST46, and SS53. Pipelines have been repaired, and there are currently no known leaks in OU 5. A railroad maintenance operation at SD 40 was considered a potential source of contamination. The operation was never verified, and no contamination can be attributed to activities at the location.

Potential sources in other OUs include sanitary landfills (OU 1), fire training areas (OU 4), a solvent disposal trench (OU 3), and fuel pipeline and underground storage tanks managed under the state environmental program that could be affecting groundwater and surface water quality within OU 5.

The organic contaminants of concern in soil at OU 5 include fuels (total fuel hydrocarbon in the diesel range [TFH diesel], TFH gasoline, and JP-4 jet fuel), and benzene, toluene, ethylbenzenes, and xylenes (BTEX). The organic contaminants of concern in groundwater, surface water, and sediments include fuels, BTEX, and chlorinated solvents (VOCs). Polychlorinated biphenyls were detected in five sediment samples within the snowmelt pond. More detailed discussion of the results is provided in Section 7.6.

Hydrogeology is generally consistent throughout OU 5. Interbedded sand, gravel, and minor silt layers, deposited in a glacial outwash plain, comprise the vadose zone and upper unconfined aquifer beneath OU 5. Three fuel pipelines along the southern boundary of OU 5 parallel the top of a bluff formed by the erosion of the outwash plain deposits by the action of Ship Creek. At the base of the bluff is the Ship Creek floodplain, containing shallow ponds and the wetlands that are maintained by snowmelt runoff and groundwater seepage from the bluff. Since the 1950s, occasional releases of fuel from the pipeline have resulted in seeps of hydrocarbons from the bluff that prompted cleanups, environmental investigations, and repairs of the pipelines.

At the base of the upper aquifer is the Bootlegger Cove Formation, consisting of 50 to 200 feet of silt and clay layers that separate the upper and lower aquifers. Because the formation acts as a confining layer, groundwater in the upper aquifer flows laterally to the south beneath the pipelines. Groundwater from much of Elmendorf AFB flows beneath OU 5 before reaching Ship Creek.

7.2.1 Groundwater/Seep Interaction

Some of the contaminants migrating in groundwater are discharged in seeps along the bluff in OU 5. Groundwater flows in the upper aquifer southward from OUs 2, 3, and 4 toward OU 5 (Figure 7-3). The water table and capillary fringe of the upper aquifer beneath OUs 2, 3, 4, and the northern portion of OU 5 are at a higher elevation than the toe of the bluff, the wetlands, and Ship Creek. Therefore, the southerly flowing groundwater can approach and seep from the bluff face or toe. The volume of seepage is likely to be greater when the water table is higher as a result of increased water infiltration from snowmelt or rain. Groundwater discharged from the seeps flows into ponds, wetlands, and drainage ditches.

Contaminants entering groundwater from surface sources in OU 5 or upgradient operable units are likely to be attenuated by natural processes. Biodegradation, advection, dispersion, dilution, and volatilization may occur as contaminants are transported through OU 5. Advection and dispersion are mechanical processes that reduce the concentration of contaminants as groundwater flows. Dilution that also reduces contaminant concentrations may occur as uncontaminated surface water infiltrates the upper aquifer. Biodegradation of fuel hydrocarbons occurs where contaminated groundwater contacts sufficient air to support aerobic bacterial activity, such as the upper groundwater surface, at seeps or in surface ponds. Halogenated VOCs may be undergoing degradation by anaerobic bacteria below the surface of the upper aquifer or in the bottoms of surface ponds, where oxygen content is reduced. The BTEX and halogenated VOCs are released to the atmosphere from groundwater at surface seeps and at the surface of ponds fed by contaminated groundwater.

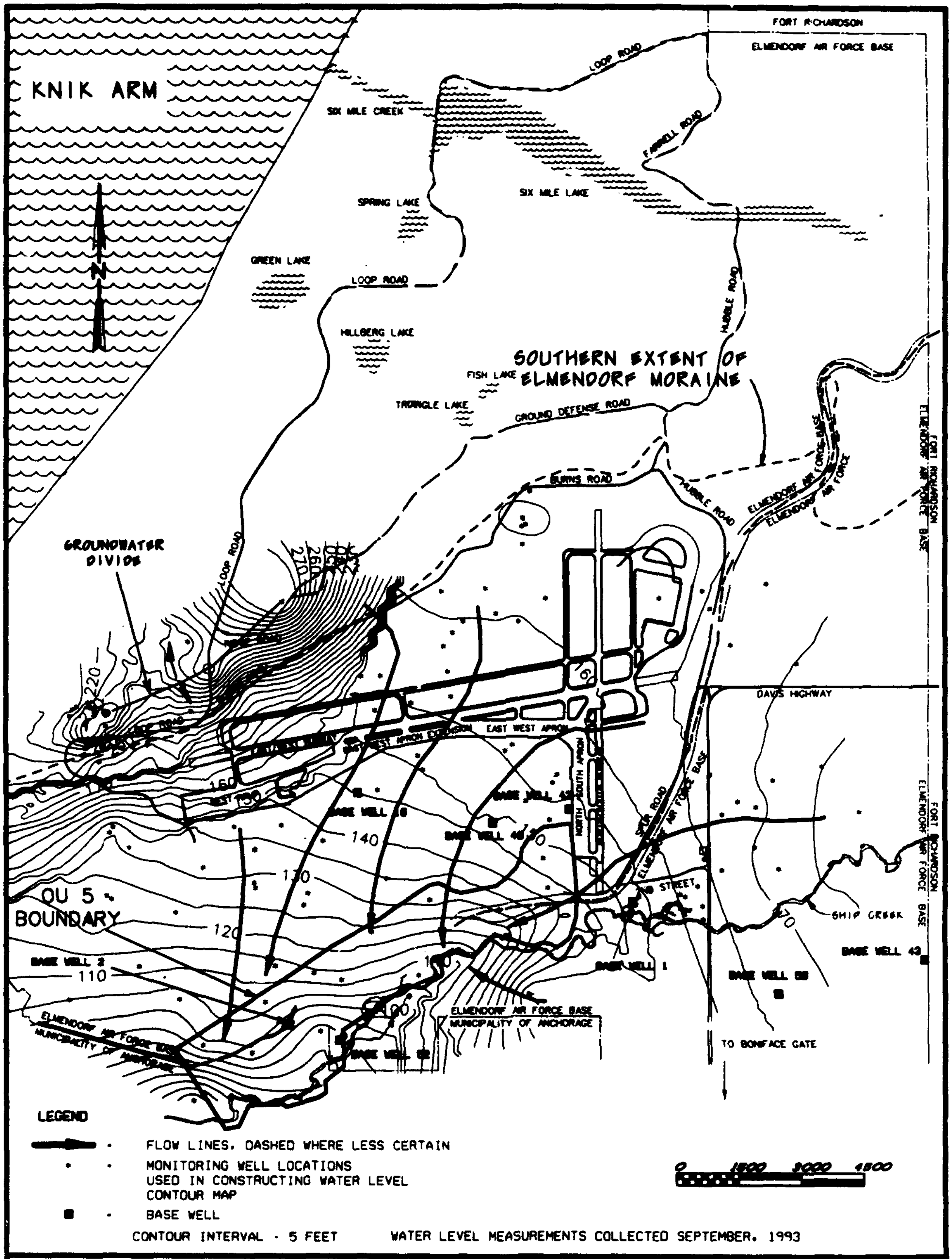


Figure 7-3. Water Level Contour Map with Flow Lines

ELM4 WTRLEV93 SAC

7.2.2 Groundwater/Ship Creek Interaction (Stream Gaging Results)

To determine the hydrologic interaction between groundwater and Ship Creek, flow in the creek was determined from stream gaging measurements collected between 30 March and 15 September 1993. Four gaging stations (Figure 7-4) — three in OU 5 and one upstream from OU 5 — were used for measuring total flow, Q. Flow data are summarized in Table 7-2. Results of the gaging indicate that Ship Creek, which parallels the long axis of OU 5, gains water along its course when creek flow at the first gaging station is less than approximately 300 cubic feet per second (cfs). This condition is expected to exist most of the year. Stream flow has not been gaged in the fall and winter, but these seasons are generally low flow months because of the lower temperatures. (Water is stored as snow pack and ice.) When creek flow is greater than approximately 300 cfs at the first gaging station, the creek loses water along the same course. Figure 7-4 approximates the differences in flow into and out of the creek channel that occurred from March through September 1993.

The stream gaging data for low-discharge months (March, April, May, July, and projected fall and winter months) indicate that groundwater from OU 5 contributes to Ship Creek during much of the year. Groundwater flowing toward Ship Creek that does not contribute to creek flow will contribute to underflow. Ship Creek underflow migrates downstream in the upper aquifer beneath the base of the creek channel.

The complex relationship between the creek flow, groundwater discharged as underflow from OU 5, and groundwater discharge entering the creek from the south side of Ship Creek make accurate estimates of the percentage contribution from each source difficult with available data. An additional deterrent to accurate estimates is that gaging station 4 is in central part of OU 5, and there are no flow estimates available downstream from that point. However, the effects of the groundwater/surface water interactions on contaminant concentrations can be qualitatively evaluated.

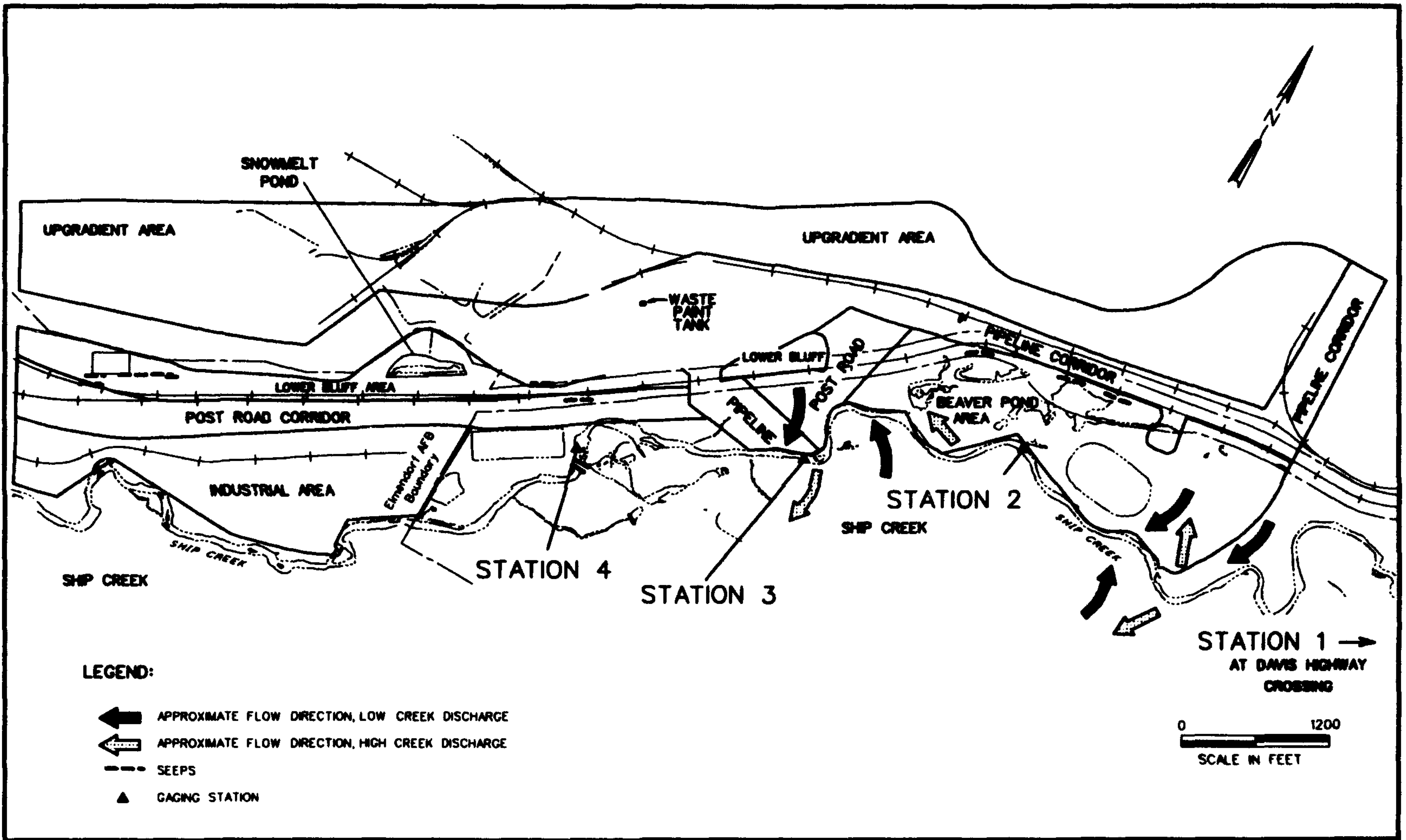


Figure 7-4. Ship Creek Gaging Stations and Flow Interactions with Groundwater in OU 5

ELM5 OUSFLOW VRL SAC

Table 7-2

Ship Creek Flow, Q, in OU 5 from Stream Gaging, March through September 1993

Sampling Date	Station 1 Mile 4.9	Station 2 Mile 3.6		Station 3 Mile 3.1		Station 4 Mile 2.2	
	Q (cfs)[a]	Q (cfs)	Gain[b] (cfs)	Q (cfs)	Gain[b] (cfs)	Q (cfs)	Gain[b] (cfs)
3/30/93	0.24	11.2	11	15.7	4.5	17.6	1.9
4/18/93	23.7	39.8	16.1	43.3	3.5	44.8	1.5
5/11/93	95.2	<136[c]	<40.8[c]	126	-10[c]	129	3.0
6/19/93	471	448	-23	439	-9	353[d]	-86[d]
6/26/93	329	320	-9	298	-22	NM	—
7/26/93	99.5	123	23.5	135	12	87.5[d]	—
8/15/93	132	152	20	155	3.0	160	5.0
9/15/93	198	219	21	218	-1.0	223	5.0

NM = Not measured
[a] cfs = Cubic feet per second
[b] Positive values indicate Ship Creek gained flow between upstream station and this station; negative values indicate a loss of flow between stations.
[c] Station 2 measurement suspect (too high). Gain calculations potentially affected.
[d] Station 4 measurement may reflect upstream diversion of flow through beaver pond. Gain calculation affected.

The Ship Creek channel and groundwater underflow comprise a mixing zone. Groundwater that flows through OU 5, groundwater flowing from the south (northern part of Anchorage), and Ship Creek combine in the mixing zone adjacent to OU 5. As the waters mix, any contaminants that have not previously been naturally attenuated are also mixed. Contaminant concentrations are reduced in the mixing zone through surface and subsurface advection, dispersion, and dilution. Groundwater leaving OU 5 in Ship Creek or as underflow would have significantly lower concentrations than found in groundwater in OU 5.

Presented below is a summary of the RI findings discussed by geographic area of OU 5 (western, central, and eastern areas). Specific results and details are provided in the previous sections of this RI/FS report.

7.3 Western OU 5

The Western Area of OU 5 includes the Corps of Engineers building, the north source area (ST37), and the industrial area north of Ship Creek.

7.3.1 Conceptual Site Model

A plan view of the western area of OU 5 showing the sampling locations and the approximate extent of contamination in soils and groundwater is shown on Figure 7-5. The schematic cross section in Figure 7-6 illustrates the conceptual migration path of fuel hydrocarbons from pipelines near the top of the bluff, through the vadose zone toward water table (as measured in October 1992). Contaminated soil zones lying above the water table probably represent a "smear zone" of contamination resulting from fuel that migrated to a higher water table and were left in the vadose zone or capillary fringe as the water table receded. The smearing of hydrocarbons may occur between seasons as the water table rises and falls. Hydrocarbons have migrated to surface soil along the bluff face via seep discharges. Hydrocarbon odors and surface sheens in bluff seeps are evidence of this method of migration. Data to characterize the air pathways were not collected.

