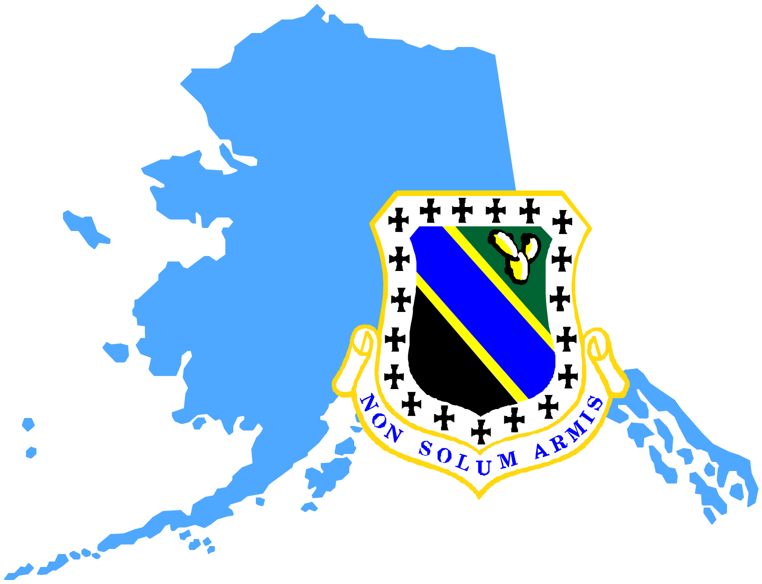

UNITED STATES AIR FORCE
ELMENDORF AIR FORCE BASE, ALASKA

ENVIRONMENTAL RESTORATION PROGRAM

REMEDIAL INVESTIGATION/FEASIBILITY STUDY FOR SITE DP98

FINAL

19 JUNE 2003

EXECUTIVE SUMMARY

The U.S. Air Force (USAF) conducted a remedial investigation/feasibility study (RI/FS) at Site DP98, Elmendorf Air Force Base (AFB) Alaska. An engineering evaluation/cost analysis (EE/CA) was completed in 2001. However, because of the nature and extent of soil and groundwater contamination, it was determined that the EE/CA was not appropriate for Site DP98. The RI/FS was conducted in accordance with the USAF Environmental Restoration Program and under the guidelines of the Federal Facilities Agreement (FFA) for Elmendorf AFB, Alaska.

REMEDIAL INVESTIGATION

Objectives for the RI were to fully delineate the nature and extent of contamination in all environmental media at Site DP98, determine what type of risks these contaminants could present to human and or ecological receptors, and establish preliminary applicable or relevant and appropriate requirements (ARARs). Once these objectives were met, their results were used to establish remedial action objectives for Site DP98, which in turn were used to develop the FS.

The RI field program was conducted in the summer and fall of 2002 to collect the data needed to meet the objectives of the RI. This included a further investigation of contaminants in shallow groundwater, surface water, and sediment and to determine if contaminants detected in previous investigations had reached a lower unit of the aquifer beneath Site DP98. Field activities included:

- Installation and sampling of four monitoring wells (plus one replacement well) to determine the hydrologic conditions beneath the shallow unconfined aquifer.
- Installation and sampling of twelve well points at the base of the slope located approximately 300 feet north of the Facility.
- Collection of six surface water and sediment samples near areas of potential contamination to evaluate the risk to human health and the environment.
- Completion of an aquifer pump test in one of the new wells (41755-WL21) with transducers in four surrounding wells.
- Installation and operation of a free product recovery system at one well (41755-WL01) for approximately two months.

With the data from the 2002 field investigation, analytical and hydrostratigraphical information was used to evaluate the potential impacts of contaminants at Site DP98. Several investigations have been performed at Site DP98 since 1995. These include field programs conducted for the State-Elmendorf Environmental Restoration Agreement (SERA) Phases IV (1996), VI (1997), VII (1998), and VIII (1999) and the 2001 EE/CA. Data from these previous investigations as well as the data collected in 2002 were evaluated together to reach a more thorough understanding of conditions at Site DP98.

Hydrogeology

The objective of the hydrogeologic evaluation was to identify the major water-bearing units, assess the groundwater flow regime, and identify any preferential pathways for groundwater flow.

Site DP98 is located on Elmendorf End Moraine deposits, which overlie clay and silt units of the Bootlegger Cove Formation. As a result, the geology and hydrogeology of the site is very complex and controlled by lateral and vertical heterogeneities typical of glacial moraine deposits. Five separate geologic units were identified at Site DP98. Two of these units are the primary water-bearing zones at Site DP98. These zones consist of a clayey gravelly silt and gravelly sand unit, and a gravelly silty sand unit.

These two water-bearing units are not, however, separated by a continuous aquitard and are considered to be within the same aquifer system. A discontinuous aquitard is present beneath the Facility and southern portion of Site DP98, which thins and changes composition (and permeability) northward into the wetland area. The presence of the aquitard results in semi-confined conditions in several locations. This accounts for the rise in groundwater head in some wells above the static water level table. In summary, it is likely that only one water table aquifer is present beneath Site DP98 and, in some locations, demonstrates semi-confined conditions.

An aquifer pump test was conducted to acquire additional data on aquifer characteristics and to determine if communication between the two water-bearing units is occurring through the discontinuous aquitard. Results indicated that some degree of groundwater communication between the clayey gravelly silt and sandy gravel water-bearing units was occurring.

Contaminant Screening Criteria

To establish the nature and extent of contamination in any of the environmental media at Site DP98, a comparison of analytical data was required. Preliminary ARARs and media-specific toxicity data were used to establish screening criteria. These criteria included both Alaska Department of Environmental Conservation (ADEC) and Federal regulatory action levels. Where more than one potential screening criteria was available, the most conservative values were chosen. A summary of proposed action levels is provided in Table ES-2.

Nature and Extent of Soil and Sediment Contamination

Results from the screening of soil analytical data indicate that diesel range organics (DRO) are the primary petroleum hydrocarbon contaminant in soils, and that trichloroethene (TCE) is the most common volatile organic compound (VOC) observed in soil at the site. Additional contaminants (gasoline range organics [GRO] and TCE breakdown products) are also prevalent and detected above screening criteria at Site DP98.

There are two distinct and separate areas of DRO contaminated soil. One area is located approximately 600 feet north-northwest of the former underground storage tank (UST) area at the southwest corner of Building 18224 (Figure 1-2). Groundwater is shallow in this area, and most of the soil impacts are below the saturation zone. DRO is present in soil at concentrations up to 42,000 milligrams per kilogram (mg/kg). DRO is observed in soil to depths of 5 to 10 feet below ground surface (bgs) in this area. The other area, located beneath Building 18224, has DRO concentrations in soil up to 37,100 mg/kg. DRO is observed in soil to depths of at least 26 feet bgs in this area. GRO and residual range organics (RRO) concentrations were measured in soil samples from the same area at lower concentrations. TCE was measured in soil samples at concentrations up to approximately 60 mg/kg. The highest area of TCE concentrations in soils center around the end of the former drainage tile which extends north from Building 18224. TCE contaminants commingled with the DRO contamination beneath Building 18824 and near the outfall of the drainage tile.

Volume estimates of contaminated soil included soil above the water table (unsaturated) and below the water table (saturated) in what is often referred to as a groundwater smear zone. The total volume of soil (both saturated and unsaturated) with DRO concentrations greater than the screening criteria (250 mg/kg) was estimated to be approximately 360,000 cubic yards. The volume of soil with DRO concentrations greater than the screening criteria above the saturated zone is estimated via computer interpolation to be approximately 107,000 cubic yards. The volume of TCE contaminated soil above the screening value of 0.027 mg/kg in unsaturated soil is approximately 127,000 cubic yards.

As with soil, DRO is the most prevalent fuel contaminant in sediment samples; for VOCs, both TCE and cis-1,2-dichloroethelene (DCE) are common contaminants.

The extent of DRO contamination in the sediment indicates a potential impact to the nearby wetlands. A review of all sediment results revealed DRO and RRO in the sediment north of Building 18224 at concentrations above preliminary ARARs. The source of these fuel compounds is probably groundwater seepage at, or very near, the base of the slope where contaminated groundwater intercepts the ground surface.

RCRA metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver) were also sampled for and evaluated at Site DP98. Metals that were not considered to be within background levels were included for further evaluation in the human health and ecological risk assessments.

Nature and Extent of Groundwater and Surface Water Contamination.

Results from the screening of groundwater and surface water analytical data indicate that DRO are the primary petroleum hydrocarbon contaminant in water, and that TCE is the most common chlorinated contaminant observed in water at the site. Additional fuel contaminants (GRO) and chlorinated contaminants (TCE breakdown products) are also found above screening criteria at Site DP98.

Dissolved DRO were detected at concentrations up to 1,300 mg/L in groundwater. The screening criteria used for DRO is 1.5 milligrams per liter (mg/L). Dissolved DRO concentrations above screening levels were also observed in the same area as the soil impacts, with the highest concentrations observed approximately 300 feet north-northwest of the northern extension of Building 18220. Dissolved DRO in groundwater extends approximately 600 feet north-northwest of Building 18224, with a plume width of approximately 300 feet. Dissolved GRO (screening criteria of 1.3 mg/L) and RRO (screening criteria of 1.1 mg/L) concentrations were measured in groundwater samples from the same area at concentrations up to 4.4 mg/L and 1.7 mg/L respectively. Free product has been observed on the groundwater surface in the area beneath and around Building 18224 at thicknesses ranging from a thin sheen to over 3 feet. Product thickness has decreased since the maximum of 3.26 feet was measured in well WL01 in 1998.

Based on historical site operations and the observed contaminant distributions, it is inferred that the DRO distribution at the site is a result of releases from the former USTs and vehicle maintenance operations in Building 18224. A portion of the released DRO migrated vertically through unsaturated soil and dispersed laterally, resulting in the distribution observed under Building 18824. A portion of the released DRO also appears to have preferentially migrated through the western Building 18224 drain tile network. This portion of the release appears to have been discharged to the surface near the base of the slope where it then migrated over the surface and infiltrated into the subsurface to produce the distribution observed north of Building 18220. The two plumes combine downgradient due to groundwater migration pathways.

TCE was observed in groundwater at concentrations above the screening criteria (0.005 mg/L) up to 5.0 mg/L. The distribution of TCE in groundwater is less extensive than DRO, and is centered under Building 18824. The distribution of GRO, RRO, and TCE are inferred to be a result of vehicle maintenance activities conducted at Building 18224, with minor releases to floor drains and the drain tile resulting in the observed distribution.