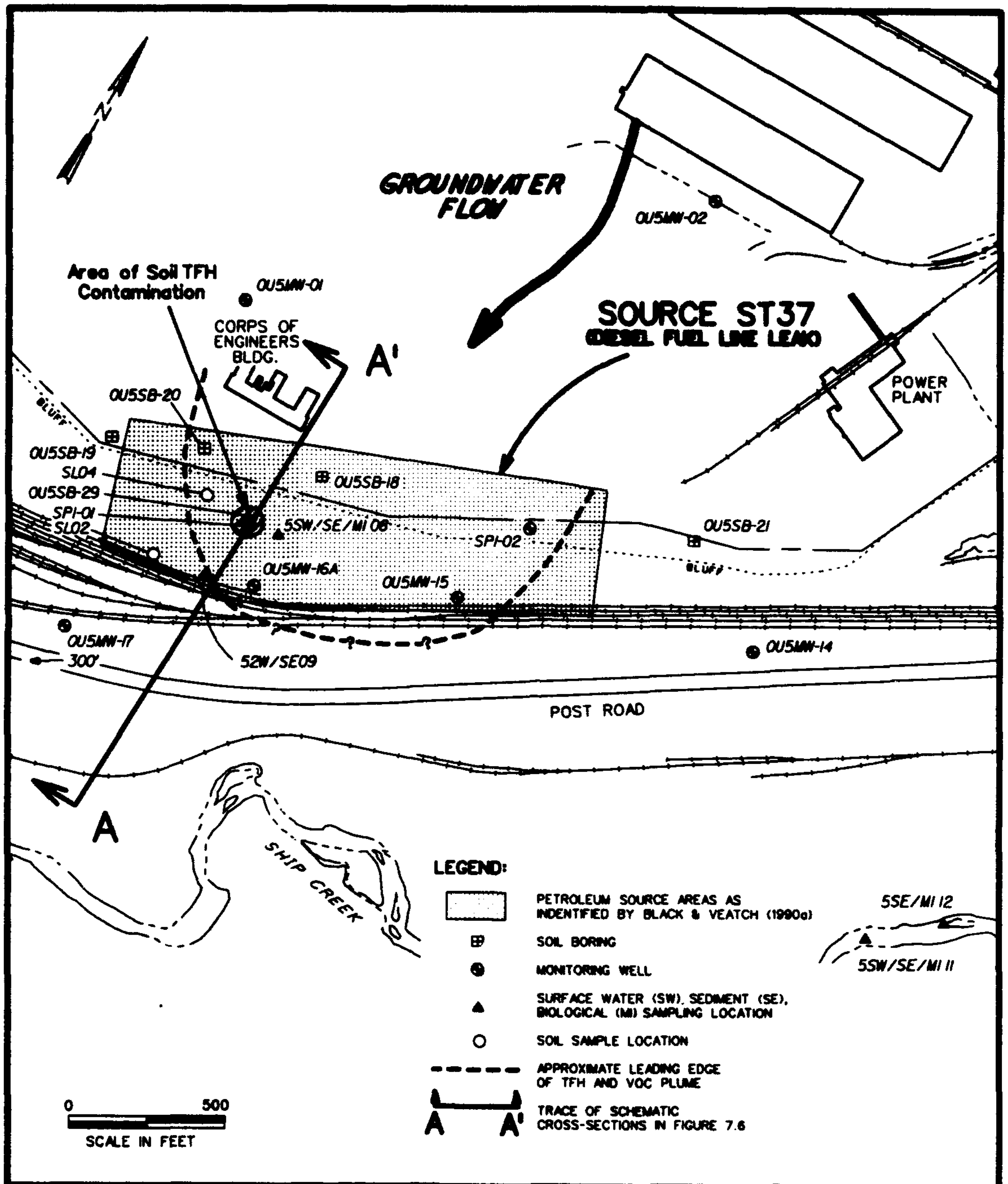
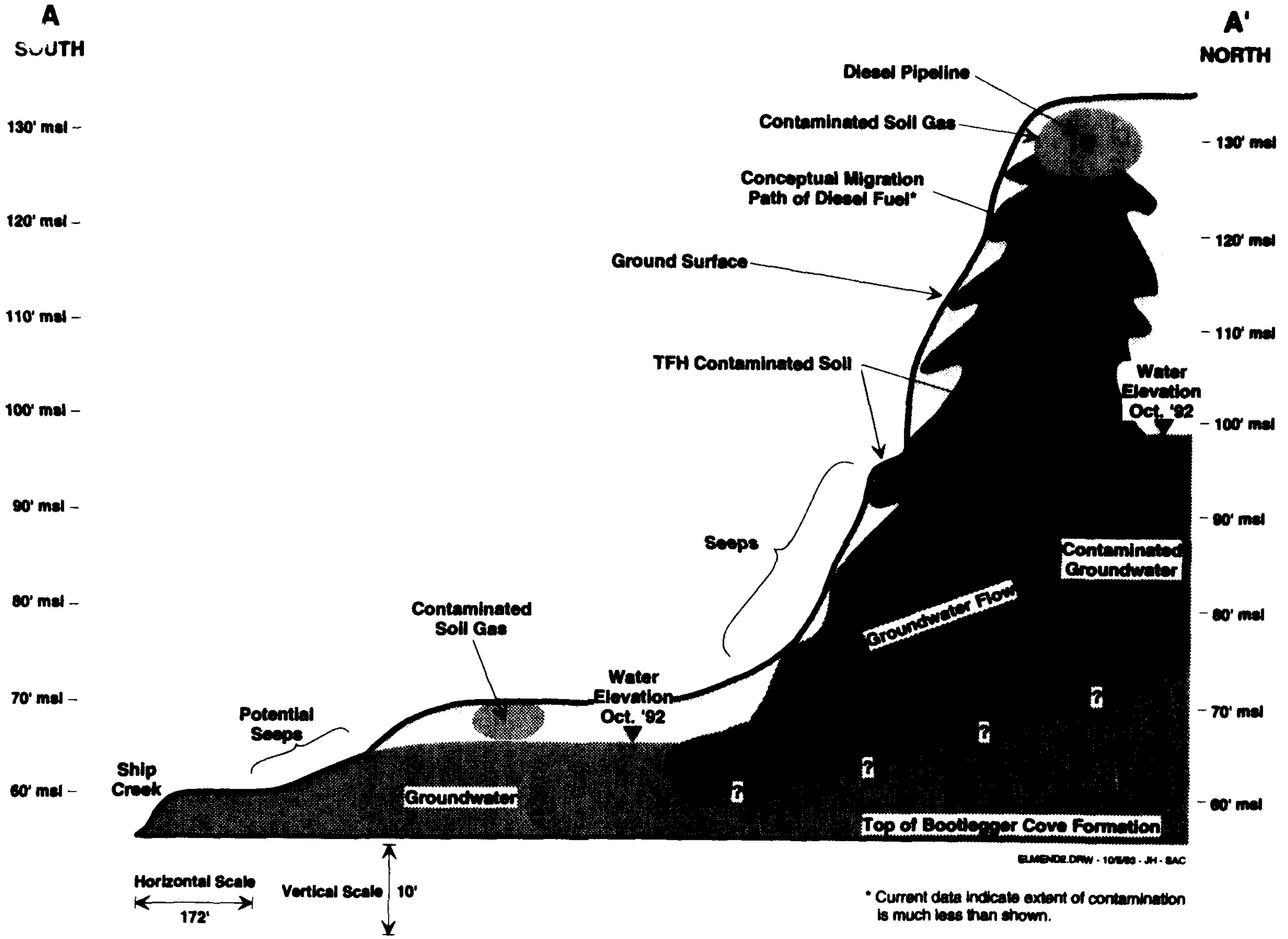


Figure 7-5. Sampling Locations and Contaminant Distribution in Western OU5

ELM4 OU5A4 VRL SAC 11/03/93



* Current data indicate extent of contamination is much less than shown.

Figure 7-6. Conceptual Site Model - Schematic Cross Section A-A', Western OU 5

7.3.2 Soil

Fuel hydrocarbons, JP-4, gasoline, and diesel fuel were detected at concentrations from 6.1 to 1,160 mg/kg from surface to a depth of 37 feet at locations SL04, SB18, and SB29. Diesel fuel (151 mg/kg) was detected in soils near the surface (0 to 2 feet) at SL04. The greatest concentrations of gasoline range (168 mg/kg) and diesel range (1,160 mg/kg) were detected at 10 to 12 feet below surface in SB29. The deepest fuel hydrocarbon-contaminated samples were collected from the saturated zone in SB18, indicating that the contaminants either migrated to groundwater at this location or at a location further north, in the upgradient direction of groundwater flow.

7.3.3 Surface Water and Sediments

Fuel hydrocarbons (JP-4 [0.8 mg/L] and gasoline [0.3 mg/L]), BTEX (0.001 - 0.27 mg/L), and 1,1-dichloroethane (0.002 mg/L) were detected in water sample SW08 from a puddle that is fed by groundwater seeps on the face of the bluff. The puddle formed in depressions on the bluff face by slope failure. Contaminants may have reached the puddle through the vadose zone soil, surface water runoff, or groundwater seepage.

Water sample SW09 from a ditch, downslope from the puddle, had a detectable concentration of 1,1,1-trichloroethane (0.0018 mg/L), a VOC not detected in the puddle or in groundwater within Western OU 5; its source is unknown.

7.3.4 Groundwater

Concentrations of TCE (5.2 to 33 μg/L) were detected in groundwater samples collected from MW01, MW02, and SP1-02 on the bluff in the Western Area of OU 5. In wells SP1-01, MW15, and MW16A on and below the bluff face, TCE was not detected, but fuel hydrocarbons, benzene, toluene, xylenes, and naphthalene were. Groundwater flow directions in October 1992 indicate that the contamination would migrate toward the south.

The downgradient (southern) extent of groundwater contamination that exceeds 1×10^{-6} cancer risk is estimated in Figure 7-5.

The Bootlegger Cove Formation, at the base of the upper aquifer (approximately 20 to 50 feet below surface in Western OU 5), consists of fine-grained deposits (clays and silts) of low permeability that will impede downward migration of contaminants from the upper to the lower aquifer. Therefore, groundwater containing contaminants that is not lost to surface water or soil from bluff seeps will flow southward and is unlikely to migrate downward to the lower aquifer. Upper aquifer groundwater will mix with water flowing along the course of Ship Creek, as base flow or underflow, and will flow toward the mouth of the creek at Knik Arm.

7.3.5 Human Health Risk

In the Western Area of OU 5, human health risks were estimated for multiple exposure routes for potential receptors. Maximum additive health risks that equal or exceed 1×10^{-6} (carcinogenic) and a Hazard Index (HI) of 1 (noncarcinogenic) and the major contributors to the risk, listed by medium, are:

Medium	Risk to Future Resident		Major Contributors
	Carcinogenic	Noncarcinogenic	
Surface Soil @ SB-29	4.7×10^{-5}	<1	Arsenic, polycyclic aromatic hydrocarbons
Groundwater at SP1-01	1×10^{-4}	3	Arsenic, manganese, TFH gasoline, TFH diesel, benzene
Groundwater at MW-02	4×10^{-6}	<1	TCE

The future residential scenario, which results in the highest human health risk values in Western OU 5, is highly conservative. Calculation of the values assumes that a residence is built on the most contaminated surface soil and that groundwater from the monitoring wells is used as the only domestic water in the residence. There are currently no residences in OU 5. Groundwater from the upper aquifer is not used and is unlikely to be used because of the availability of water from the deep aquifer.

Arsenic is a major contributor to both carcinogenic and non-carcinogenic risk values calculated for soil and groundwater. However, three factors allow for arsenic not to be considered a COC. First, arsenic concentrations in Western OU 5 groundwater samples are less than federal and state MCLs of 50 $\mu g/L$. Second, the arsenic concentrations that contribute to risk in surface soil in Western OU 5 are less than Elmendorf AFB background concentrations. Finally, an increasing body of data indicates that arsenic is not a contaminant in the Western Area of OU 5. Analytical data indicate that arsenic occurs naturally in soil and water of OU 5 at concentrations greater than those detected in uncontaminated media in the continental U.S. The average background arsenic concentrations (9 to 13 mg/kg) in the surface and root zone soil of Elmendorf AFB are greater than average values (5.3 to 7.5 mg/kg) in a database of shallow soil analyses from locations throughout the U.S. (Carey and Barrett, 1990). The arsenic background concentrations in the soil at Elmendorf AFB provide a natural source of the arsenic detected in groundwater, surface water, and sediments.

7.3.6 Aquatic Biota

The puddle on the bluff near MI 08 contained aquatic organisms associated with the water column, but no aquatic life was noted in qualitative collections of bottom debris. It could not be determined if the absence of aquatic life is the result of fuel hydrocarbons and metals at this location.

7.3.7 Terrestrial Plants and Animals

Plants exhibiting evidence of stress were evaluated throughout OU 5. An evaluation of fuel hydrocarbon and benzene, toluene, and xylene concentrations was conducted at SL04, an area where stressed vegetation in the western area was observed. The results indicated that the concentrations detected were not the cause of plant stress. Evaluations of potential contaminant stress on animals were not specific to the Western OU 5. However, there is no clear evidence that contaminants detected in soils and surface water throughout OU 5 are affecting terrestrial species.

7.3.8 Conclusions for the Western OU 5

Concentrations of COCs in soils 10 to 12 feet below ground surface at SB29 exceed the interim remediation goals for diesel (200 mg/kg) and gasoline (100 mg/kg) range TFH. Groundwater in the vicinity of MW01, MW02, and SP1-02 exceeds the interim remediation goals based on federal and state MCLs for TCE; water in MW16A exceeds the Alaskan Water Quality Standards (AWS) (10 μg/L) for TFH gasoline in groundwater. Cancer risks exceed 1 x 10^{-6} at MW02, SP1-01, and SP1-02, even if the contribution of arsenic is not included. Groundwater seepage in the puddle at SW/SE08 exceeds the AWS of 10 μg/L for total hydrocarbons because of JP-4 (770 μg/L) and TFH gasoline (320 μg/L). No other surface water interim remediation goals were exceeded at SW08 or SW09. Sediment concentrations do not exceed interim remediation goals. Surface soil at SB29 exceeds the interim remediation goal of 1 x 10^{-6} cancer risk. The major contributors to the risk are polycyclic aromatic hydrocarbons (PAHs) and arsenic. Even if arsenic concentrations are excluded from the cancer risk for surface soils at SB29, PAHs cumulatively result in a cancer risk greater than 1 x 10^{-5}. However, the PAHs occur in surface soils on the bluff face where a residence could not be constructed. Therefore, the scenario of the ingestion of soil by a residential receptor at SB29 is conservative, and the potential for exposure would be limited.

SB29 is an area near a seep that forms a puddle. The area measures only approximately 50 feet by 50 feet. Because of the small size of the affected area, the improbability of any residential exposure, and the single compound nature of the impact, the FS will not focus on the PAH surface soil impacts. If any remedial action is deemed necessary, clearly limited excavation and disposal of the affected soil would be the most effective action.

Based on the conclusions, the FS in Western OU 5 should focus on impacts to subsurface soil, seeps, and groundwater. The areas to be considered for remediation are shown on Figure 7-5.

7.4 Central OU 5

The Central Area of OU 5 extends from the western outlet of the snowmelt pond to the east of the waste paint tank (see Figure 7-7). The area includes source areas ST38, SS42, and the snowmelt pond. The fish hatchery is located in this area between the toe of the bluff and Ship Creek.

7.4.1 Conceptual Site Model

The conceptual site model of Central OU 5 in plan view, showing sample locations and the approximate extent of contamination in soils and groundwater, is shown in Figure 7-7. A conceptual cross section is shown on Figure 7-8. Remedial investigation results for the snowmelt pond are reported separately in Section 7.6. A small volume of near-surface soil with concentrations of diesel hydrocarbons and concentrations of inorganic elements greater than background levels represents the only soil contamination exceeding interim remediation goals in Central OU 5. The surface soil contamination is near the toe of the bluff and is probably the result of seeps of contaminated groundwater. Hydrocarbon odors and surface sheens in bluff seeps are evidence of this method of migration.

Fuel hydrocarbons and BTEX compounds are present in the groundwater pathway. Surface water contamination resulting from seeps occurs in drainage ditches adjacent to the face of the bluff. Data to characterize the air pathway were not collected.

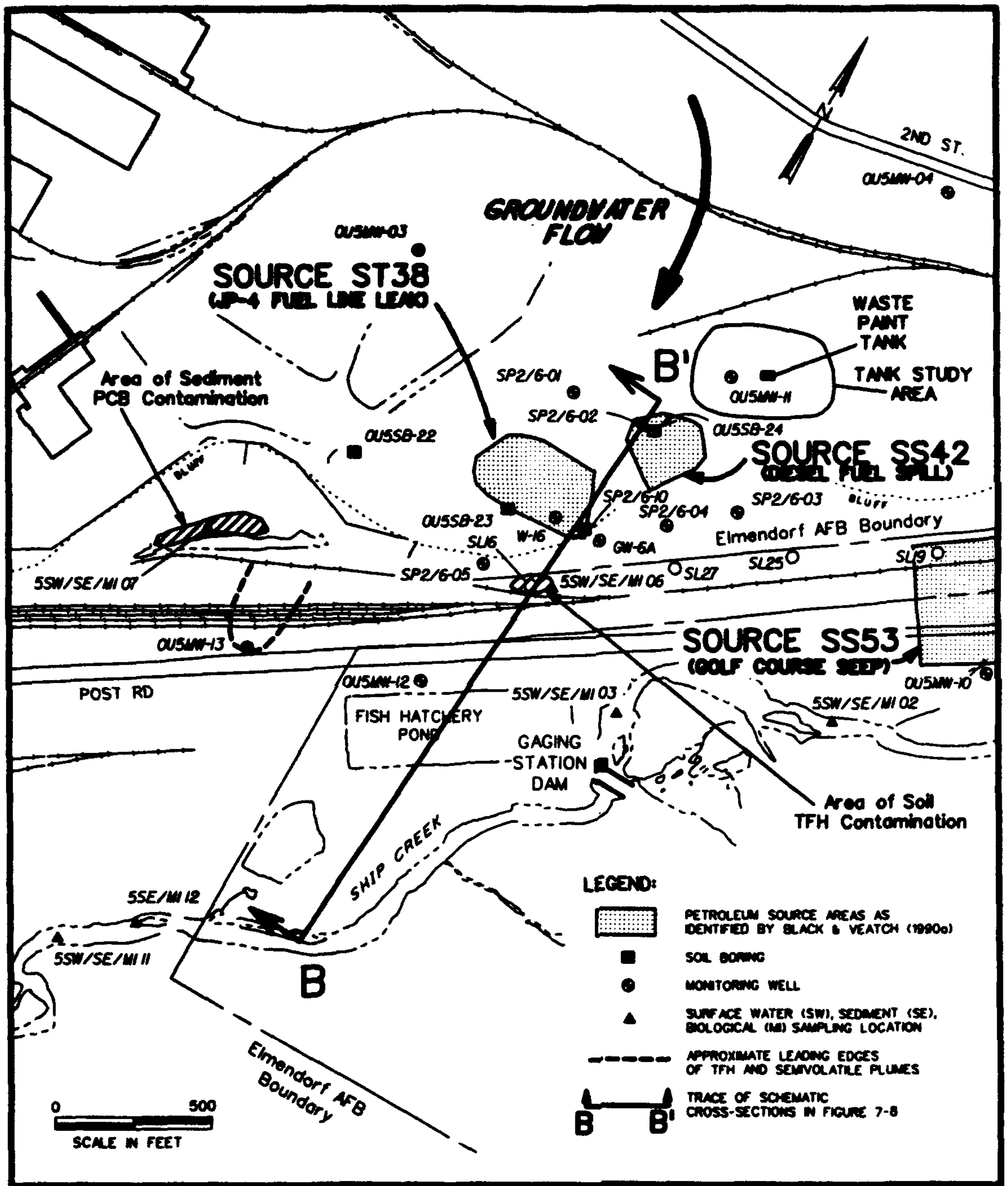
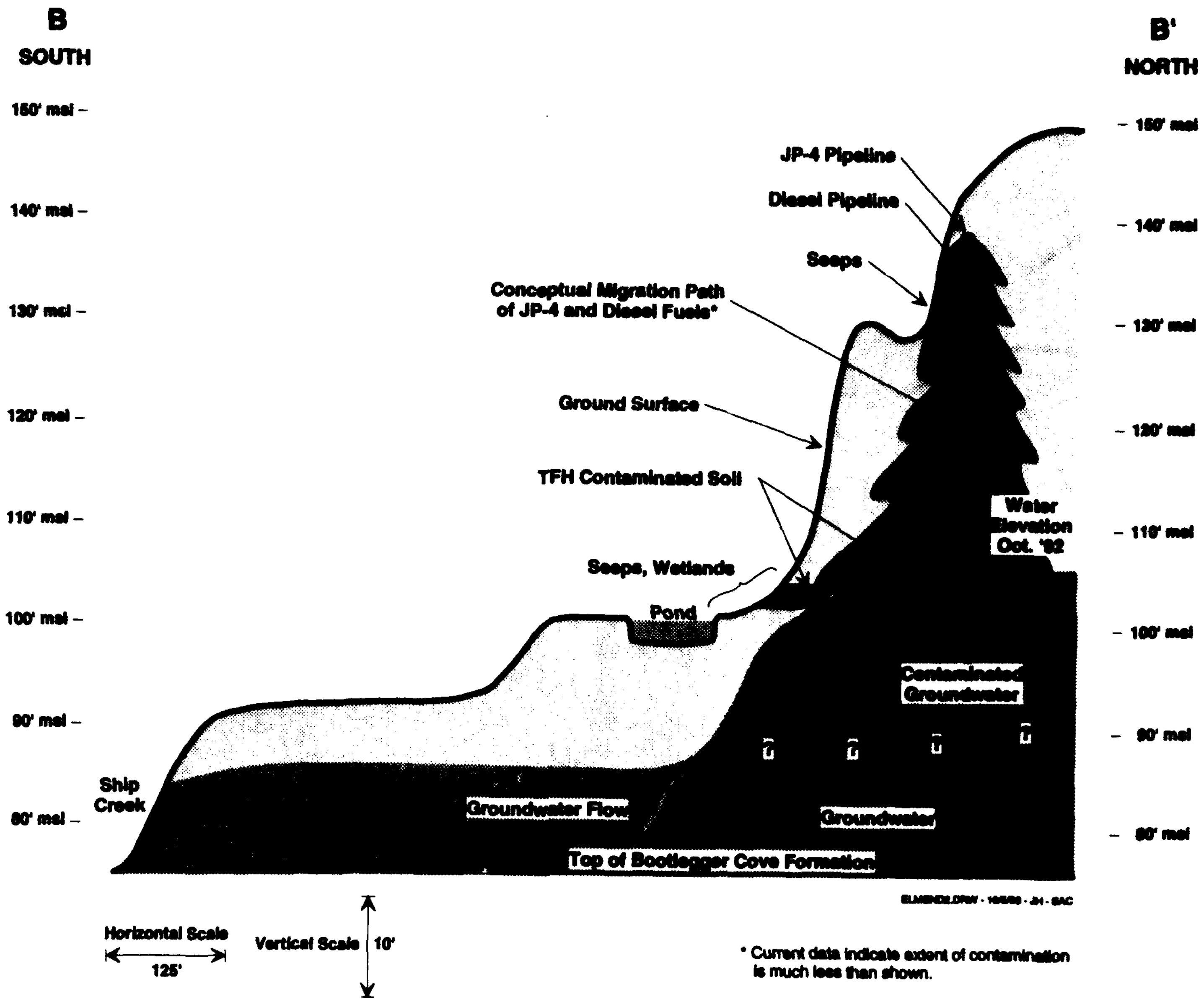


Figure 7-7. Sampling Locations and Contaminant Distribution in Central OU 5

ELMS OU5B4 VRL SAC 02/02/94



* Current data indicate extent of contamination is much less than shown.

Figure 7-8. Conceptual Site Model - Schematic Cross Section B-B', Central OU 5

7.4.2 Soil

The analytical results indicate that fuel hydrocarbons have migrated vertically to groundwater in several locations within Central OU 5 and have migrated horizontally in groundwater to the surface near the toe of the bluff. The data indicate that residual contamination is not present in the vadose zone at the locations sampled. Contamination remains in the soil at the water table. A concentration of fuel hydrocarbons (9,843 mg/kg) was detected in a soil sample from 30 to 31.5 feet below surface in the boring SP2/6-10 beneath ST38, the JP-4 Fuel Line Leak source area (Black and Veatch, 1990). Diesel fuel concentrations were also detected in two other samples at 53 mg/kg in soil at 58 to 60 feet below surface in SB23, and at 720 mg/kg in soil at 2 feet below the surface at seep SL16 at the toe of the bluff. The TFH contamination detected between 30 and 60 feet below ground surface occurs in the saturated zone and should be considered with groundwater. The sample from SL16 exceeds the interim remediation goal for soil.

Concentrations of several inorganic elements exceed soil background concentrations in Central OU 5. Arsenic, barium, beryllium, copper, lead, manganese, selenium, silver, and thallium were detected at concentrations greater than soil background concentrations in near-surface soil samples collected at seep SL25. One to four of these inorganic elements also exceeded background concentrations in the soils at SL16, SL19, and SL27. The natural organic carbon in the samples ranges from 2.7 to 19.5%. Soils with high concentrations of organic carbon adsorb inorganic elements more effectively than soils with little or no natural organic carbon. The organic material in the soils most likely has adsorbed and concentrated the inorganic elements from seep water that flowed through the soil. The soils at SL25, which contain the highest concentrations of organic carbon in Central OU 5, also have the highest concentrations and the greatest number of inorganic elements reported above background levels. Manganese may have been concentrated in the soils from SL25 and SL27 due to adsorption on organic carbon; however, all of the manganese analytic data collected from OU 5 soils are qualified. Also, the manganese concentrations reported by the laboratory have a "high bias" and, therefore, are likely to be higher than the manganese concentration that is actually present in the soils.

7.4.3 Surface Water and Sediment

The sediment sample collected at location 5 SW/SE06 had concentrations of 7,400 mg/kg TFH diesel, 17 mg/kg gasoline, and 23.1 mg/kg arsenic. There are no interim remediation goals that specifically address sediment contamination. However, the TFH in sediment is probably related to TFH in soils. The sediment sample was collected near the soil sample at seep SL16 that had concentrations of 720 mg/kg TFH diesel, which exceeds the interim remediation goal of 200 mg/kg. The contaminated soil and sediment should be considered a single soil contaminated area in the FS.

7.4.4 Groundwater

There is no identifiable trend in the compounds detected or their respective concentrations in monitoring well samples. The greatest concentrations and the greatest number of compounds were detected in samples from MW13, the well located furthest in the downgradient direction. Groundwater from the well had concentrations of JP-4 fuel (730 μg/L), gasoline (250 μg/L), and benzene (0.6 μg/L). Upgradient well samples contain lower concentrations of toluene, N-nitrosodiphenlyamine, and diesel fuel. Contaminant plume boundaries in Figure 7-7 estimate the extent of groundwater exceeding 1 x 10^{-6} cancer risk.

7.4.5 Human Health Risk

The potential cancer risk from residential exposure to soils at SL25 is greater than 7 x 10^{-5} because of the arsenic concentration in the soil. Potential cancer risk is less than 1 x 10^{-6} and the noncancer risk Hazard Index is less than 1 for residential exposure to all other inorganic element concentrations in Central OU 5 soils. Maximum additive cancer health risks exceeding 1 x 10^{-4} were calculated for the groundwater pathway. The Hazard Index for noncancer risks is less than one. Results of risk calculations are:

Medium	Risk to Future Resident		Major Contributor
	Carcinogenic	Noncarcinogenic	
Soil at SL25	9 x 10^{-5}	< 1	Arsenic
Groundwater at MW13	6 x 10^{-4}	< 1	TFH gasoline, benzene

7.4.6 Aquatic Biota

The wetland pond at MI 06 in Central OU 5 exhibited a restricted invertebrate community structure; i.e., fewer species were found in the pond than are considered normal for a healthy habitat. The presence of organic contaminants may be the cause of restricted community. The presence of aquatic life suggests that contaminants in the pond sediments are not acutely toxic to some of the invertebrate life forms.

7.4.7 Terrestrial Plants and Animals

There are two areas of stressed vegetation; however, no evaluation of plant or animal stress resulting from contaminants was conducted in Central OU 5.

7.4.8 Conclusions for Central OU 5

Diesel fuel (720 mg/kg) in soil 1 to 2 feet below surface, the result of groundwater seepage, does not pose a significant health risk. However, the soil should be evaluated in the FS because it exceeds the interim remediation goal of 200 mg/kg. Sediments, represented by sample SE06, containing TFH diesel and gasoline, should be considered a part of the area of soil contamination. Hydrocarbon concentrations of 50 to 9,843 mg/kg that occur from 30 to 60 feet below surface pose no risk to surface receptors unless they migrate to the surface as seeps in the future. Because these concentrations are at or below the water table, they should be addressed with groundwater.

The arsenic concentrations at sample locations SB06 (23.1 mg/kg) and SL25 (28.2 mg/kg) are probably the result of leaching of naturally occurring arsenic from surface soils and adsorption from water onto organic-rich soil. The detected concentrations are less than three times the mean background concentration (7.2 mg/kg) for arsenic in surface soils and do not cause concentrations in surface water to exceed interim remediation goals of 50 μg/L. Therefore, remediation on the basis of arsenic concentrations is not warranted.

Concentrations of barium, copper, lead, manganese, selenium, silver, and thallium in near-surface soils at seeps SL16, SL19, SL25, and SL27 do not result from discharges of contaminants. These inorganic elements exceed soil background concentrations because of high organic carbon concentrations in the soils that adsorb the elements from seeping groundwater. Although the inorganic element concentrations exceed soil background concentrations, they are present because of natural processes and do not exceed interim remediation goals. Therefore, soil remediation on the basis of inorganic element concentrations is not warranted.

A groundwater plume with gasoline and benzene concentrations that pose greater than 1 x 10^{-6} cancer risk was detected at MW13. Because of the potential health risks, the gasoline and benzene plume should be evaluated for feasibility of remedial action.

In initial sampling, the concentration (20 μg/L) of bis (2-ethyl hexyl) phthalate at MW11 exceeded the interim remediation goal of 6 μg/L. The well was resampled in December 1993 because this compound is atypical in OU 5. No phthalates were discovered in this second sample. Since the phthalate is a potential laboratory contaminant, it was concluded that the first sampling results were inaccurate.

7.5 Eastern OU 5

The Eastern Area of OU 5 extends from the eastern side of the waste paint tank to the eastern edge of source ST46 (Figure 7-9). Source areas SS53, SD40, and ST46 are located in this area. Eastern OU 5 includes an area at the top of the bluff, a bluff face less steep than in Central OU 5, and wetlands between the toe of the bluff and Ship Creek. The most significant feature in the wetlands is the beaver pond. The beaver pond is discussed separately in Section 7.7.

7.5.1 Conceptual Site Model

Sampling locations and areas of contamination in Eastern OU 5 are shown in plan view on Figure 7-9. A conceptual cross section of the migration pathways is shown on Figure 7-10. Fuel hydrocarbons and BTEX compounds are present in the soil of the golf course seep area as a result of leaks from the fuel pipelines crossing the northern portion of eastern OU 5. The greatest concentration of TFH occurs in the smear zone near the water table at SB26. This smear zone likely resulted from fuel contaminants that migrated to a higher water table and were left in the vadose zone or capillary fringe as the water table receded. The smearing of hydrocarbons may occur between season as the water table rises and falls. From the area below the pipeline leak, where the hydrocarbons reached the water table, the fuel hydrocarbons have migrated on the upper groundwater surface to seeps along the bluff and have affected surface soil and sediment in the beaver pond. Hydrocarbon odors and surface sheens in bluff seeps are evidence of this method of migration. Groundwater beneath Eastern OU 5 contains compounds that have migrated to the bluff face and beyond to well GW5A. Data to characterize the air pathways were not collected.

7.5.2 Soil

Fuel hydrocarbons (JP-4 and diesel) were detected at concentrations of 165 mg/kg and 172 mg/kg, respectively, in the saturated zone at boring SB26. This soil boring

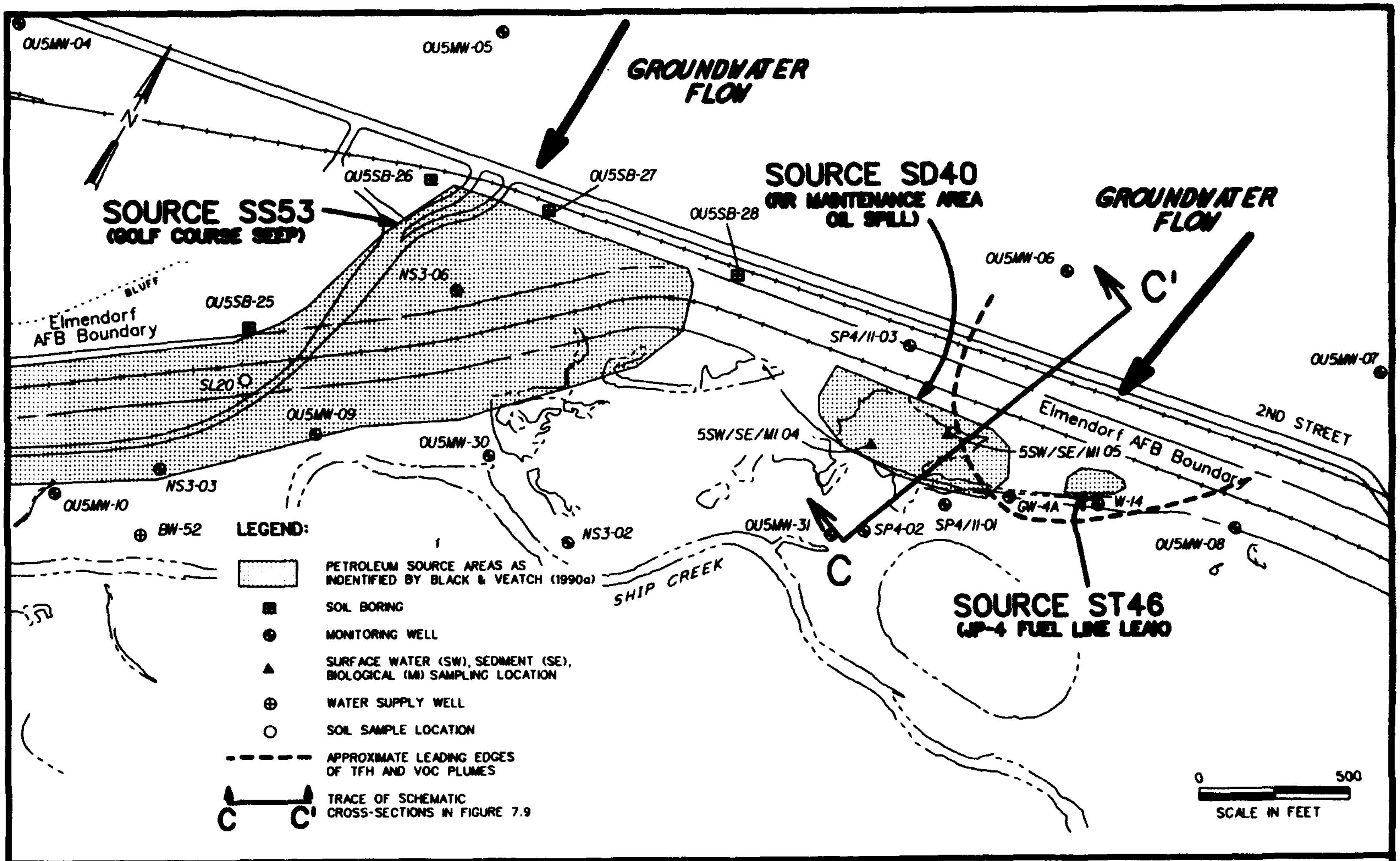


Figure 7-9. Sampling Locations and Contaminant Distribution in Eastern OU 5

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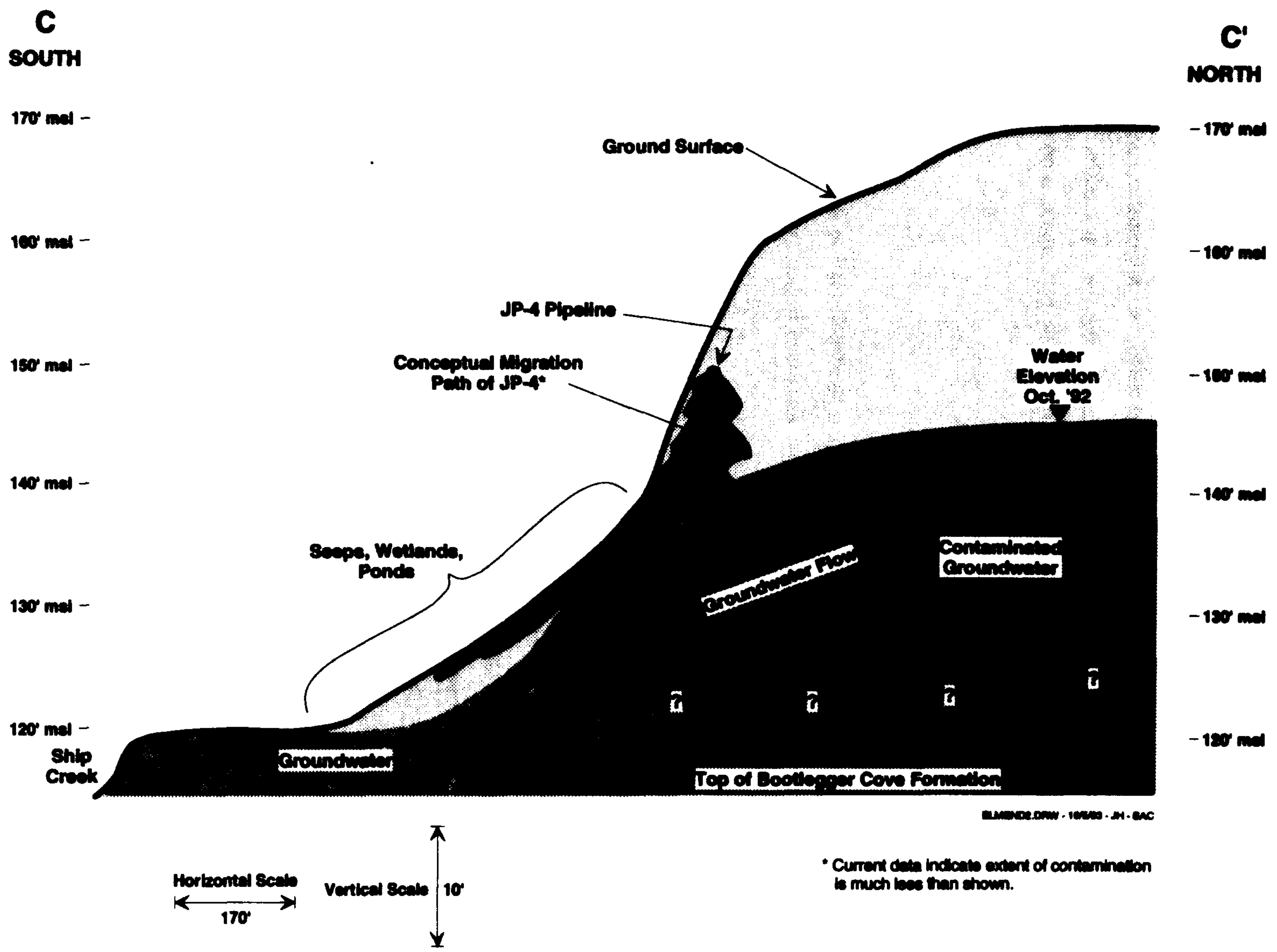

* Current data indicate extent of contamination is much less than shown.