All but one of the surface water samples were collected at the same locations as sediment samples in the wetland area. Analytical results indicated that surface water in some areas has been impacted by contaminants from Site DP98, with RRO being the most common fuel contaminant and TCE the most common chlorinated contaminants. RRO was detected twice above the screening criteria (1.1 mg/L) and DRO once above screening criteria (1.5 mg/L). TCE was detected in one sample above the screening criteria (0.005 mg/L). No sample results exceeded screening criteria for total aromatic hydrocarbons (TAH) or total aqueous hydrocarbons (TaqH).

Free Product Recovery

In July 2002, the Magnum Spillbuster™, was installed in well 41755-WL01 to determine the maximum amount of product that could be recovered using an active skimmer system. The system operated for approximately 3 weeks before malfunctioning. During this time, the system collected less than 1 gallon of product. After cleaning and optimizing of the system components in August 2002, the product recovery system was restarted. However, after another month of continuous operation, less than 0.5 gallon was recovered. The system was shut down in September 2002.

Groundwater Modeling

Fate and transport modeling using BIOCHLOR computer software demonstrated that natural attenuation of both chlorinated solvent and fuel contaminants is occurring in the unconfined aquifer.

However, using modeling, concentrations of these contaminants above preliminary ARARs are estimated to reach the wetland within 5 years. TCE and DRO have been detected at the base of the slope and edge of the wetland, which confirms the results of the groundwater model.

Max flux calculations suggest that no less than 137 years, at a minimum, would be required before all of the dissolved DRO in groundwater migrated from the Facility area to the wetland area. It is estimated to take approximately 29 years, at a minimum, for all of the dissolved TCE to migrate from the upper elevated area to the wetland area. It should be noted that these estimates do not take into consideration continued contribution of TCE and DRO contamination from soils above the groundwater saturation zone, which contain high concentrations of these contaminants. They also do not take into account natural attenuation of the contaminants.

Human Health Risk Assessment

A conceptual site model (CSM) was developed for each of two land use scenarios at Site DP98; current land use and future land use.

As part of the current land use at Site DP98, three human populations were evaluated as part of the risk assessment: civilian and military building workers, and construction workers. Three populations were selected for evaluation under future land use conditions: residents, neighborhood children (ages 6 to 12 years) as recreational users or trespassers, and construction worker exposure (also selected for quantification under the current land use scenario). Two separate conceptual site models (CSMs) were prepared to reflect the current and future land use scenarios. From the CSMs, the following pathways and potential exposure scenarios were evaluated:

Current Land Use:

- Military and civilian workers in Building 18224 exposed to volatile contaminants in indoor air moving from groundwater through the subsurface into the building;
- Military and civilian workers using impacted groundwater as a drinking water source;
- Construction worker exposure to contaminants in the surface and subsurface soils (also evaluated under future land use); and
- Construction workers exposed to contaminated groundwater through inhalation of volatiles and dermal absorption through the skin (also evaluated under future land use).

Future Residential Land Use:

- Future residents exposed to contaminants in groundwater through incidental ingestion, dermal contact, and inhalation of groundwater vapors during use of groundwater by residents for domestic activities, including drinking, bathing, and cleaning;
- Future residents exposed to contaminants in surface soil through incidental ingestion, dermal contact and inhalation of fugitive dusts and soil vapors;
- Neighborhood child exposures to wetland sediment through incidental ingestion, vapor inhalation, and dermal contact with sediment during recreational/trespass activities; and
- Neighborhood child exposures to wetland surface water through inhalation of vapors and dermal contact with surface water during recreational/trespass activities.

Noncancer health hazards and cancer risks were calculated for reasonable maximum exposures (RMEs) and central tendency (CT) exposure conditions (see Table ES-1). RME hazard/risk estimates are based on the maximum exposure that is reasonably expected to occur at the site. CT hazard/risk estimates are based on the typical or average population exposure concentration. The target cumulative cancer risk level for ADEC is 1×10^{-5}, and EPA defines acceptable target risks to range from 10^{-4} to 10^{-6}. The target health goal for noncancer compounds is a hazard quotient (HQ) equal to or less than 1. The HQ is the ratio of contaminant intake to the contaminant specific reference dose, which is the dose above which is

Table ES-1
Summary of RME and CT Cumulative Human Health Hazard/Risk Estimates for Each Exposure Scenario