Figure 7-10. Conceptual Site Model - Schematic Cross Section C-C', Eastern OU 5 was drilled adjacent to a water drain pit on the JP-4 pipeline, where a leak was detected in 1982. Each of the BTEX compounds were also detected in the sample from 25 to 27 feet below surface. Hydrocarbons were not detected in samples from shallower depths in the boring. The absence of fuel hydrocarbons in the shallow soil suggests that the leaking fuel did not migrate laterally in the vadose zone toward SB26, but migrated vertically to groundwater, and then laterally toward soils at SB26 after reaching the water table. Diesel fuel has migrated in groundwater and reached the surface soil in the golf course seep at surface seep SL20.

7.5.3 Surface Water and Sediment

Surface water and sediment samples were collected in the beaver pond. Results of sampling and analysis in the pond are discussed in Section 7.7.

7.5.4 Groundwater

The estimated extent of the contaminant plume exceeding 1 x 10^{-6} cancer risk in the Eastern Area of OU 5 is shown in Figure 7-9. Monitoring well MW06, north of the bluff, yielded a sample with concentrations of TCE (52 μg/L), ethylbenzene (0.67 μg/L), toluene (1.4 μg/L), xylenes (2.7 μg/L), and gasoline hydrocarbons (0.082 μg/L). Only the TCE concentration exceeds the groundwater interim remediation goal of 5 μg/L. A sample from monitoring well GW4A had concentrations of TFH gasoline (260 μg/L) and benzene (0.84 μg/L). The TFH gasoline concentration exceeds the interim remediation goal of 10 μg/L. A sample from MW07 had a concentration of 8 μg/L of 1,1,2,2-tetrachloroethane, which does exceeds an interim remediation goal (1 μg/L). All of these compounds were also detected in water or sediment samples from the beaver pond (Section 7.7).

7.5.5 Human Health Risk

No cancer risk values were calculated for surface or subsurface soil in the Eastern Area of OU 5 because only diesel fuel, which has only non-cancer health effects, was detected at the surface. The BTEX compounds, which can pose carcinogenic effects, were detected at 25 feet below surface, and are thus below the depth of any potential human exposure. Hazard indices for both surface and subsurface soils are less than 1. Groundwater is the only medium in the Eastern OU 5 with calculated cancer risks exceeding 1×10^{-6}. Health risk results for three wells are:

Medium	Risk to Future Resident	Major Contributor
	Carcinogenic	
Groundwater at GW4A	8×10^{-6}	TFH gasoline, TCE, benzene
Groundwater at MW06	4×10^{-5}	TFH gasoline, TCE
Groundwater at MW07	3×10^{-5}	1,1,2,2-Tetrachloroethane

7.5.6 Aquatic Biota

Aquatic biota in Eastern OU 5 were evaluated in the beaver pond. See Section 7.7.

7.5.7 Terrestrial Plants and Animals

There are two areas of stressed vegetation; however, no evaluation of plant or animal stress resulting from contaminants was conducted in the Eastern area of OU 5.

7.5.8 Conclusions for the Eastern Area of OU 5

The principal pathway in the Eastern Area of OU 5 is groundwater. Excess lifetime cancer risks to future residential receptors exceed 1×10^{-6} at the wells. Concentrations of TCE at MW06 and TFH gasoline at GW5A also exceed the interim remediation goals of 5 μg/L TCE and 10 μg/L TFH gasoline, respectively. The VOC and BTEX concentrations beneath the southern portion of the area may increase in the future because of greater concentrations of TCE in groundwater upgradient at MW06. These increasing concentrations may affect the surface water pathway through surface seeps. If volatile concentrations increase in seeps and surface water, the air pathway may be also be affected by increased concentrations of volatile compounds lost from the water surface.

The FS should focus on groundwater in Eastern OU 5 because of potential health risks and exceedance of potential ARARs for groundwater. Surface water originating from groundwater seeps and sediment in the beaver pond also should be evaluated.

7.6 Snowmelt Pond

Three studies of the snowmelt pond have been performed. The first study, performed as part of the 1992 RI, indicated that PCBs may be present in the sediment of the pond. The second study was performed in June 1993 to confirm the presence of the PCBs in the sediment and to determine if sources of PCBs occurred in the area. The third study was performed in September 1993 to determine if PCBs were in the pond water and to evaluate the risk to aquatic life posed by the PCBs when the total organic carbon content of the sediment is considered. A land ownership study and a site inspection for potential sources of PCBs was conducted as part of the third study. Detailed reports on the second and third studies are provided in Appendix Q.

7.6.1 Initial Remedial Investigation Study

Water samples from snowmelt pond contained concentrations of 1.4 to 2.5 μg/L of three VOCs that have been detected in groundwater in the Western and Eastern Areas of OU 5, but not in Central OU 5. Groundwater from the bluff area to the north discharges into the pond and may contain concentrations of the VOCs. Analysis of a composite sediment sample from the pond detected 0.057 to 0.240 mg/kg of 11 different polycyclic aromatic hydrocarbons (PAH) compounds and 1,600 μg/kg of PCBs (Arochlor 1260). Additional sampling and analysis was conducted in the pond because an initial evaluation indicated that the PCB concentration in the sediment may pose a threat to aquatic life.

7.6.2 Second Sediment Sampling

Five sample locations were selected to determine if a specific source area of the PCBs could be identified and to determine the extent of the contamination. The additional samples were collected in June 1993 and were analyzed for PCB concentrations by Method SW8080. Locations of the additional sediment samples are shown in Figure 7-11. Sample location SD-01, at the eastern end of the pond, was selected to determine if PCBs were entering the pond from its eastern drainage. Sample location SD-02 was selected to determine if PCBs were entering the pond from the fill area located immediately north of the eastern half of the pond. Sample location SD-03 was placed at the downstream edge of the fill area. Sample location SD-04 was selected to determine if the abandoned building was the source of the PCBs. Sample location SD-05 was selected to determine if the PCBs occurred where the water flowed out of the pond.

The reported PCB concentrations in these samples ranged from "not detected" to 1,460 μg/kg (see summary table in Section 7.6.4). Since the presence of PCBs in the sediment was confirmed, a third study was performed to determine if the PCBs were present in surface water and to determine the potential threat to aquatic life.

7.6.3 Third Sampling Event and Site Inspection

The objectives of the third study were:

- To determine if the PCBs in the sediments represented a threat to aquatic life;

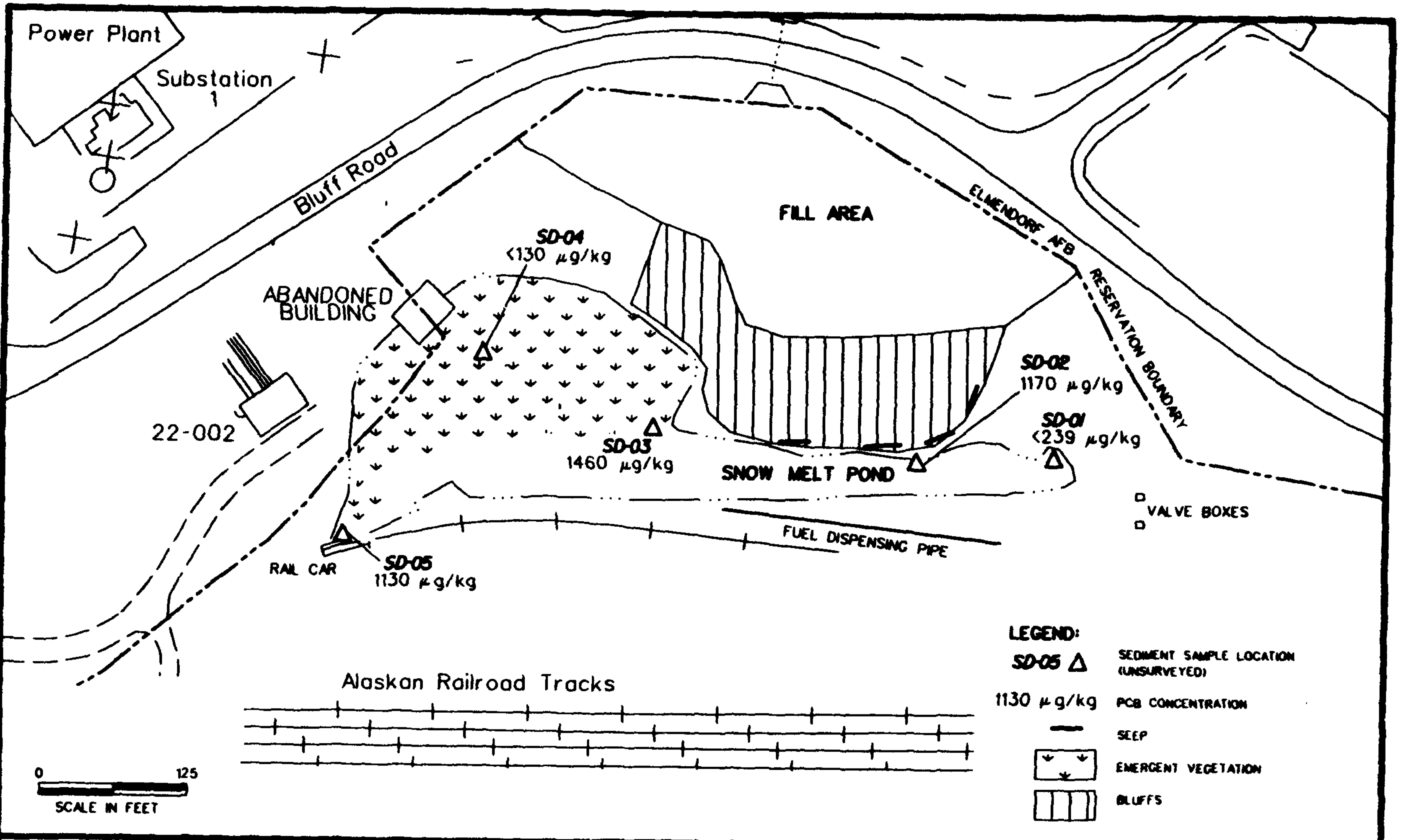

Figure 7-11. Approximate Locations of Sediment and Surface Water Samples and PCB Analysis Results, Snowmelt Pond, OU 5

- To determine if PCBs were present in the pond's water;
- To conduct a site inspection for visible sources of the PCBs; and
- To obtain information on the property boundaries in the vicinity of snowmelt pond.

The site inspection in September 1993 examined a variety of structures and physical features in the vicinity of the snowmelt pond. Seeps entering the pond at the base of the bluff (see Figure 7-11) contained a visible hydrocarbon sheen. The sheen extended a few feet into the pond and violates Alaska Water Quality Standards for no visible sheens. No other potential sources of PCBs or other contamination were observed during the inspection. A detailed report on the site inspection is provided in Appendix Q.

As shown in Figure 7-11, the property boundary information indicates that snowmelt pond lies almost entirely on Alaska Railroad property. A very small portion of the pond near the abandoned building lies within the Elmendorf AFB property.

The third sampling effort was performed in September 1993. Sediment and surface water samples were collected at the three locations where PCBs were detected during the second round of sampling. The sediment samples were analyzed for total organic carbon (TOC) because PCB toxicity in sediments is dependent on the TOC concentration in the sediments. The water samples were analyzed to determine if PCBs are present in the water phase.

7.6.4 Final Results and Analysis

The results of the sediment and surface water analyses from the second and third sampling events are:

Sample Location	Location Description	TOC[a] (Percent)	PCB (Aroclor 1260) Concentration		Sediment Quality Criteria
			Surface Water[a] (μg/L)	Sediment[b] (μg/kg)	
SD-01	Surface water inflow point	NS	NS	ND (239)	NC
SD-02	Downslope from fill area	3.2	ND (0.05)	1,170	604
SD-03	End of soil peninsula	9.1	ND (0.05)	1,460	1,730
SD-04	Near abandoned building	NS	NS	ND (130)	NC
SD-05	Surface water outflow point	2.5	ND (0.05)	1,130	475
Average		4.9	NC	790	936

[a] From third sampling event.
[b] From second sampling event.
NS = Not sampled
ND = Not detected (detection limit)
NC = Not calculated

The distribution of PCB concentrations in the snowmelt pond does not indicate a specific source area or discharge point for the contaminants. The result from SD-01 from the inflow point indicates that PCBs have not migrated into the pond from another area to the east. The result from SD-04 indicates that the abandoned building is not a source of the PCBs. Evidence that PCB contaminated sediment has been transported across the pond to the point where surface water flows downstream is provided by the SD-05 sample. No data are available regarding a PCB source lying along the side of the pond.

To determine if the PCBs in the sediments pose a threat to aquatic life, the reported concentrations were compared to sediment quality criteria (SQC) (U.S. EPA, 1990). The SQC were designed to be protective of aquatic life and animals that consume aquatic life. U.S. EPA recommends that the SQC be considered in establishing remediation goals for contaminated sediments. The PCB SQC is not a fixed value; rather, it is dependent on the TOC concentration in the sediment. At higher TOC levels, PCBs are less biologically available because a greater fraction of the total PCBs will be sorbed to organic material in the sediments. Therefore, the SQC is higher at higher TOC concentrations. The PCB SQC for the snowmelt pond, shown in the previous table, were interpolated from the established freshwater SQCs of:

- 1,900 μg/kg if TOC equals 10%; and
- 190 μg/kg if TOC equals 1%.

The SQCs were exceeded in two of the five sampling locations: downslope from the fill area and at the surface water outflow point. Aquatic receptors may be at risk based on this assessment. However, PCBs were not detected in any of the water samples. The detection limits were not low enough to determine if the National Ambient Water Quality Criteria of 0.014 μg/L was exceeded.

7.6.5 Conclusions for the Snowmelt Pond

Interim remediation goals for PCBs in sediment are exceeded in two locations. However, PCBs were not detected in any water samples. A small hydrocarbon sheen on the pond was found to be in violation of AWQS. The FS should consider the Snowmelt Pond sediment due to possible risks to aquatic life from PCBs. The sheen on the surface water should also be addressed in the FS.

7.7 Beaver Pond

The beaver pond is a potentially sensitive receptor of contaminated groundwater. Because of the sensitivity, two studies of the pond have been conducted. The first study was performed as part of the RI and focused on the identification of contamination in the water and sediment in the pond. The second study evaluated the ability of the pond to naturally attenuate the known types and concentration of contaminants detected during the RI. The results of each study are discussed below.

7.7.1 Summary of the Remedial Investigation

Water samples collected from the golf course beaver pond contained 0.6 μg/L of benzene, 0.7 μg/L of toluene, 4.3 μg/L of 1,1,2,2-tetrachlorethane, 6.6 μg/L of trichloroethene, and 52 μg/L of gasoline hydrocarbons. The beaver pond is fed by groundwater seeps and indicates the contaminants migrating in groundwater to the pond. Sediment samples from the pond had concentrations of JP-4, diesel fuel, gasoline, ethylbenzene, naphthalene, phenanthrene, toluene, cadmium, chromium, copper, lead, mercury, silver, and zinc.

7.7.2 Aquatic Biota

In eastern OU 5, invertebrate community structure in the golf course beaver pond is dominated by taxa that are considered tolerant. Station MI 05, located at the beaver pond, appeared to be the most biologically affected station in eastern OU 5. Fuel hydrocarbon products were observed in the sediment sample results at this location.

7.7.3 Natural Attenuation Study

Wetlands have been shown, through numerous studies performed through the United States and other countries, to naturally attenuate a variety of contaminants. Wetlands typically contain aerobic, anaerobic, and filtration environments. These environments have the ability to attenuate aromatic VOCs, halogenated VOCs, and metals in water.

The attenuation systems in the beaver pond, and other seeps throughout OU 5, were evaluated in September 1993. Based on analysis of data collected during the investigation, the following conclusions have been made.

- The beaver pond is within Section 404 jurisdiction; while a 404 permit would not be required for allowing the wetland to continue natural degradation of contaminants, the substantive requirements of the permit must be met.