Land Use Scenario	Exposure Scenario	Exposure Population	Exposure Medium	Total Hazard/Risk	
				Hazard Index	Cancer Risk
Reasonable Maximum Exposure					
Current	Civilian Building Worker	Adult	Tap Water	**83**	**3E-03**
			Indoor Air (GW)	0.5	**4E-04**
			Total	**84**	**3E-03**
	Military Building Worker	Adult	Tap Water	**83**	**4E-04**
			Indoor Air (GW)	0.5	**6E-05**
			Total	**84**	**5E-04**
	Construction Worker	Adult	Surface/Subsurface Soil	0.07	1E-06
			Groundwater	**9**	**3E-05**
			Total	**9**	**3E-05**
Future	Resident	Child (age 0-6 years)	Tap Water	**875**	NE
			Surface Soil	0.2	NE
			Total	**875**	NE
		Child/Adult (age 0-70 years)	Tap Water	**476**	**6E-02**
			Surface Soil	0.05	9E-06
			Total	**476**	**6E-02**
	Neighborhood Recreational Child	Elementary Aged Child (age 6-12 years)	Wetland Surface Materials	0.01	6E-08
			Wetland Surface Water	0.007	8E-07
			Total	0.02	8E-07
Central Tendency					
Current	Civilian Building Worker	Adult	Tap Water	**50**	**4E-04**
			Indoor Air (GW)	0.4	**7E-05**
			Total	**50**	**5E-04**
	Military Building Worker	Adult	Tap Water	**57**	**1E-04**
			Indoor Air (GW)	0.5	**3E-05**
			Total	**57**	**2E-04**
	Construction Worker	Adult	Surface/Subsurface Soil	0.03	6E-07
			Groundwater	**6**	2E-05
			Total	**6**	2E-05
Future	Resident	Child (age 0-6 years)	Tap Water	**346**	NE
			Surface Soil	0.07	NE
			Total	**346**	NE
		Child/Adult (age 0-70 years)	Tap Water	**168**	**6E-03**
			Surface Soil	0.03	2E-06
			Total	**168**	**6E-03**
	Neighborhood Recreational Child	Elementary Aged Child (age 6-12 years)	Wetland Surface Materials	0.006	9E-09
			Wetland Surface Water	0.003	2E-07
			Total	0.009	2E-07

Risks and hazards that exceed target health goals are bolded.
CT – Central tendency

NE – Not evaluated. Cancer risks are not evaluated separately for the 0 to 6 year old age group, but are included in the child/adult evaluation.
RME – Reasonable maximum exposure
GW – Groundwater

associated with adverse health effects with an adequate margin of safety. The hazard index is a summation of all non-cancer human health hazards (HQs) combined for a certain exposure pathway, such as contact with soil or use of groundwater for domestic purposes.

Under current land use conditions, use of the groundwater as a drinking water source would result in risks and hazards that exceed target health goals primarily due to the occurrence of elevated levels of TCE, DRO, cis-1,2-dichloroethene (DCE), and tetrachloroethene (PCE). Indoor air presents some health concerns to workers due primarily to concentrations of TCE as well. TCE is also the risk driver for construction worker dermal contact with groundwater. Currently, groundwater is not used for domestic purposes by the Facility at Site DP98.

Again, under future residential land use conditions, drinking the groundwater would result in risks and hazards in excess of target health goals due to elevated concentrations of mostly TCE, PCE, naphthalene, and cis-1,2-DCE.

Contaminants that exceeded human health goals were considered to be contaminants of concern (COCs) and were assigned preliminary action levels. These chemicals and action levels are discussed in the RAO section in this summary. A summary of risks and hazards for each exposure scenarios is included in Table ES-1. Table ES-2 contains a list of COCs identified for Site DP98.

Ecological Risk Assessment

The first stage of the ecological risk assessment for Site DP98 was to determine whether a detailed, quantitative ecological risk assessment (required whenever the potential for an ecological threat from site contaminants exists) of the site was required. While it was determined that no federally or state-designated critical habitat is present at Site DP98, complete exposure pathways exist at Site DP98 that result in a exposure of ecological receptors to site contaminants. In particular, it was found that aquatic receptors may be exposed to site contaminants in freshwater and sediments and that terrestrial receptors may be exposed to site contaminants in surface soil 0 to 2 feet bgs.

Ecological risk assessments do not normally evaluate risks to all species present at a site. The large number of species present at most sites makes this impractical. Instead, one or more target ecological receptors are selected as representative species, and risks to the target receptors are evaluated. With the exception of plants, which represent the primary producers at the site, all target ecological receptors are intended to be representative of a functional feeding group of animals present at the site. Each target receptor is exposed to site contaminants through a different combination of exposure pathways, primarily differences in diet. The terrestrial ecological receptors chosen for this assessment include terrestrial plants, terrestrial invertebrates, the dark eyed-junco (*Junco hyemalis* Linnaeus, an avian herbivore), the American robin (*Turdus migratorius*, an terrestrial avian invertivore), the common snipe (*Gallinago gallinago*, an invertivore which feeds primarily on aquatic macroinvertebrates), the meadow vole (*Microtus pennsylvanicus*, a mammalian herbivore), the masked shrew (*Sorex cinereus*, a mammalian invertivore), the least weasel (*Mustela nivalis*, a mammalian carnivore), and the wood frog (*Rana sylvatica*, the adult life stage of which is a terrestrial insectivore). With the exception of the meadow vole, a replacement for the tundra vole (*Microtus oeconomus*) apparently not found on site, all target receptors have been identified by ADEC as appropriate default ecological receptors in southcentral Alaska.

For surface water, all fresh water aquatic invertebrates resident in the water column, phytoplankton, and macrophytes have been selected as target ecological receptors for exposure to surface water contaminants. The tadpole lifestage of the wood frog is also a target ecological receptor.

For sediment, rooted macrophytes and benthic invertebrates have been selected as the target ecological receptors exposed to contaminants in sediment.

A screening-level ecological risk assessment was performed to identify the contaminants and environmental media, if any, which warranted detailed evaluation in a baseline risk assessment. To maximize the likelihood that all detected contaminants with a potential to pose unacceptable ecological risks are retained for more detailed evaluation, the maximum detected concentration for each analyte was divided by a conservative risk-based screening concentration (RBSC) to derive the hazard quotient (HQ). The sources and derivations of the RBSCs are described in detail in Appendix I. A summary of the RBSC sources is as follows:

Soil – URS 1996c or Appendix I of this RI report
Surface water – USEPA 1999, USEPA 1991, MDEQ 2001 and URS 1996c
Sediment – URS 1996c

Site-specific soil, surface water, and sediment data revealed that no soil contaminants, two surface water contaminant, and four sediment contaminants exceeded RBSCs. These four sediment contaminants and the surface water contaminant, along with a second surface water contaminant for which no RBSC was available were retained as contaminants of potential ecological concern (COPECs) for a more detailed baseline risk assessment.

In the baseline risk assessment, the contaminants identified as COPECs are again evaluated to determine a HQ. In the baseline risk assessment however, more site-specific data is used. Contaminants with an HQ (derived during the baseline assessment) with a value greater than 1 are than considered to be COCs.

The two surface water COPECs, DRO and RRO, were identified as surface water COCs. DRO concentrations exceeded its RBSC, while RRO does not have a surface water RBSC. Both DRO and RRO in surface water exceeded their predicted maximum water solubility in most samples, thus presenting the possibility of both chemical and physical toxicity. The DRO surface water RBSC is designed to evaluate only chemical toxicity at DRO concentrations lower than its maximum water solubility, not the physical toxicity that may occur from oil sheens, slicks or emulsions under supersaturated conditions.

All four sediment COPECs (2-methylnaphthalene, fluorene, DRO, RRO) were identified as having the potential to pose unacceptable ecological risks to benthic biota and were retained as COCs. Contaminants were considered COCs if they were given a hazard quotient (HQ) greater than 1. The reasonable maximum exposure concentration of four sediment contaminants are DRO (HQ = 47), 2-methylnaphthalene (HQ = 13), Fluorene (HQ=4.3), and RRO (HQ=2.2).

Based on these data, a potential ecological risk exists to freshwater and benthic biota from surface water and sediment contaminants within Site DP98. Risks from all contaminants identified as COCs, except for RRO in sediment, appear to be limited to a relatively small area. This area is located northwest of Building 18220, at the base of the slope and wetland. Surface soils do not appear to pose a risk to wildlife.

Development of COCs and Remedial Action Objectives (RAOs).

COCs were developed in three different processes during the RI phase, the screening of contaminant concentrations against preliminary ARARs in the nature and extent section (Section 5, the baseline human health risk assessment (Section 7) and the baseline ecological risk assessment (Section 8).

Contaminants that exceeded chemical-specific ARARs in the screening phase (Section 5) were identified as COPCs. These COPCs were than later identified as COCs for the development of RAOs. Although these contaminants may not pose a risk to human health or ecological receptors as determined during the risk assessments, they still exceed preliminary ARARs.

Table ES-2

Summary of Contaminants of Concern, Proposed Remedial Action Objectives, and General Response Actions for Site DP98

Media	COC	Remediation Goal	Basis for Identification as COC	General Response Action
Groundwater	Free Product	Remove floating product	ARAR	Natural attenuation
	DRO	1.5 mg/L	ARAR	Natural attenuation; Land use controls* (restrict use as drinking water source); Containment; Source removal (groundwater extraction); Ex situ treatment of extracted groundwater; In situ treatment of groundwater; and Disposal of extracted groundwater.
	GRO	1.3 mg/L	ARAR	
	RRO	1.1 mg/L	ARAR	
	Benzene	0.005 mg/L	ARAR	
	Cis-1,2-Dichloroethene	0.07 mg/L	ARAR	
	1,1-Dichloroethene	0.007 mg/L	ARAR	
	Trichloroethene	0.005 mg/L	ARAR	
	Tetrachloroethene	0.005 mg/L	ARAR	
	Vinyl Chloride	0.002 mg/L	ARAR	
Surface Water	TAH	10 µg/L	ARAR	Natural attenuation; Land use controls* (prevent exposure to future residents); Containment; Source removal (groundwater extraction); Ex situ treatment of groundwater; and disposal of extracted groundwater.
	TAqH	15 µg/L	ARAR	
Sediment	cis-1,2-Dichloroethene	0.2 mg/kg	ARAR	Natural attenuation; Land use controls (prevent future human exposure); Containment; and In situ treatment.
	Trichloroethene	0.027 mg/kg	ARAR	
Soil	GRO	300 mg/kg	ARAR	Natural attenuation; Land use controls* (prevent future human exposures); Containment; Removal; Ex situ treatment; In situ treatment; and Disposal.
	DRO	250 mg/kg	ARAR	
	RRO	10,000 mg/kg	ARAR,	
	1,1-Dichloroethene	0.03 mg/kg	ARAR	
	Benzene	0.02 mg/kg	ARAR	
	Tetrachloroethene	0.03 mg/kg	ARAR	
	Cis-1,2-Dichloroethene	0.2 mg/kg	ARAR	
	Trichloroethene	0.027 mg/kg	ARAR	

* Land use controls for Site DP98 are included under the Basewide Land Use Control Management Plan for Elmendorf AFB
ARAR – applicable or relevant and appropriate requirement
COC – contaminant of concern
DRO – diesel range organics
GRO – gasoline range organics
RRO – residual range organics

The human health and ecological risk assessments for Site DP98 also screened COPCs according to completed exposure pathways and potential receptors and from this process developed COCs. COCs were defined for the site as contaminants that exceed concentrations that pose a cancer risk to human health greater than 10^{-5}, or a non-cancer risk to human health with an HQ greater than 1 for both current (civilian, building, and construction workers) and future (residential, recreational, and construction worker) land use. COCs identified in the ecological risk assessment were identified as contaminants with concentrations high enough to represent an HQ greater than 1.