- The assessment of functions suggests that the beaver pond is capable of treating contamination in excess of that currently discharging into the system.
- The seeps not related to the beaver pond contain hydrocarbon degrading bacteria, yet residence time in the system is probably not sufficient for complete degradation.

Although the beaver pond is within 404 jurisdiction, and activities involving discharge of fill into the system would not require a permit, as long as substantive requirements of this permit are met. Discharge of fill is broadly interpreted by the Corps of Engineers (COE) to include activities that alter the hydrology or surface flow in a wetland. This can include most activities requiring any equipment heavier than a pick-up truck, any ditching or draining, or any re-routing of water flow. Any remedial action involving earth moving, capture of surface water, or capture of groundwater that naturally discharges to the pond would not require a 404 permit, although the substantive requirements of the permit must be met. A 404 permit would not be required for allowing the beaver pond to continue natural degradation of contaminants, although again, the substantive requirements of this permit must be met. Continuation of natural degradation would not entail any alteration of the system whatsoever, and therefore, would cause no impacts to the hydrology. A long-term monitoring program would be needed to ensure continued effective water treatment and to track potential impacts to the ecosystem.

The assessment of wetland functions within the beaver pond shows a storage capacity and residence time that is more than adequate for the measured contaminant loading rate. The water quality tests suggest that the water leaving the system is of better quality than that at the sites of contamination. Hydrocarbon-degrading bacteria counts also indicate adequate treatment capabilities. Design criteria for constructed wetlands systems were used to calculate the necessary treatment acreage for the contaminant loading rate of Beaver Pond. The results suggest that the beaver pond is 18 times larger than necessary for successful remediation of the influent seeps.

The other seeps investigated during this study were found to have hydrocarbon degrading bacteria. However, the hydraulic residence time in the system is too short to allow for complete degradation. There are no natural controls to the flow and precipitation mixes with the seeps and washes immediately to more major drainages. Modifying the seep areas to control the flow thereby increasing the hydraulic residence time may be a viable remedial alternative.

A detailed report on the study is provided in Appendix R.

7.8 Contaminants of Concern

By comparing contaminant concentrations in OU 5 soil and water with interim remediation goals, the contaminants of concern (COC) in OU 5 have been identified (Table 7-3). These COCs combined with the affected media and pathways form the basis of the identification and screening of remedial technologies and the detailed analysis of alternatives in the FS.

On the basis of the analysis, the COCs in the water and soil of OU 5 are:

Water COCs

- Fuel hydrocarbons (JP-4, TFH-diesel, TFH-gasoline);
- Halogenated volatile organic compounds (VOCs); and
- Aromatic volatile organic compounds (BTEX).

Table 7-3

Summary of Contaminants of Concern (COCs) Analysis

Potential COC	Water	Soil
Halogenated VOCs	Confirmed as a COC. Levels exceed background, exceed potential ARARs, and contribute to cancer risk.	Not a COC. Not detected.
Aromatic VOCs	Confirmed as a COC. Levels exceed background, exceed potential ARARs, and contribute to cancer risk.	Confirmed as a COC. Levels exceed background and constituents contribute to TFH levels of potential ARARs.
Total Fuel Hydrocarbons	Confirmed as a COC. Levels exceed background, exceed potential TBC level, contribute to risk, and cause sheens on surface water.	Confirmed as a COC. Levels exceed background and potential TBC levels.
Metals	Not a COC. Only two metals in one sample exceed potential ARARs and are minor contributors to risk.	Not a COC. Levels exceed background concentrations only in soils with high organic carbon content.
Arsenic	Not a COC. Concentrations less than potential ARAR (50 μg/L).	Not a COC. Levels exceed background concentrations only in soils with high organic carbon content.
Polycyclic Aromatic Hydrocarbons (PAHs)	Not a COCs. Detectable concentrations are below potential ARARs, and not significant contributors to risk.	Not a COC. Levels do not exceed potential ARARs. Potential cancer risks from ingestion are reduced because the location cannot be used as a future residence.
PCBs	Not confirmed as a COC. Not detected in water.	Confirmed as a COC. Levels exceed background and SQC levels. Potential environmental risks to aquatic receptors.

Soil COCs

- Fuel hydrocarbons (JP-4, TFH-diesel, TFH-gasoline);
- BTEX compounds; and
- PCBs (Arochlor 1260).

Remedial actions considered for groundwater and surface seeps in OU 5 must also accommodate contaminants that may migrate in groundwater from all upgradient sources. Therefore, the list of COCs may be expanded in the future, if new COCs are identified during groundwater characterization investigations in areas upgradient from OU 5.

7.8.1 Inorganic Elements in Soils

Arsenic is a major contributor to both carcinogenic and non-carcinogenic risk in the soil and groundwater. However, arsenic concentrations in OU 5 groundwater samples are less than federal and Alaskan MCLs for drinking water. Most arsenic concentrations that contribute to risk in surface soil are less than Elmendorf AFB background levels. The natural arsenic in the soil at Elmendorf AFB provides a source of the arsenic detected in groundwater, surface water, and sediments.

Arsenic, barium, beryllium, copper, lead, manganese, selenium , silver, and thallium were detected at concentrations greater than soil background concentrations in near-surface soils at several seeps in Central OU 5. These inorganic element concentrations can be attributed to high natural organic carbon concentrations (2.7 to 19.5%) in the soils and to the effects of analytical problems on some of the results. The high organic carbon concentrations in the soils are likely to have adsorbed and concentrated the inorganic elements from seep water that flowed through the soil. Soil samples containing the highest concentrations of organic carbon also contain the highest concentrations and the greatest number of inorganic elements reported above background levels. Manganese may have been concentrated in the soils, along with the other inorganic elements, because of adsorption on natural organic carbon; however, all of the manganese analytical data collected from OU 5 soils are qualified. The manganese concentrations reported by the laboratory have a high bias, and, therefore, are likely to be higher than the manganese concentration that is actually present in soils. For these reasons, the inorganic element concentrations in soils at seeps are not considered COCs.

7.9 Recommendations

On the basis of the comparison of remedial investigation data to interim remediation goals, the following recommendations are made for each area of OU 5.

7.9.1 Areas Recommended for No Further Action

No further action is recommended for the following source areas or specific pathways in each of the three geographic areas of OU 5 because remedial actions are not warranted.

Central OU 5

Source Areas ST38 and SS42 — No further action for the soil, surface water, and sediment pathways are warranted for the following reasons:

- TFH diesel, JP-4, and BTEX compounds were only detected in soil 10 to 60 feet below surface SB23, MW11, SP2/6-10, and SP2/6-04 and are not in a surface soil pathway accessible by residents or terrestrial animals; compounds detected below 30 feet are related to groundwater contamination;
- Detected contaminant concentrations pose less than 1×10^{-6} cancer risk and have a Hazard Index less than 1 for non-cancer risks;
- COC concentrations do no exceed potential ARAR or TBC levels; and

- There are no identifiable effects of contaminants on aquatic biota or terrestrial plants and animals.

Outside of Source Areas — No further action is warranted for soils at SL16, SL19, SL25, or SL27 for the following reasons:

- Concentrations of inorganic elements exceed soil background levels because of 2.7 to 19.5% natural organic carbon that has adsorbed the elements from water to a much higher degree than normal soils have, not because of contaminant discharge;
- With the exception of the near-surface arsenic concentration at SL25, none of the inorganic element concentrations exceed interim remediation goals; and
- The arsenic concentration at SL25 is the result of naturally high arsenic concentrations in Elmendorf AFB soils and the high concentration of organic carbon that has adsorbed the arsenic leached from soils by surface water and groundwater.
- The manganese concentrations at SL25 and SL27 are the result of the high concentration of organic carbon that has absorbed the manganese leached from soils by surface water and groundwater. In addition, the manganese measurements at these locations have a high bias, indicating the actual concentrations are likely to be lower than reported.

Eastern OU 5

Source Area SS53 — No further action is warranted for the soil pathway for the following reasons:

- TFH diesel, JP-4, and BTEX compound concentrations were detected in SB26 at a depth of 25 to 27 feet and is related to groundwater contamination; TFH diesel concentration in near surface soil at SL20 was only 2 mg/kg;

- Detected contaminant concentrations pose less than 1 x 10^{-6} cancer risk and have a Hazard Index less than 1 for non-cancer risk; and
- Contaminant concentrations do no exceed potential ARAR or TBC levels.

Source Areas SD40 and ST46 — No further action is warranted for the soil pathway for the following reasons:

- Detected contaminant concentrations in all soil samples pose less than 1 x 10^{-6} cancer risk and have a Hazard Index less than 1 for non-cancer risk;
- COC concentrations do no exceed potential ARAR or TBC levels; and
- There are no identifiable effects of contaminants on aquatic biota or terrestrial plants and animals.

7.9.2 Areas and Media Recommended for Evaluation in the Feasibility Study

Remedial actions for COCs in specific pathways should be evaluated in the feasibility study because contaminants exceed potential ARARs or TBC regulatory levels or pose cancer risks greater than 1 x 10^{-6} or non-cancer risks with a Hazard Index greater than 1. The pathways that will be evaluated in each geographic area and the reasons for selecting the pathway are explained below.

Western OU 5

Source Area ST37 — Remedial actions should be evaluated for the soil pathway for the following reason:

- TFH diesel and gasoline concentrations exceed the interim remediation goals of 200 mg/kg and 100 mg/kg, respectively, in a sample from 10 to 12 feet below ground surface at SB29.

Remedial actions are not evaluated for surface soil for the following reasons:

- The major contributors to the risk are polycyclic aromatic hydrocarbons (PAHs) and arsenic. Even if arsenic concentrations are excluded from the cancer risk for surface soils at SB29, PAHs cumulatively result in a cancer risk greater than 1 x 10^{-5}. However, the PAHs occur in surface soils on the bluff face where a residence could not be constructed. Therefore, the scenario of the ingestion of soil by a residential receptor at SB29 is conservative and the potential for exposure is limited. SB29 is an area and a seep that forms a puddle. The area measures only approximately 50 feet by 50 feet. Because of the small size of the affected area, the improbability of any residential exposure, and the single compound nature of the impact, the FS will not focus on the PAH surface soil impacts. If any remedial action is deemed necessary clearly limited excavation and disposal of the affected soil would be the most effective action.

Remedial actions should be evaluated for the surface water pathway for the following reason:

- The concentrations of JP-4 (770 μg/L) and TFH gas (320 μg/L) exceed the Alaska Surface Water Quality (ASWQ) potential ARAR of (10 μg/L) at location SW08.

The surface water is a puddle caused by seep water. This pathway should be evaluated in the FS as a seep of groundwater.

Remedial actions should be evaluated for the groundwater pathway for the following reasons:

- Potential federal and state ARARs for groundwater are exceeded for benzene (5 μg/L) at SP1-01, for TCE (5 μg/L), and TFH (10 μg/L) at SP1-01, MW15, and MW16A; and
- Excess lifetime cancer risks to a future residential receptor exceed 1 x 10^{-6} in groundwater at wells MW02, SP1-01, and SP1-02 locations even if arsenic is deleted as a contributor to risk.

Central OU 5

Outside of Source Areas — Remedial actions should be evaluated for the soil pathway for the following reasons:

- The TFH diesel concentration exceeds the interim remediation goal of 200 mg/kg in a small volume of soil south of ST38 at SL16 and the sediments at SE06.

This soil is contaminated by groundwater seeps. Because the soil is impacted as a result of a seep, the remediation of soil should not be considered independently, without evaluation of alternatives for seeps.

Remedial actions should be evaluated for the groundwater pathway for the following reasons:

- Interim remediation goals based on potential ARARs for JP 4 and TFH gasoline (10 μg/l) are exceeded in MW 13.
- Excess lifetime cancer risks to a future residential receptor exceed 1 x 10^{-6} in groundwater at wells MW13.

Snowmelt Pond

Remedial actions should be evaluated for the sediment pathway for the following reasons:

- Interim remediation goals for PCBs are exceeded in two pond locations. The PCBs may pose a risk to aquatic receptors; and
- A hydrocarbon sheen violates Alaska Water Quality Standards.

Eastern OU 5

Beaver Pond

Remedial actions should be evaluated for the surface water pathway for the following reason:

- A TFH gasoline concentration of 52 μg/L exceeds the interim remediation goal of 10 μg/L and TCE exceeds the interim remediation goal of 5 μg/L.

Groundwater Outside of Source Areas

Remedial actions should be evaluated for the groundwater pathway for the following reasons:

- Interim remediation goals for groundwater are exceeded for TCE (5 μg/L) at MW06 and for TFH gasoline (10 μg/L) at GW5A; and
- Excess lifetime cancer risks to a future residential receptor exceed 1 x 10^{-6} at wells MW06, MW07, and GW5A.

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8.0 REMEDIAL ACTION OBJECTIVES

Remedial action objectives (RAOs) are the goals that the remedial action alternatives proposed in the feasibility study (FS) are designed to achieve. RAOs can be subdivided into general RAOs, that are applicable to all CERCLA sites, and specific RAOs, that are applicable to conditions at OU 5. Specific RAOs must ensure that compliance with potential ARARs is achieved.

8.1 General and Specific Remedial Action Objectives for OU 5

Overall goals for the remedial action are to:

- Protect human health by reducing the risk from the potential exposures identified in the human health evaluation;
- Protect environmental receptors;
- Restore contaminated media for present and future land use;
- Protect uncontaminated media by preventing releases from sources;
- Expedite site cleanup by applying the U.S. EPA Superfund Accelerated Cleanup Model goals; and
- Use permanent solutions and alternative treatment technologies to the maximum extent practicable.

Specific remedial action objectives derived from these goals are identified in Table 8-1. To meet these specific objectives, a range of remedial alternatives have been developed to allow an appropriate, cost-effective remedial action to be selected.

8.2 Potential Location- and Action-Specific ARARs

Section 7.0 specified potential contaminant-specific ARARs, which were the criteria used to establish geographical areas and contaminants of concern to be carried

Table 8-1

Specific Remedial Action Objectives for OU 5

Remedial Action Objectives

- Meet potential contaminant-, action-, and location-specific ARARs.
- Reduce the site's cancer risk to between 1 x 10^{-4} and 1 x 10^{-6}, and reduce the non-carcinogen hazardous index to less than one. For detailed analysis of the remedial action alternatives, an excess cancer risk of 1 x 10^{-6}, the most conservative point of the acceptable range, was used. A single cancer risk number was needed to define potential response areas. Using 10^{-6} to evaluate alternatives does not mean that this cancer risk is the approved risk management goal. The goal will be established after regulatory comments are incorporated into this FS and as the proposed plan is being developed and reviewed by the public.
- Reduce the risk posed by contaminants that present an unacceptable level of risk to the existing ecology.
- Prevent any contaminants with detectable levels exceeding potential ARARs from reaching Ship Creek.
- Select alternatives that include treatment, where applicable and practicable, as opposed to alternatives that are limited to simply moving contamination to disposal sites.
- Optimize the cost/risk reduction quotient, i.e., select cost effective alternatives.
- Abate any imminent hazards to water supplies or environmental receptors.
- Design the remedial action for groundwater to address contaminants from groundwater at Elmendorf AFB upgradient from OU 5. Build enough flexibility into the alternatives to allow for addressing new contaminants and varying concentrations of contaminants.
- Maintain the physical integrity of the bluffs and other topographical features.
- Maintain the integrity of the wetlands area. Minimize disruption to the natural flow of water through the wetlands system so that effects on existing ecology and water balance are minimized.
- Meet all Federal Facility Agreement schedule due dates.

forward into this FS. Two other types of potential ARARs must be also considered as alternatives are being evaluated.

8.2.1 Potential Location-Specific ARARs

Potential location-specific ARARs are requirements that affect the management of hazardous constituents, or the units in which they are managed, due to the location of the unit(s). They might be triggered, for example, if groundwater remediation were selected as a remedial action which required the construction of new surface wastewater treatment units. Examples of sensitive locations for such units include wetlands, floodplains, historic areas, and wildlife refuges. More details on potential location-specific ARARs are presented in Section 3.0 of Appendix N, Potential ARARs Identification.

8.2.2 Potential Action-Specific ARARs

Potential action-specific ARARs are technology-based or activity-based requirements that may be triggered by the particular remedial action chosen for OU 5. Potential action-specific ARARs do not in themselves determine the remedial action; rather, they place restrictions on the manner in which a selected alternative may be achieved. While the remedial action for this OU has yet to be specified, it is useful to consider potential ARARs as early as possible. More details on potential action-specific ARARs are presented in Section 4.0 of Appendix N, Potential ARARs Identification.

8.3 Interim Remediation Goals

Interim remediation goals are specific clean-up levels and related requirements to be met at OU 5. These goals are based on the RAOs identified in Sections 8.1 and 8.2. These goals are specified for all contaminants of concern (COCs) in each environmental medium. Interim remediation goals and general response actions are summarized for soil, sediments, groundwater, surface water, and seepage in Table 8-2. These goals are

Table 8-2

Summary of Interim Remediation Goals and General Response Actions for OU 5

Environmental Medium	COC	Remediation Goals	General Response Action	Comments
Soil (includes sediments)	Fuel hydrocarbons	100 mg/kg for TFH-gasoline 200 mg/kg for TFH-diesel	Natural degradation Institutional action Excavation/Disposal Containment Ex-Situ treatment In-Situ treatment	Based on Alaska Guidance on Surface and Groundwater Cleanup Levels (a potential TBC). To define geographic areas that may require remediation, a single acceptable risk target is needed. To define this target, the most conservative value of 1×10^{-6} risk was used. This value is the high end of the typically acceptable range of 1×10^{-4} to 1×10^{-6}.
	Aromatic VOCs	1×10^{-6} cancer risk Hazard Index of 1		
Water (includes groundwater, surface water, and seeps)	Fuel hydrocarbons VOCs	Meet MCLs and MCLGs for all COCs (e.g., 5 μg/L for benzene and TCE) 1×10^{-6} cancer risk Hazard Index of 1 Preserve the wetland areas No visible sheens on surface water 10 μg/L for TFHs in surface waters	Natural attenuation Institutional action Containment Ex-Situ treatment In-Situ treatment	MCLs and MCCs are key potential ARARs. Non-zero MCLGs and, if none, the MCLs are generally relevant and appropriate for any aquifer that is a potential drinking-water source. To define geographic areas that may require remediation, a single acceptable risk target is needed. To define this target, the most conservative value of 1×10^{-6} risk was used. This value is the high end of the typically acceptable range of 1×10^{-4} to 1×10^{-6}. Wetland standards are likely to apply in "wetland" areas of OU 5. A formal determination of the wetland status is needed to determine if the standards apply. 10 μg/L TFH standard and no visible sheens based on Alaska Water Quality Standards.