Remedial action objectives consist of media-specific goals to protect human health and the environment. Identification of RAOs is necessary as they establish what is to be achieved by the remedial actions evaluated in the FS. The development of RAOs for Site DP98 included identifying the following three components to be evaluated as part of the process to determine the final list of RAOs:

- COCs;
- Receptors and exposure routes that could be affected by COCs; and
- Remedial goals (preliminary ARARs) to address COCs for each exposure pathway that is protective of human health and the environment.

These RAOs are based on the potential chemical-, physical-, and action-specific preliminary ARARs included in Section 9. Because more than one environmental medium at Site DP98 contains COCs, RAOs are listed according to environmental media in Table ES-2.

Feasibility Study/ Remedial Action Alternative Scoring

The purpose of the feasibility study is to provide decision makers with the information needed to select a preferred remedial action alternative that will protect human health and the environment from the contaminated media identified in the remedial investigation.

The potential remedial technologies considered for Site DP98 were identified and screened. General response actions and process options were identified for each contaminated medium (soil and sediment, groundwater and surface water). Potential remedial technology types for the process options were then identified.

Once the technology types and process options were identified, they underwent preliminary screening. During this screening, process options and/or entire technology types may be eliminated from further consideration, based on technical implementability for the site. If deemed technically viable, a more detailed screening evaluated effectiveness, implementability, and cost. The most promising process options were retained and evaluated according to media-specific remedial alternatives.

The process options not screened out were combined to form candidate remedial alternatives for either soil (soil and sediment) or water (groundwater and surface water) at Site DP98. A total of 17 media-specific remedial alternatives were developed for treating soil and sediment and groundwater and surface water at Site DP98. Technologies were chosen based on their ability to treat the COCs and otherwise satisfy the RAOs established in Section 10.

The final evaluation involved combining the media-specific alternatives into six sitewide alternatives. The detailed evaluations of these sitewide alternatives were scored based on CERCLA criteria. A summary of this evaluation and associated scoring for each of the six-sitewide remedial alternatives is included in Table ES-3.

Chlorinated compounds are the primary risk drivers in the human health risk assessment and, therefore, are considered to be higher priority for remedial action. Fuel contaminants are present at the site but pose less of a risk than chlorinated contaminants. The presence of fuel compounds has been demonstrated to accelerate the breakdown of chlorinated compounds by providing a carbon source and promoting anaerobic dechlorination. Therefore, the presence of fuel contamination may prevent further migration of the chlorinated plume. For these reasons, no alternatives that solely address fuel compounds through active treatment were developed. Once the chosen remedial action has been implemented and cleanup goals for chlorinated contaminants are met in soil and groundwater, and levels of fuel contaminants still remain above cleanup goals, additional remedial actions may be implemented.

A summary of the comparative rankings and cumulative score for each alternative is provided in Table ES-3. In addition, the table provides a summary of the Total Effectiveness score, which includes all ranking except Implementability. The scores were then used to calculate the effectiveness to cost ratio. Table ES-4 summarizes the costs and the lists effectiveness to cost ratio for each alternative. (The effectiveness to cost ratio is calculated by dividing the total effectiveness score by the total present worth in millions of dollars.) For effectiveness to cost quotients, Alternative 2 ranks highest with a ratio of 7.8, and the second best ratios are 6.5 for Alternative 6 and 6.4 for Alternatives 4 and 5.

Table ES-3

Comparative Analysis of Remedial Alternatives[a]

Criterion	Alternative 1 No Action	Alternative 2 Monitored Natural Attenuation	Alternative 3 Limited Steam Stripping of Chlorinated Contaminated Soils and Groundwater and GW MNA	Alternative 4 Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal, and GW MNA	Alternative 5 Limited Source Removal of Chlorinated Contaminated Soils, On-Site Treatment and Disposal, and GW MNA	Alternative 6 SVE for Soil and GW MNA
Overall protection of human health and the environment	0	3	4	4	4	4
Compliance with remediation goals	0	4	5	5	5	5
Long-term effectiveness	0	2	4	3	3	3
Reduction of toxicity, mobility, and volume of contaminants through treatment	0	2	4	3	3	3
Short-term effectiveness	3	3	2	3	3	3
Technical and administrative implementability	5	4	1	3	3	2
Cost of Implementation	$0	$1,790,000	$3,920,000	$2,660,000	$2,650,000	$2,760,000
State acceptance	NE	NE	NE	NE	NE	NE
Community acceptance	NE	NE	NE	NE	NE	NE
Total effectiveness score[b]	4	14	19	17	17	18
Total score	9	18	20	21	21	20

[a] Alternatives scored from lowest to highest (0 to 5) for each criterion.
[b] Total of all criterion except technical and administrative implementability and cost of implementation.
ARARs – Applicable or relevant and appropriate requirement
GW – Groundwater
MNA – Monitored natural attenuation
NE – Not evaluated at this time, but will be evaluated once public and agency comments are received
SVE – Soil vapor extraction

Table ES-4

Summary of Costs for Candidate Remedial Alternatives

Cost	**Alternative 1 No Action**	**Alternative 2 Monitored Natural Attenuation**	**Alternative 3 Limited Steam Stripping of Chlorinated Contaminated Soils and Groundwater and GW MNA**	**Alternative 4 Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal and GW MNA**	**Alternative 5 Limited Source Removal of Chlorinated Contaminated Soils, On-Site Thermal Treatment and Disposal and GW MNA**	**Alternative 6 SVE for Soil and GW MNA**
Capital Cost	$0	$370,000	$1,790,000	$1,240,000	$1,170,000	$800,000
Present Worth O&M Cost (75 yrs, 7%)	$0	$1,420,000	$2,130,000	$1,420,000	$1,480,000	$1,960,000
Total Present Worth (75 yrs, 7%)	$0	$1,790,000	$3,920,000	$2,660,000	$2,650,000	$2,760,000
Total Effectiveness Score	4	14	19	17	17	18
Effectiveness to Cost Quotient	NA	7.8	4.8	6.4	6.4	6.5

[a] – The effectiveness-to-cost quotient is calculated by dividing the total effectiveness score by the total present worth (in millions of dollars).

GW – Groundwater
MNA – Monitored natural attenuation
NA – Not analyzed (can't divide by a zero cost)
O&M – Operation and maintenance
SVE – Soil vapor extraction

[This page intentionally left blank.]

TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS (Continued)

PAGE

TABLE OF CONTENTS (Continued)

PAGE

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

PAGE

APPENDICES

TABLE OF CONTENTS (Continued)

FIGURES

TABLE OF CONTENTS (Continued)

FIGURES (Continued)

PAGE

TABLES

TABLE OF CONTENTS (Continued)

TABLES (Continued)

PAGE

TABLE OF CONTENTS (Continued)

TABLES (Continued)

PAGE

TABLE OF CONTENTS (Continued)

ACRONYMS AND ABBREVIATION

1CFOK	one compartment first order kinetic
ACL	alternative cleanup level
AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
AFCEE	Air Force Center for Environmental Excellence
AFID	Air Force Identification Number
ARAR	applicable or relevant and appropriate requirement
ASTM	American Society of Testing Materials
atm x m^3/mol	atmosphere pressure x meter^3 per mole
ATSDR	Agency for Toxic Substances and Disease Registry
BCF	bioconcentration factor
bgs	below ground surface
btoc	below the top of well casing
bw	body weight
BTEX	benzene, toluene, ethylbenzene, and total xylenes
ºC	degree Celsius
CBR	critical body residue
CESARS	Chemical Evaluation Search and Retrieval System
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm/sec	centimeter per second
COC	contaminant of concern
COPC	contaminant of potential concern
COPEC	contaminant of potential ecological concern
CZMA	Coastal Zone Management Act
CSM	conceptual site model
CT	central tendency
DCE	dichloroethene
DNAPL	dense nonaqueous phase liquid
DoD	U.S. Department of Defense
DRO	diesel range organics
DRPH	diesel range petroleum hydrocarbons
dw	dry weight
EAFB	Elmendorf Air Force Base
EcoRA	ecological risk assessment
EE/CA	engineering evaluation/cost analysis
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentrations
ERP	Environmental Restoration Program
ERPIMS	Environmental Resources Program Information Management System
ETH	ethane/ethane

TABLE OF CONTENTS (Continued)

ACRONYMS AND ABBREVIATIONS (Continued)

ºF	degree Fahrenheit
FFA	Federal Facilities Agreement
FS	feasibility study
ft	foot
ft/ft	feet per foot
ft/yr	foot per year
f_{oc}	fraction of organic carbon
g	gram
GAC	granular-activated carbon
g/cc	grams per centimeter
gpm	gallons per minute
GRO	gasoline range organics
GRPH	gasoline range petroleum hydrocarbons
HAC	halogenated aliphatic compounds
HHRA	human health risk assessment
HPC	heterotrophic plate count
HQ	hazard quotient
HSDB	Hazardous Substance Database
HVE	high-vacuum extraction
HVO	halogenated volatile organics
Hz	hertz
ID	inside diameter
IDW	investigation-derived waste
in. Hg	inch of mercury
IRIS	Integrated Risk Information System
IS	Intelligence Squadron
kcc	unitless measure for soil absorption coefficient
kg	kilogram
kg/L	kilograms per liter
LCS	laboratory control sample
LDLO	lowest published lethal dose
L/min	liter per minute
LNAPL	light nonaqueous phase liquid
LOAEL	lowest observable adverse effect level
LTTD	low-temperature thermal desorption
m^3/mg	cubic meters per microgram
MBTA	Migratory Bird Treaty Act
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDC	maximum detected concentration
MDEP	Massachusetts Department of Environmental Protection
MDL	method detection limit
µg/L	micrograms per liter