COC = Chemical of concern
VOC = Volatile organic compound
TFH = Total fuel hydrocarbons
ARAR = Applicable or relevant and appropriate requirement

TBC = To be considered
MCL = Maximum contaminant level
MCC = Maximum contaminant concentration
MCLG = Maximum contaminant level goal

preliminary in that negotiations between the Air Force and regulatory agencies are required before these interim goals can be finalized. Since the water media are so closely related at OU 5, i.e., water interfaces between the media, a single "water" medium was selected to simplify the analysis. The cleanup standards were selected based on protectiveness criteria and the requirements of law. Because the groundwater upgradient from OU 5 is not fully characterized, these remediation goals could change based on future remedial investigation efforts.

8.4 General Response Actions

The identification of remedial action objectives and potential ARARs, together with the evaluation of environmental media and COC-specific remediation goals, has led to the selection of the following potential general response actions for soil and water:

- Natural attenuation;
- Institutional controls;
- Containment;
- Excavate and dispose (soil only);
- Extract, treat, and dispose; and
- In-situ treatment.

The remainder of the FS identifies, screens, and selects technologies, process options, and alternatives that may be used to implement these response actions. Each of these technologies, process options, and alternatives must be evaluated by their ability to achieve both the RAOs and interim remediation goals presented in this section.

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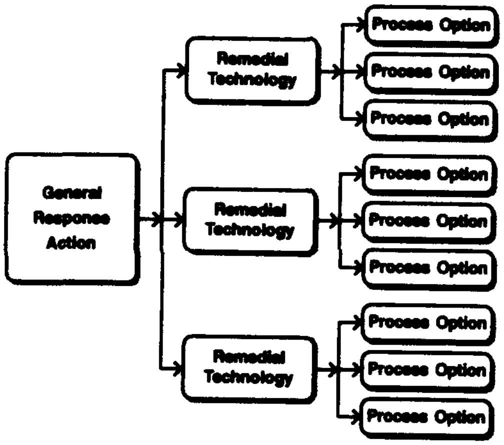
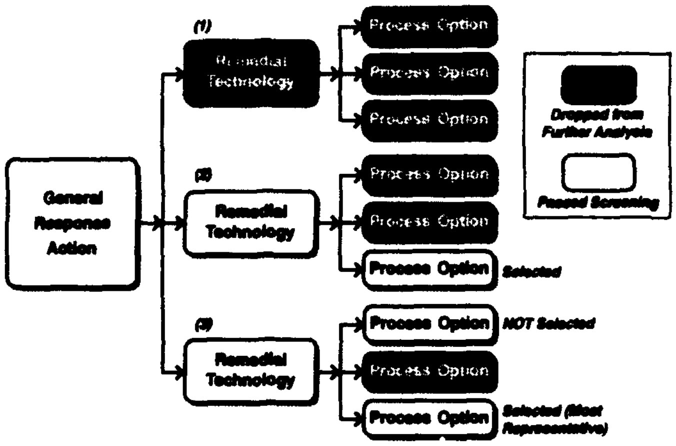
9.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

The identification and screening of remedial technologies is a two-step process, which is displayed in the two figures below. The process took into consideration the environmental conditions at Operable Unit (OU) 5 and the remedial action objectives. The identification process began by defining **general response actions**. A general response action is a type of remedial action that alone, or in combination with other actions, could potentially satisfy the remedial action objectives for OU 5. Potential **remedial technologies** and specific **process option(s)** for each technology were then identified that would have the potential to implement each general response action. This identification process is displayed below.



Technology and Process Option Identification

Once the above process options were identified, they were then screened and selected for applicability to the conditions at OU 5. This selection process is displayed below.



Technology and Process Option Selection

The figure indicates three possibilities. In (1), all process options were screened out, which means the associated technology also gets screened out. In (2), only one option passes the screening and is, therefore, selected. In (3), two options pass the screening. However, to simplify the rest of the feasibility study (FS), only the process option thought to be the best at meeting the criteria, i.e., most representative, is selected for further analysis in Section 10.

Once this initial screening is complete, different combinations of applicable response actions, technologies, and process options will be combined into remedial alternatives. These alternatives will later address different media at the different geographical locations within OU 5.

To identify general response actions, OU 5 was divided into two media: water (groundwater, seeps, and surface water) and soil (including sediment). Groundwater includes the unconfined aquifer upgradient of OU 5 beneath Elmendorf Air Force Base (AFB). Seeps are springs and seeps downgradient of the bluff area. Surface water includes ditches, ponds, and other expressions of surface water downgradient from the seeps. These three types of water were combined in the analysis because water migrates from one state to the other and because technologies and process options to remediate each are similar. Soil includes unconsolidated deposits from the surface to the water table within the geographic area of OU 5.

9.1 General Response Actions for Water

Five general response actions were identified for water.

9.1.1 Natural Attenuation

This response action involves no remedial response at OU 5. Natural attenuation is relied upon to degrade, adsorb, or volatilize any contaminants of concern. Natural attenuation is used as a baseline to compare alternatives.

9.1.2 Institutional Actions

Institutional actions limit human exposure to the groundwater and surface water. Institutional actions could include access restrictions (fencing, warning signs), restrictions on groundwater use, and monitoring.

9.1.3 Containment

Containment prevents or minimizes the spread of contaminated water through the use of barriers. Containment methods include capping and hydraulic barriers. Containment would not reduce the toxicity or volume of contamination; however, it could serve to limit contaminant mobility to the area within the barriers by constraining the contaminant's ability to migrate beyond the physical barriers. Containment is typically used as part of a remedial alternative that limits migration rather than eliminating contaminant concentrations.

9.1.4 Extraction/Treatment/Discharge

This response action consists of collecting and treating contaminated water, and then discharging it. Possible extraction methods include use of vertical or horizontal extraction wells and interceptor trenches. The water can be treated using physical, chemical, or biological methods prior to on-site or off-site discharge.

9.1.5 In-Situ Treatment

Contaminated water could be treated in-situ using chemical oxidation, air sparging, permeable treatment beds, vapor extraction, bioremediation, or steam stripping methods. These methods will often also treat the soil in contact with the contaminated water.

9.2 General Response Actions for Soil

Six general response actions were identified for soil.

9.2.1 Natural Degradation

The term "Degradation" is used for soils as opposed to "Attenuation" used for water since the processes differ slightly. Soils degrade contaminants through adsorption and biological destruction/oxidation capability of naturally occurring bacteria. In the wetlands environment, additional attenuation occurs through biological uptake processes of organisms and plants.

9.2.2 Institutional Controls

Institutional controls include actions such as land use deed restrictions and fencing. As with water, institutional controls are used to limit human exposure to the contaminants in the soil.

9.2.3 Excavation and Disposal

Contaminated soils are excavated and transported directly to an on- or off-base landfill for disposal. This general response action would result in removal of some of the contamination and would, therefore, help achieve the applicable cleanup criteria. Removal of contaminants would also reduce long-term risk to human health, but may be offset by the short-term risks associated with the actual excavation.

9.2.4 Containment

Containment prevents or minimizes the spread of contaminants by reducing the infiltration of rainwater and reducing dust migration. Direct contact with contaminated soil is eliminated and the potential for migration of contaminants to surrounding soil by rainwater runoff and infiltration is reduced. Containment methods include capping, vertical barriers, sediment control barriers, and lateral barriers.

9.2.5 Excavation/Treatment/Disposal

Contaminated soil is excavated, treated, and disposed. Treatment methods might include soil washing, low temperature thermal treatment, biopiling or incineration. Disposal options could include reburial or disposal in on-base or off-base landfills. The resulting holes can be backfilled, or treated soil could be used for general fill if clean-up levels are achieved. As with the excavate and disposal option (Section 9.2.3), this action will help achieve cleanup levels and reduce long-term risk, but may result in a short-term increase in risk.

9.2.6 In-Situ Treatment

In-situ treatment methods are implemented without excavating the contaminated soil. In-situ treatment includes stabilization, soil heating, soil vapor extraction with offgas treatment, in-situ vitrification, bioventing, and bioremediation. Additionally, combinations of these process options may be used (e.g., vapor extraction enhanced by steam injection).

9.3 Identification and Screening of Technology Types and Process Options

Technology types and process options that may be applicable to OU 5 are discussed below. Descriptions of the technologies are provided in Appendix S. The purpose of this Appendix is to provide the reader with general background information on the technologies to assist in understanding the analyses to follow. An initial screening was performed to reduce the number of technology types and process options based on the three Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) screening criteria of effectiveness, implementability, and cost.

9.3.1 Identification and Screening of Technologies

For each media-specific general response action, remedial technologies were identified that are potentially applicable to the contamination at OU 5. Specific process options were then identified for each technology. For instance, under the general response actions that include treatment, the technologies could include physical treatment, chemical treatment, biological treatment, and thermal treatment. Process options for chemical treatment could include precipitation and carbon adsorption, among others. The sources for process option selection were EPA CERCLA guidance documents, Air Force Center for Environmental Excellence (AFCEE) guidance and experience at numerous other CERCLA sites.

A summary of the evaluation is shown in Tables 9-1 and 9-2. In this evaluation, effectiveness was a measure of: 1) the suitability of the process option for handling the estimated areas and volumes of media and for meeting the remediation goals; 2) the potential impacts to human health and the environment during the construction and implementation phase; and 3) the reliability of the process with respect to the contaminants and conditions at the site. Both short and long term effectiveness were considered.

The implementability of each process option was evaluated for both technical and administrative feasibility to implement each option at OU 5. Issues considered included the developmental state of the technology (commercial, bench scale, etc.); conditions at OU 5; the ability to obtain necessary permits (or satisfy the substantive requirements of a permit); the availability of treatment, storage, and disposal (TSD) facilities; the availability of necessary equipment and skilled workers to implement the technology; and political and public perception.

Relative capital and operation and maintenance (O&M) costs were identified as high, moderate, or low compared to other process options within the same remedial technology. A present-worth cost exceeding $5 million was considered high, $1.5 to $5 million moderate, and less than $1.5 million was considered low. Costs are provided for comparative purposes, but options were not screened out based on cost alone. However, costs could be a factor in selecting from several similar screened process options. To provide general cost estimates at this stage, consideration was given to the site specific conditions at OU 5. However, specific volumes of water and soil requiring remediation were not calculated at this stage. Costs were for typical applications at CERCLA sites similar to OU 5. The actual volumes and/or quantities of soils and water to be remediated would be a function of system design and applicable or relevant and appropriate requirements (ARARs). Estimates of volumes to be remediated, per alternative, are provided in the detailed analysis of alternatives in Section 11.0 and the back-up for Cost Estimating (Appendix T).

The process options that are not shaded in Tables 9-1 and 9-2 were considered to be potentially implementable and effective at OU 5. The shaded options were dropped from further consideration because of difficulties in implementation or their marginal effectiveness. The specific reasons for eliminating process options are noted in the tables.

9.3.2 Selection of Technologies

To develop and evaluate alternatives, a single process option was selected to represent all of the technologies for a particular general response action. Combinations of responses actions, technologies and process options will later be assembled into alternatives to address remedial actions. Identifying representative process options greatly simplifies the identification and evaluation of alternatives. The rationale for selecting a representative option included superior effectiveness, ease of implementability, and/or relative cost compared to other equally effective options. Not all remedial technologies were selected as representative process options. However, all general response actions are represented. The representative process options selected for water and soil, along with the rationale for selection, are shown in Tables 9-3 and 9-4. In most cases, one effective and implementable process option is identified for each viable technology. However, for some general response actions, more than one process option was worth evaluating.

9.3.3 Surface Water and Sediments

Due to their unique characteristics, surface water bodies, and the soil sediments beneath them, at OU 5 demand specific analysis. Surface water evaluated in this FS are grouped into the following:

- Beaver Pond;
- Snowmelt Pond; and
- Ditches unrelated to the Beaver and Snowmelt ponds.

Each of these surface water bodies, along with their associated sediments, will not require further analysis for the remediation alternatives described in Sections 10 and 11 due to site-specific factors. These factors are described in the text below.

Beaver Pond—The Beaver Pond wetlands system consists of an 18-acre wetlands as described in Appendix R, the Beaver Pond Study. For Beaver Pond, no response actions, other than natural attenuation and institutional controls, were determined to be both effective and implementable. Any attempt to either contain, excavate, or treat in-situ surface water or sediments using any of the process options in Tables 9-1 or 9-2 would have a severe detrimental effect on the wetlands area. For example, physically removing visible sheens, dredging sediments, or processing wetlands water through a treatment facility would all upset ecological balances, disturb the water flow, and/or violate potential ARARs, that specify minimal disturbance of wetlands. The risk of upsetting the ecological balance of Beaver Pond is great in comparison to the relative lack of significant concentrations of COCs in the pond. Also, since the source of any contaminants in Beaver Pond is from the seeps and groundwater, effective measures to remediate the seeps and groundwater will eventually reduce contamination. It has been demonstrated in the Beaver Pond Study (see Appendix R), that Beaver Pond is a viable natural wetland that can remediate chemicals entering it.

Snowmelt Pond—Snowmelt Pond is described in detail in Appendix Q. Chapter 7 concluded that ecological impacts are a concern for aquatic life at this location due to the concentrations of PCB in the sediments. This site is unique in that it is the only location within OU 5 where PCBs are a constituent of concern. The options for dealing with this site are very limited. Natural attenuation processes are not as effective on PCBs as on the other OU 5 constituents of concern, i.e., VOCs and fuel hydrocarbons. Excavation of sediments would create risks of spreading the PCBs to downstream ditches. No effective in-situ treatment methods are known unless the sites were drained. Draining may be impractical because the water levels are controlled to a degree by groundwater infiltration. Thus, containment is the only applicable general response action. Capping is not implementable or effective in a wetlands or saturated environment because of the groundwater infiltration that would either inundate or "float" the cap. The only available option to reasonably prevent exposure to the PCBs in the sediment is to prevent contact with environmental receptors by isolating the sediment with a material such as sand or gravel. To treat the sheens caused by discharging groundwater, Snowmelt Pond would be converted into a constructed wetland, with the gravel cover being an integral part of the subflow design of the wetland. Since isolating the sediment and converting the pond to a wetland is the only implementable and effective remedial action at this location, it is defined as the presumptive remedy for Snowmelt Pond. No further analysis of alternatives to remediate these sediments is therefore required in Sections 9, 10, and 11 of this FS. However, each of the soil remediation alternatives in Section 11, Table 11-6 will include the costs for this presumptive remedy, which will be carried forward into the comparative analysis in Section 11.

Ditches—This pathway consists of all ditches, ponds, and other surface water that is not connected into either the Beaver Pond or Snowmelt Pond hydrologic system. Regulation of these ditches is more appropriately carried out under the Elmendorf AFB NPDES program, as opposed to the CERCLA program. The NPDES program is designed to monitor discharges and implement corrective actions for any discharges found to have a detrimental effect on human health or the environment. The NPDES program at Elmendorf AFB should therefore regulate the discharge of this surface water, and take into consideration the results of this RI/FS in identifying appropriate constituents to monitor.

Table 9-1

Summary of Evaluation of Process Options for Water

☐ Technologies and process options selected for further analysis.

▨ Technologies and process options dropped from further analysis. The number in the lower right corner of the Process Option box indicates the reason(s) for screening out.

General Response Actions	Remedial Technology	Process Options	Media[1]	Effectiveness	Implementability	Cost[2]
Natural Attenuation	Includes natural attenuation within the wetlands and in the groundwater	Not applicable, although mechanisms include adsorption, microbial breakdown, volatilization, and filtration.	S,G	Natural attenuation will provide some degree of treatment. Modeling and monitoring programs required to determine level of effectiveness.	Easily implemented, assuming public and regulatory acceptance.	Low
Institutional Action	Access restrictions	Deed/water rights restrictions, fences.	S,G	Effectiveness depends on continued future implementation. Does not reduce contamination.	Implementable for on-base contamination as long as base maintains control over land use. Implementability decreases for off-base contamination since coordination with private parties and legal issues can decrease likelihood for protective deed restrictions.	Low
		Land purchase/eminent domain	S,G	Effectiveness depends on continued future implementation. Does not reduce contamination.	Purchase must be negotiated with current land owners. Further migration of contamination could require additional land acquisition.	Moderate

[1] Media treated: groundwater (g) and seeps (s)

[2] Costs are present-worth and include both capital and operation/maintenance costs
Low = <$1.5 million; Moderate = $1.5 to $5 million; High = >$5 million

[3] No reduction in risk achieved

[4] Very difficult to implement in a bluff or wetlands environment

[5] Not effective on the contaminants of concern

[6] Difficulty in obtaining regulatory approvals/public acceptance

[7] Does not prevent migration of contaminants

[8] Detrimental effect on future land use

[9] Limited commercial experience or extensive equipment and/or land involved

[10] Groundwater treated if actively extracted

Table 9-1

(Continued)

☐ Technologies and process options selected for further analysis.

▨ Technologies and process options dropped from further analysis. The number in the lower right corner of the Process Option box indicates the reason(s) for screening out.

General Response Actions	Remedial Technology	Process Options	Media[1]	Effectiveness	Implementability	Cost[2]
Institutional Action (cont.)	Alternate water supply	Domestic. Provide alternate water supply to domestic (municipal and private) users. 3, 7, 8	G	No known domestic users of shallow groundwater so no beneficial effect. However, could provide beneficial effect to future users.	Alternate water supplies can be obtained.	Moderate
		Agricultural. Provide alternate water supply for agricultural users. 3, 7, 8	G	No known agricultural users of shallow groundwater so no beneficial effect. However, could provide beneficial effect to future users.	Alternate water supplies can be obtained.	Moderate
		Industrial. Provide alternate water supply for industrial users. 3, 7, 8	G	No known industrial users of shallow groundwater so no beneficial effect. However, could provide beneficial effect to future users.	Alternate water supplies can be obtained.	Moderate
	Monitoring	Monitoring wells and surface water sampling.	S,G	Effectively documents current conditions and degree of treatment achieved.	Easily implemented.	Low

[1] Media treated: groundwater (g) and seeps (s)

[2] Costs are present-worth and include both capital and operation/maintenance costs
Low = <$1.5 million; Moderate = $1.5 to $5 million; High = >$5 million

[3] No reduction in risk achieved

[4] Very difficult to implement in a bluff or wetlands environment

[5] Not effective on the contaminants of concern

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[7] Does not prevent migration of contaminants

[8] Detrimental effect on future land use

[9] Limited commercial experience or extensive equipment and/or land involved

[10] Groundwater treated if actively extracted

Table 9-1

(Continued)

☐ Technologies and process options selected for further analysis.

▨ Technologies and process options dropped from further analysis. The number in the lower right corner of the Process Option box indicates the reason(s) for screening out.

General Response Action	Remedial Technology	Process Options	Media	Effectiveness	Implementability	[illegible]
Containment	Vertical barrier	Slurry wall/grout curtain	S,G	In short term, effectively reduces lateral migration. Long term, groundwater, surface water, and seeps could back up and overflow the barrier. Usually requires associated pumping and/or capping actions to maintain effectiveness.	Difficult to implement due to limited access and construction in wetland environment.	High
		Sheet pile wall	S,G	In short term, effectively reduces lateral migration. Long term, groundwater, surface water, and seeps could back up and overflow the barrier. Usually requires associated pumping and/or capping actions to maintain effectiveness.	Difficult to implement due to limited access and construction in wetland environment. More difficult to construct than slurry walls.	High
		Injection wells (hydraulic barrier)	S,G	In short term, effectively reduces lateral migration. Long term, groundwater, surface water, and seeps could migrate laterally around injection well.	Difficult to implement due to limited access and construction in wetland environment. Also extensive areas of contamination would require large and complex well system. Also detrimental effect on water balance.	Moderate

[1] Media treated: groundwater (g) and seeps (s)

[2] Costs are present-worth and include both capital and operation/maintenance costs
Low = <\$1.5 million; Moderate = \$1.5 to \$5 million; High = >\$5 million

[3] No reduction in risk achieved

[4] Very difficult to implement in a bluff or wetlands environment

[5] Not effective on the contaminants of concern

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[8] Detrimental effect on future land use

[9] Limited commercial experience or extensive equipment and/or land involved

[10] Groundwater treated if actively extracted

Table 9-1

(Continued)

☐ Technologies and process options selected for further analysis.
▨ Technologies and process options dropped from further analysis. The number in the lower right corner of the Process Option box indicates the reason(s) for screening out.

General Response Actions	Remedial Technology	Process Options	Media[1]	Effectiveness	Implementability	Cost[2]
Containment (cont.)	Vertical barrier (cont.)	Booms and barriers for surface water 4, 7	S	Limits migration of hydrocarbons, but not reduction in contaminant concentrations. Limiting migration is not an effective option for surface water since exposure pathway still exists.	Implementable, but aesthetically undesirable and potential negative effect on wetlands ecology.	Low
		Grout injection (subsurface barrier) which creates a solidified horizontal barrier through the injection of a grout slurry that hardens 4, 7	S,G	Limits vertical migration if used in conjunction with other barriers such as vertical barriers. No reduction in contaminant concentrations. No effect on lateral migration, which is the dominant direction of movement.	Difficult to implement. Collects water that must be removed. Limited space along bluff. Sensitive wetland environments could affect implementability. Horizontal barriers are even more difficult to implement than vertical barriers since they would require greater disruption of the wetlands areas.	High
	Horizontal barrier	Capping with clay, asphalt, or concrete 4, 7	S	Limits downward migration of contaminants to groundwater from the soil. No effect on lateral migration, which is the dominant direction of movement.	Implementable, although to have a significant effect, the extensive areas required to be capped would be very expensive and could disrupt base operations.	High

[1] Media treated: groundwater (g) and seeps (s)
[2] Costs are present-worth and include both capital and operation/maintenance costs
Low = <$1.5 million; Moderate = $1.5 to $5 million; High = >$5 million
[3] No reduction in risk achieved
[4] Very difficult to implement in a bluff or wetlands environment
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[9] Limited commercial experience or extensive equipment and/or land involved
[10] Groundwater treated if actively extracted

Table 9-1
(Continued)

☐ Technologies and process options selected for further analysis.
▨ Technologies and process options dropped from further analysis. The number in the lower right corner of the Process Option box indicates the reason(s) for screening out.

General Response Action	Remedial Technology	Process Options	Media[1]	Effectiveness	Implementability	Cost[2]
Collection/Treatment/Discharge						
Collection	Extraction	Extraction wells	S,G	Effective removal of contaminated groundwater. Could affect ecology unless flow rates of water into the wetlands are maintained after collection.	Wells can be drilled and pumps installed.	Moderate
		Horizontal drains (lateral pipes into bluff)	S	Effective removal of water, but only water that can be drained, without pumping, from the upper portion of the shallow aquifer. Could affect ecology unless water balance of the wetlands is maintained after collection.	Lateral drains easily drilled. Must maintain slope stability, or drains could be damaged.	Low
	Surface collectors	Berm/swale (earth)	S	Effective capture of seeps although constituents could migrate through earth. Could affect flow into wetlands and have negative impact on ecology.	Implementable. Limited access and construction problems could affect portions of the installation.	Low
		Concrete trench	S	Effective capture of seeps. Could affect flow into wetlands and have negative impact on ecology.	Implementable. Limited access and construction problems could affect portions of the installation.	Moderate

[1] Media treated: groundwater (g) and seeps (s)
[2] Costs are present-worth and include both capital and operation/maintenance costs Low = <\$1.5 million; Moderate = \$1.5 to \$5 million; High = >\$5 million
[3] No reduction in risk achieved
[4] Very difficult to implement in a bluff or wetlands environment
[5] Not effective on the contaminants of concern
[6] Difficulty in obtaining regulatory approvals/public acceptance
[7] Does not prevent migration of contaminants
[8] Detrimental effect on future land use
[9] Limited commercial experience or extensive equipment and/or land involved
[10] Groundwater treated if actively extracted

Table 9-1

(Continued)

▭ Technologies and process options selected for further analysis.
▨ Technologies and process options dropped from further analysis. The number in the lower right corner of the Process Option box indicates the reason(s) for screening out.

General Response Action	Remedial Technology	Process Options	Media[1]	Effectiveness	Implementability	Cost[2]
Collection (cont.)	Subsurface drains	Collection trenches (French drain)	S,G	Effectively removes shallow groundwater. Could affect flow into wetlands and have negative impact on ecology.	Moderately difficult to implement due to space limitations. Potential to disrupt wetlands although not as much as other remedial actions, such as permeable beds and grout injection, which require greater depths of excavation.	Moderate
Ex-Situ Treatment	Biological treatment (Aerobic)	Activated Sludge 9	S,G[10]	Effectively breaks down organic compounds.	[illegible]	High
		Fixed film 9	S,G[10]	Effectively breaks down organic compounds.	[illegible]	High
	Biological treatment (Anaerobic)	Fixed bed reactor 5	S,G[10]	TPH does not readily degrade anaerobically.	[illegible]	Moderate
		Fluidized bed reactor 5	S,G[10]	TPH does not readily degrade anaerobically.	[illegible]	Moderate
	Physical treatment	Gravity separation	S,G[10]	[illegible] VOCs.	Easily implemented.	Low

[1] Media treated: groundwater (g) and seeps (s)
[2] Costs are present-worth and include both capital and operation/maintenance costs
Low = <$1.5 million; Moderate = $1.5 to $5 million; High = >$5 million
[3] No reduction in risk achieved
[4] Very difficult to implement in a bluff or wetlands environment
[5] Not effective on the contaminants of concern
[6] Difficulty in obtaining regulatory approvals/public acceptance
[7] Does not prevent migration of contaminants
[8] Detrimental effect on future land use
[9] Limited commercial experience or extensive equipment and/or land involved
[10] Groundwater treated if actively extracted

Table 9-1

(Continued)

☐ Technologies and process options selected for further analysis.

▨ Technologies and process options dropped from further analysis. The number in the lower right corner of the Process Option box indicates the reason(s) for screening out.

General Response Action	Remedial Technology	Process Options	Media[1]	Effectiveness	Implementability	Cost[2]
Ex-Situ Treatment (cont.)	Physical treatment (cont.)	Air stripping	S,G[10]	Effective and reliable for removal of volatile contaminants. Must be used in conjunction with other technologies to remove metals and semivolatiles.	Technology available and implementable. Treatment unit must be located on top of the bluff, which would require water to be pumped up to the unit. Pipes containing this water must be protected from breakage due to potential slope failure. Air permitting and monitoring requirements for vapor discharges.	High
		Steam stripping [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Carbon adsorption	S,G[10]	Effective and reliable for organics.	Easily implemented. Requires regeneration of carbon.	High
		Reverse osmosis [illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[1] Media treated: groundwater (g) and seeps (s)

[2] Costs are present-worth and include both capital and operation/maintenance costs
Low = <\$1.5 million; Moderate = \$1.5 to \$5 million; High = >\$5 million

[3] No reduction in risk achieved

[4] Very difficult to implement in a bluff or wetlands environment

[5] Not effective on the contaminants of concern

[6] Difficulty in obtaining regulatory approvals/public acceptance

[7] Does not prevent migration of contaminants

[8] Detrimental effect on future land use

[9] Limited commercial experience or extensive equipment and/or land involved

[10] Groundwater treated if actively extracted

Table 9-1

(Continued)

☐ Technologies and process options selected for further analysis.
▨ Technologies and process options dropped from further analysis. The number in the lower right corner of the Process Option box indicates the reason(s) for screening out.

General Response Actions	Remedial Technology	Process Options	Media[1]	Effectiveness	Implementability	Cost[2]
Ex-Situ Treatment (cont.)	Physical treatment (cont.)	Ultrafiltration 5	S,G[10]	Effective, although a single system unlikely to be effective on all COCs.	Implementable. Water pressure and filter use must be carefully monitored.	Moderate
		Ion exchange 5	S,G[10]	Effective only for the removal of ionic contaminants. Must be used in conjunction with other technologies to be effective.	Implementable. Organics may degrade resin.	Moderate
	Chemical Treatment	Chemical oxidation, with possible addition of oxidizing agent such as ultraviolet light.	S,G[10]	Effective destruction of organics.	Implementable. Requires treatability tests to select correct oxidizing agent and dosages. Oxidizing agents may be hazardous materials requiring special care.	Moderate
		Chemical dechlorination 5	S,G[10]	Effective destruction of chlorinated contaminants. Does not treat non-chlorinated compounds.	Implementable.	Moderate

[1] Media treated: groundwater (g) and seeps (s)
[2] Costs are present-worth and include both capital and operation/maintenance costs
Low = <\$1.5 million; Moderate = \$1.5 to \$5 million; High = >\$5 million
[3] No reduction in risk achieved
[4] Very difficult to implement in a bluff or wetlands environment
[5] Not effective on the contaminants of concern
[6] Difficulty in obtaining regulatory approvals/public acceptance
[7] Does not prevent migration of contaminants
[8] Detrimental effect on future land use
[9] Limited commercial experience or extensive equipment and/or land involved
[10] Groundwater treated if actively extracted

Table 9-1

(Continued)

☐ Technologies and process options selected for further analysis.

▨ Technologies and process options dropped from further analysis. The number in the lower right corner of the Process Option box indicates the reason(s) for screening out.

General Response Actions	Remedial Technology	Process Options	Media[1]	Effectiveness	Implementability	Cost[2]
Ex-Situ Treatment (cont.)	Wetland Remediation	Constructed wetlands	S,G[10]	Effective on metals and organics. May have reduced effectiveness in cold months. Monitoring required to demonstrate effectiveness.	Implementable. Requires close monitoring of parameters to ensure optimal performance. Relatively high flow will require extensive land on top of bluff to provide adequate residence time. A lower flow constructed wetland can be built below the bluff by altering Snowmelt Pond.	Low
Discharge	On-site discharge	Direct discharge to Ship Creek 6	S,G	[illegible]	[illegible]	[illegible]
		Direct discharge to reinjection wells	S,G	Effective disposal method. May upset the water balance of the wetlands if water is reinjected that would have gone to the wetlands areas.	Discharge limits and monitoring required. Potential regulatory and public perception problems. Reinjection must be designed to not contaminate Ship Creek.	Moderate

[1] Media treated: groundwater (g) and seeps (s)

[2] Costs are present-worth and include both capital and operation/maintenance costs
Low = <\$1.5 million; Moderate = \$1.5 to \$5 million; High = >\$5 million

[3] No reduction in risk achieved

[4] Very difficult to implement in a bluff or wetlands environment

[5] Not effective on the contaminants of concern

[6] Difficulty in obtaining regulatory approvals/public acceptance

[7] Does not prevent migration of contaminants

[8] Detrimental effect on future land use

[9] Limited commercial experience or extensive equipment and/or land involved

[10] Groundwater treated if actively extracted

Table 9-1

(Continued)

☐ Technologies and process options selected for further analysis.
▨ Technologies and process options dropped from further analysis. The number in the lower right corner of the Process Option box indicates the reason(s) for screening out.

General Response Actions	Remedial Technology	Process Option	Media[1]	Effectiveness	Implementability	Cost[2]
Discharge (cont.)	On-site discharge (cont.)	Wetlands	S,G	Effective disposal method.	Discharge limits and monitoring required. Potential regulatory and public perception problems.	Low
	Off-site discharge	Direct discharge to off-site reinjection wells	S,G	Effective disposal method. May upset the water balance of the wetlands if water is reinjected that would have gone to the wetland areas.	Discharge limits and monitoring required. Potential regulatory and public perception problems. Reinjection must be designed to prevent contamination of Ship Creek.	Moderate
		Treated water discharged to POTW.	S,G	Effective.	POTW may not accept the discharge because of volume. Reinjection must be designed to not contaminate Ship Creek.	Low
In-Situ Treatment	Chemical treatment	Chemical oxidation 6, 9	G	Effective destruction of organics. Effectiveness limited by lithology and ability to contact all contaminated media.	Injection of reagents may require special permitting requirements. Reagents may also be hard to control and form undesirable by-products.	Moderate

[1] Media treated: groundwater (g) and seeps (s)
[2] Costs are present-worth and include both capital and operation/maintenance costs
Low = <\$1.5 million; Moderate = \$1.5 to \$5 million; High = >\$5 million
[3] No reduction in risk achieved
[4] Very difficult to implement in a bluff or wetlands environment
[5] Not effective on the contaminants of concern
[6] Difficulty in obtaining regulatory approvals/public acceptance
[7] Does not prevent migration of contaminants
[8] Detrimental effect on future land use
[9] Limited commercial experience or extensive equipment and/or land involved
[10] Groundwater treated if actively extracted

Table 9-1

(Continued)

☐ Technologies and process options selected for further analysis.
▨ Technologies and process options dropped from further analysis. The number in the lower right corner of the Process Option box indicates the reason(s) for screening out.

General Response Action	Remedial Technology	Process Options	Media[1]	Effectiveness	Implementability	[illegible]
In-Situ Treatment (cont.)	Chemical treatment (cont.)	Permeable treatment beds	G	Effective and reliable. Effectiveness limited by lithology and ability to contact all contaminated media.	Implementable. Must monitor for medium breakthrough and then remove and replace treatment medium. Multiple construction efforts may be limited by space limitations and could disturb large areas of land.	Moderate
	Physical treatment	In-situ air stripping	G	Effective for removal of volatile contaminants. Effectiveness limited by lithology and ability to contact all contaminated media.	Implementable.	Low
	Biological treatment	Air sparging (note this option also has physical aspects due to ability to volatilize COCs).	G	Effective for destruction and volatilization of degradable organic contaminants. Effectiveness limited by lithology and ability to contact all contaminated media.	Implementable. Low ambient temperatures could impact degradation rates.	Low
	Thermal treatment	In-situ steam stripping	G	Effective for destruction of degradable organic contaminants. Effectiveness limited by lithology and ability to contact all contaminated media.	Implementable. Low ambient temperatures could impact removal rates, although this could be counteracted by heat from the steam.	Moderate

[1] Media treated: groundwater (g) and seeps (s)

[2] Costs are present-worth and include both capital and operation/maintenance costs
Low = <\$1.5 million; Moderate = \$1.5 to \$5 million; High = >\$5 million

[3] No reduction in risk achieved

[4] Very difficult to implement in a bluff or wetlands environment

[5] Not effective on the contaminants of concern

[6] Difficulty in obtaining regulatory approvals/public acceptance

[7] Does not prevent migration of contaminants

[8] Detrimental effect on future land use

[9] Limited commercial experience or extensive equipment and/or land involved

[10] Groundwater treated if actively extracted

Table 9-2

Summary of Evaluation of Process Options for Soil

☐ Technologies and process options selected for further analysis.

▨ Technologies and process options dropped from further analysis. The number in the lower right corner of the Process Option box indicates the reason(s) for screening out.

[illegible]	[illegible]	Process Option	[illegible]	[illegible]	[illegible]
Natural Degradation	Natural degradation	Not applicable, although mechanisms include natural, physical, chemical, and biological processes	Natural degradation will provide some degree of treatment.	Easily implemented, assuming public and regulatory acceptance.	Low
Institutional Action	Access Restrictions	Land Use Restrictions	Effectiveness depends on continued future implementation. Does not reduce contamination, or prevent migration of contaminated material.	Implementation for on-base contamination as long as base maintains control over land use. Implementability decreases for off-base contamination since coordination with private parties and legal issues can decrease likelihood for protective deed restrictions.	Low
		Deed Restrictions	Effectiveness depends on continued future implementation. Does not reduce contamination, or prevent migration of contaminated material.	Implementation for on-base contamination as long as base maintains control over land use. Implementability decreases for off-base contamination since coordination with private parties and legal issues can decrease likelihood for protective deed restrictions.	Low
		Land purchase/eminent domain	Effectiveness depends on continued future implementation. Does not reduce contamination, or prevent migration of contaminated material.	Purchase must be negotiated with current land owners.	Moderate
		Fencing	Effective and reliable.	Easily implemented. Base must maintain control over land use.	Low

[1] Costs are present-worth and include both capital and operation/maintenance costs. Low = <\$1.5 million; Moderate = \$1.5 to \$5 million; High = >\$5 million.

[2] No reduction in risk achieved

[3] Very difficult to implement in a bluff or wetlands environment

[4] Not effective on the contaminants of concern

[5] Difficulty in obtaining regulatory approvals/public acceptance

[6] Does not prevent migration of contaminants

[7] Detrimental effect on future land use

[8] Limited commercial experience or extensive equipment and/or land involved

Table 9-2

(Continued)

☐ Technologies and process options selected for further analysis.

▨ Technologies and process options dropped from further analysis. The number in the lower right corner of the Process Option box indicates the reason(s) for screening out.

General Response Action	Remedial Technology	Process Options	Effectiveness	Implementability	[illegible]
Institutional Action (cont.)	Access Restrictions (cont.)	Soil gas	Does not directly measure soil contamination.	Easily implemented.	Low
		Borings	Effective and reliable.	Easily implemented.	Low
Excavation/Disposal					
Excavation	Shallow Excavation (less than 15 feet in depth) and backfilling	Backhoe, bulldozer, scraper, truck loader, etc.	Effective and reliable, but only for top 10–15 feet of soil. Not effective on sediments in the beaver pond since disturbance of sediments would degrade surface water and disrupt the ecology of the pond.	Easily implemented.	Low
	Deep Excavation (greater than 15 feet in depth)	Clam shell 3	Effective.	[illegible]	[illegible]
		Drag line 3	Effective.	[illegible]	[illegible]

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[1] Costs are present-worth and include both capital and operation/maintenance costs. Low = <$1.5 million; Moderate = $1.5 to $5 million; High = >$5 million.

[2] No reduction in risk achieved

[3] Very difficult to implement in a bluff or wetlands environment

[4] Not effective on the contaminants of concern

[5] Difficulty in obtaining regulatory approvals/public acceptance

[6] Does not prevent migration of contaminants

[7] Detrimental effect on future land use

[8] Limited commercial experience or extensive equipment and/or land involved

Table 9-2

(Continued)

☐ Technologies and process options selected for further analysis.
▨ Technologies and process options dropped from further analysis. The number in the lower right corner of the Process Option box indicates the reason(s) for screening out.

General Response Action	Remedial Technology	Process Options	Effectiveness	Implementability	Cost
Disposal	Off-site disposal	RCRA landfill	Effective and reliable for hazardous wastes.	Nearest hazardous waste landfill is in Arlington, Oregon (Chemical Waste Management).	High
		Industrial landfill	Effective and reliable for non-hazardous, but contaminated soils (>100 mg/kg TFH)	Implementable, although public and industry concerns could arise over transport and disposal of soils from a CERCLA site.	Low
Containment	Capping	Bentonite and soil	Effective at preventing surface contact and reducing migration of contaminants. Cracks are self-healing. Less effective at preventing migration from the contaminated area if a hydraulic gradient still exists after capping (e.g., in a wetlands or seep environment).	Topography may limit cap location (e.g., caps on sloped areas not implementable). Saturated soil also inhibits installation (e.g., in a wetlands or seep environment).	Low
		Clay	Effective at preventing surface contact and reducing migration of contaminants. Susceptible to weathering and cracking. Less effective at preventing migration from the contaminated area if a hydraulic gradient still exists after capping (e.g., in a wetlands or seep environment).	Topography may limit cap location (e.g., caps on sloped areas not implementable). Saturated soil also inhibits installation (e.g., in a wetlands or seep environment).	Low

[1] Costs are present-worth and include both capital and operation/maintenance costs. Low = <$1.5 million; Moderate = $1.5 to $5 million; High = >$5 million.
[2] No reduction in risk achieved
[3] Very difficult to implement in a bluff or wetlands environment
[4] Not effective on the contaminants of concern
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Table 9-2

(Continued)

☐ Technologies and process options selected for further analysis.

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General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost
Containment (cont.)	Capping (cont.)	Asphalt	Same comments as clay cap, with increased protection from weathering. Also can allow for contaminated areas to be used beneficially if structural integrity is adequate.	Topography may limit cap location (e.g., caps on sloped areas not implementable). Saturated soil also inhibits installation (e.g., in a wetlands or seep environment).	Moderate
		Concrete	(Same as for asphalt cap)	Topography may limit cap location (e.g., caps on sloped areas not implementable). Saturated soil also inhibits installation (e.g., in a wetlands or seep environment).	Moderate
		Multi-media (e.g., RCRA cap with layers of clay and synthetic liners).	Most effective cap at preventing migration.	Topography may limit cap location (e.g., caps on sloped areas not implementable). Saturated soil also inhibits installation (e.g., in a wetlands or seep environment).	High
	Vertical Barrier	Slurry wall 6	[illegible]	[illegible]	[illegible]
		Grout curtain 6	[illegible]	[illegible]	[illegible]

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Table 9-2

(Continued)

☐ Technologies and process options selected for further analysis.
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General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost[1]
Containment (cont.)	Vertical Barrier (cont.)	Vibrating beam 6	Effective in minimizing lateral migration. However, limited effectiveness for vadose zone contamination where most migration is vertical.	Sufficient space is available at the top of the bluff.	Moderate
		Sheet pile wall 6	Effective in minimizing lateral migration. However, limited effectiveness for vadose zone contamination where most migration is vertical.	Sufficient space is available at the top of the bluff.	Moderate
	Subsurface horizontal barrier	Grout injection (injected horizontal layer of grout). 3	Effectively minimizes vertical migration, if used in conjunction with other barriers, i.e., vertical barriers.	Difficult to construct in a wetlands environment. Water buildup over grout must be removed. Horizontal barriers are more difficult to implement than vertical barriers since they would result in greater disruption of the wetlands areas.	Moderate
	Surface controls	Sediment control barriers (e.g., silt fences, berms) 3	Generally effective and reliable for reducing migration of contaminated surface soils (0-1 foot). However, these barriers would not be effective in a wetlands environment since barriers would overflow or be washed out.	Easily implemented.	Low

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Table 9-2

(Continued)

☐ Technologies and process options selected for further analysis.
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General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost[1]
Containment (cont.)	Surface controls (cont.)	Dust control 4	Generally effective and reliable for reducing migration of contaminated surface soils (0-1 foot) to air. However, not effective at OU 5 since air is not a pathway of concern.	Easily implemented.	Low
	Encapsulation	Total encapsulation. Horizontal barrier (described above) in addition to vertical barriers with a cap and minimal hydraulic control. 3	Effective in minimizing migration.	Difficult to implement in a wetlands environment. Contaminated water must be removed. Change in water movement through wetlands area caused by encapsulation media could affect slope stability.	Moderate
Excavation/Treatment/Disposal					
Excavation	(See Excavation and Disposal)				
Ex-Situ Treatment	Physical treatment	Soil washing 4	Effective removal of inorganic contaminants but less effective on organics. Not effective on coarse-grained soils.	Extensive equipment and labor required to build and operate. Generates aqueous stream that must be treated.	Moderate
		Solvent Extraction 8	Effective removal of organic contaminants. Effectiveness depends on selection of proper extraction solvent.	Extensive equipment and labor required to build and operate. Generates solvent stream that must be treated.	Moderate

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Table 9-2

(Continued)

□ Technologies and process options selected for further analysis.
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General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost[1]
Ex-Situ Treatment (cont.)	Physical treatment (cont.)	Steam stripping 8	Effective removal of volatile and semi-volatile contaminants.	Extensive equipment and labor required to build and operate. Generates vapor stream that generates condensate that must be treated.	Moderate
		Air stripping/vacuum extraction	Effective removal of volatile contaminants.	Implementable although requires much greater effort than in situ extraction. Generates vapor stream that must be treated.	Low
		Low temperature heat treatment 5	Effective removal of volatile and semi-volatile contaminants. Requires treatment of resulting vapor phase.	Complex equipment and extensive labor required to operate. Generates vapor stream that must be treated. Potential public concerns with thermal process.	Low
	Chemical treatment	Fixation/solidification	Effectively immobilizes most contaminants. Process can be reversible due to weathering.	Implementable, but not as effective in the presence of greater than 10% organics.	Moderate
		Chemical dechlorination 4	Effectively destroys chlorinated organics. Does not treat non-chlorinated contaminants.	Implementable.	Moderate
		Chemical oxidation	Effective destruction of organic contaminants. Could be used to treat soil washing supernatant.	Implementable.	Moderate

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Table 9-2

(Continued)

☐ Technologies and process options selected for further analysis.
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General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost
Ex-Situ Treatment (cont.)	Biological treatment	Slurry phase bioreactor 8	Effective destruction of degradable organic contaminants.	Extensive equipment and labor required to build and operate.	Moderate
		Solid phase reactor 8	Effective destruction of degradable organic contaminants.	Extensive equipment and labor required to build and operate.	High
		Biopiling, with addition of air and bulking agent	Effective destruction of degradable organic contaminants.	Implementable. Elmendorf AFB has existing biopiling area on base that could be expanded for this project.	Low
		Landfarming 8	Effective destruction of degradable organic contaminants. Limited effectiveness during winter months.	Requires large areas of land and extensive monitoring and permitting.	Low
		Two stage bioreactor 8	Effective destruction of degradable organic contaminants.	Extensive equipment and labor required to build and operate.	High
	Thermal treatment	Rotary kiln incineration 5,8	Effective on organics.	Both on- and off-site options are technically implementable, although vendors and commercial facilities are limited. However, public opposition would make process very difficult to implement.	High

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Table 9-2

(Continued)

☐ Technologies and process options selected for further analysis.

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General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	Cost[1]
Ex-Situ Treatment (cont.)	Thermal treatment (cont.)	Infrared incineration 5	Effective on organics.	Both on- and off-site options are technically implementable, although vendors and commercial facilities are limited. However, public opposition would make process very difficult to implement.	High
		Co-disposal, e.g., in a cement kiln 5	Effective on organics.	Off-site option is technically implementable, although vendors and commercial facilities are limited. However, public opposition would make process very difficult to implement.	High
		Pyrolysis 5	Effective on organics.	Both on- and off-site options are technically implementable, although vendors and commercial facilities are limited. However, public opposition would make process very difficult to implement.	High

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Table 9-2

(Continued)

☐ Technologies and process options selected for further analysis.

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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Disposal	On-site disposal	Industrial landfill (on base)	Effective and reliable for non-hazardous waste.	Implementable if a location on base could be found and permitted.	Moderate
		RCRA landfill (on-base)	Effective and reliable for hazardous waste.	Implementable if there is suitable location on base. Also would require extensive efforts to meet substantive landfill design requirements of RCRA.	High
		Backfill	Effective if treated to acceptable concentrations.	Implementable for general fill if clean-up levels are achieved.	Low
	Off-site disposal	RCRA landfill (off-base)	Effective and reliable for hazardous waste.	Nearest hazardous waste landfill is located in Oregon. Since contaminated soils are managed by another party, base retains liability.	High
		Industrial landfill (off-base)	Effective and reliable for nonhazardous waste with TFH > 100 mg/kg.	Industrial waste landfills may have difficulty accepting wastes from a CERCLA site. Since contaminated soils are managed by another party, base retains liability.	Moderate

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Table 9-2

(Continued)

☐ Technologies and process options selected for further analysis.
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General Response Action	Remedial Technology	Process Options	Effectiveness	Implementability	Cost
In-Situ Treatment	Physical treatment	Vacuum extraction/soil venting	Effective for removal of volatile contaminants. Effectiveness limited by lithology and potential channeling effects	Easily implemented.	Low
		In-situ electrochemical 4,8	Effective for removal of ionic contaminants. Less effective on hydrocarbons.	Implementable, although [illegible]	[illegible]
		In-situ air stripping	Effective for removal of volatile contaminants.	Easily implemented.	Moderate
		Soil flushing	Effective for removal of soluble contaminants.	Implementable, must recover contaminants that are transferred from soil to groundwater.	Moderate
		Stabilization	Effectively prevents future migration. Effectiveness limited by organic content and valence state of metals.	Implementable.	Moderate
	Thermal treatment	In-situ vitrification 7,8	Effective removal of organics.	[illegible]	[illegible]
		In-situ steam stripping 8	Effective removal of organics. Does not address [illegible] contaminants.	[illegible]	[illegible]

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Table 9-2

(Continued)

☐ Technologies and process options selected for further analysis.

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General Response Actions	Remedial Technology	Process Options	Effectiveness	Implementability	[illegible] Cost[1]
In-Situ Treatment (cont.)	Biological treatment	Bioventing	Effective destruction of degradable organics, although time to treat is long. May be less effective in winter months.	Implementable. Approval of air emissions required.	Low
		Anaerobic 4	Effective on chlorinated compounds. TPH does not readily degrade anaerobically.	Implementable.	Low

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Table 9-3

Selected Representative Process Options for Water

General Response Action	Remedial Technology	Representative Process Option	Rationale for Selection
Natural Attenuation	Natural Attenuation	Natural attenuation (only option)	Used as a baseline; natural attenuation has potential to be effective in wetland areas of OU 5.
Institutional Action	Access Restrictions	Deed/water rights restrictions, fences, and/or land purchases	All potential options were carried forward as potential land use restrictions to limit groundwater extraction and contact with water. The alternative water supply technology was eliminated since no domestic, agricultural, or industrial users are known to use the shallow aquifer.
	Monitoring	Monitoring wells and surface water	Monitoring is an important activity to document that exposures are occurring and that natural attenuation is effective. Also documents the effectiveness of remedial actions.
Containment	Vertical Barriers	Slurry wall	Slurry walls would prevent lateral migration of groundwater and concentrate flows for treatment. Slurry wall was selected over sheet pile wall due to less cost. Injection wells would be less effective at containing contaminated water. Grout injection and surface water barriers would have negative effects in a wetlands environment. Capping would have no effect on lateral migration.
Collection/Treatment/ Discharge	Collection	Active extraction wells Passive horizontal drains Collection trenches	These process options are the most effective for extracting groundwater and seepage. Earthen berms were thought to be less effective due to migration problems and concrete trenches were more costly than drains.

Table 9-3

(Continued)

General Response Action	Remedial Technology	Representative Process Option	Rationale for Selection
Collection/Treatment/ Discharge (cont.)	Biological Treatment and Wetland Remediation	Constructed wetlands	Of the biological technologies, wetlands was the least capital intensive and, with proper operation, could be an all weather option. The four eliminated biological options were screened out as either not appropriate for the COCs or involving extensive equipment needs.
	Physical Treatment	Air stripping and carbon adsorption	Air stripping can effectively remove the contaminants. This process is more proven than the other physical or chemical treatment processes listed. UV oxidation was considered for treatment. However, it was not selected because air stripping and activated carbon were considered more proven technologies.
	On-Site Discharge	Discharge to reinjection well system	This option is most protective of Ship Creek. Direct discharge to Ship Creek, the POTW, or the wetlands is less protective. Some of the injection wells may be off-site, dependent on optimal system design.
In-Situ Treatment	Chemical Treatment	Permeable treatment beds	Permeable treatment beds can effectively remove organic contaminants. This option was the only chemical treatment option passing the screening.
	Biological Treatment	Air sparging	Air sparging was selected over in-situ steam or air stripping because of less technical complexity.

Table 9-4

Selected Representative Process Options for Soil

General Response Action	Remedial Technology	Representative Process Option	Rationale for Selection
Natural Degradation	Natural Degradation	(Not applicable)	Selected for a baseline comparison; natural degradation can effectively reduce organic contaminants.
Institutional Action	Access Restrictions	Land use/deed restrictions, land purchase, fences	These options can minimize direct contact with contaminated soil. All options were carried forward.
	Monitoring	Soil gas wells and borings	Monitoring can document the degradation of organics.
Excavation/Disposal	Shallow Excavation and Backfill	Backhoe	Shallow excavation is more implementable than deep excavation at OU 5 because of slope stability concerns with deep excavation. Risks in deep excavation would outweigh the benefits of removing relatively small volumes of contaminated soils.
	Off-Site Disposal	Industrial waste landfill	Industrial waste landfills can accept nonhazardous TFH-contaminated soil from CERCLA sites. Disposal out-of-state would be cost prohibitive. RCRA landfill not required.
Containment	Capping	Bentonite and soil cap	A bentonite and soil cap would be easiest to construct and is self-healing when cracked. Other caps would not provide additional benefits. Vertical barriers would not prevent downward migration.
Excavate/Treatment/ Disposal	Shallow Excavation	Backhoe	See Excavation/Disposal. All ex-situ options were eliminated due to the difficulty in excavating deep soils.
	Biological Treatment	Biopiling	Biopiling has been effectively used at Elmendorf AFB to treat TFH-contaminated soil before disposal. Other biological and chemical treatment options required extensive equipment. The identified physical treatment technology, air stripping/vacuum extraction, is best carried out in-situ since the excavation of soils prior to this treatment is a costly step which does not result in an increase in treatment effectiveness.

Table 9-4

(Continued)

General Response Action	Remedial Technology	Representative Process Option	Rationale for Selection
In-Situ Treatment	Physical Treatment	Vacuum extraction/soil venting	This process option effectively treats soil from any depth without producing secondary solid wastes, although air emissions must be approved. This option was judged to be the most demonstrated and cost-effective of all the physical and thermal options.
	Biological Treatment	Bioventing	This process option treats soil at any depth without any secondary treatment systems, although air emissions must be approved. This was the only option to pass the screening.

TFH = Total Fuel Hydrocarbons