ACRONYMS AND ABBREVIATIONS (Continued)

mg	milligrams
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mL/g	milliliters per gram
mm Hg	millimeters of Mercury at 68° F
mmol/kg	millimole per kilogram
msl	mean sea level
MNA	Monitoring Natural Attenuation
MTCA	Model Toxics Control Act
n	effective porosity
NAF	Naval Air Facility
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NIOSH	National Institute of Occupational Safety and Health
NOAEL	no observed adverse effect level
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity units
NWI	National Wetlands Inventory
O&M	operation and maintenance
OHM/TAB	Oil and Hazardous Materials/Technical Assistance Database
ORP	oxygen reduction potential
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PAHs	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
POTW	publicly owned treatment works
PPE	personal protective equipment
PRG	preliminary remediation goals
psi	pounds per square inch
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective
RBC	risk-based concentrations
RBSC	risk-based screening concentration
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RfDi	reference doses for inhalation
RI	remedial investigation
RME	reasonable maximum exposure
RRO	residual range organics
RTECS	Registry of Toxic Effects of Chemical Substances

ACRONYMS AND ABBREVIATIONS (Continued)

SERA	State-Elmendorf Environmental Restoration Agreement
SF	slope factor
SFi	inhalation slope factor
SHPO	State Historic Preservation Office
SQL	sample quantitation limit
SVE	soil vapor extraction
SVOC	semivolatile organic compound
TAH	total aromatic hydrocarbon
TaqH	total aqueous hydrocarbon
TBC	to be considered
TCE	trichloroethene
TDLO	lowest published toxic dose
TDS	total dissolved solids
TEL	threshold effect level
TMB	trimethylbenzene
TOC	total organic carbon
TPH	total petroleum hydrocarbon
TPHGWC	Total Petroleum Hydrocarbon Criteria Working Group
TRV	toxicity reference value
UCL	upper confidence limit
URI	unit risk factor
Ufs	uncertainty factors
USC	United States Code
USAF	U.S. Air Force
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	underground storage tank
UTL	upper tolerance limit
VC	vinyl chloride
VF	volatilization factor
VF_w	volatilization factor for water
VOC	volatile organic compound
Vs	seepage velocity
WMP	waste management plan

[This page intentionally left blank.]

Section 1.0
INTRODUCTION

The U.S. Air Force (USAF) conducted a remedial investigation/feasibility study (RI/FS) at Site DP98, Elmendorf Air Force Base (AFB), Alaska. Several previous investigations were performed under the State-Elmendorf Restoration Agreement (SERA) program for the investigation of underground storage tanks (USTs). An engineering evaluation/cost analysis (EE/CA) (USAF, 2001) was previously completed for this site, however, due to the concentration and extent of soil and water contamination at site DP98, it was determined that an RI/FS would be required.

This RI/FS has been conducted in accordance with the Air Force Environmental Restoration Program (ERP) with approval from the U.S. Environmental Protection Agency (EPA) and Alaska Department of Environmental Conservation (ADEC). The ERP is a federal program established to address past hazardous waste disposal and spill activities at U.S. Department of Defense (DoD) installations. The ERP was established in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). CERCLA mandates the investigation and remediation of hazardous substance releases from previous activities or spill incidents that may cause risk to human health or the environment.

The remainder of this section presents the objectives of the RI/FS, a site description and summary of previous activities, a description of the environmental setting, and organization of this document.

1.1 Purpose and Objectives

In general, the purpose of an RI/FS is to characterize the nature and extent of risks present at the site, and gather enough data to support an informed risk management decision regarding the selection of the most appropriate remedial action alternative for the hazardous waste site.

Between July and October 2002, a limited field investigation was conducted to gather data needed to complete the RI/FS. All available data including those collected during previous SERA investigations will be used to better define the nature and extent of contamination and identify, evaluate, and analyze costs of feasible remedial action alternatives. Alternatives will be evaluated to address any human health risk and/or ecological risks posed by contaminated media at Site DP98 on Elmendorf AFB (Figure 1-1). Specific objectives for the RI/FS program are as follows:

- Define and evaluate more fully the nature and extent of chlorinated and petroleum hydrocarbon contamination in surface water, sediment, and groundwater;
- Re-evaluate contaminants of concern (COCs) identified in the EE/CA;
- Re-evaluate applicable or relevant and appropriate requirements (ARARs);
- Evaluate chemical fate and transport mechanisms of COCs;
- Update the human health and ecological conceptual site models (CSM);
- Evaluate the potential risk to human health and the environment with additional 2002 data;
- Identify, evaluate, and select alternatives for remedial action; and
- Recommend a remedial action alternative that addresses the nature of contamination as well as physiography of Site DP98 and is protective of human health and the environment.

Figure 1-1. Location of Site DP98, Elmendorf AFB, Alaska

1.2 Facility Description

Site DP98 is located at a high-security communications facility situated in the northwestern portion of Elmendorf Air Force Base (Elmendorf AFB) (Figure 1-2). Built in the early 1950s, this facility is currently operated by the 381st Intelligence Squadron (IS). A large antenna array, commonly known as the "Elephant Cage," is a prominent landmark that is more than 100 feet high, 1,460 feet in diameter, and three-quarters of a mile in circumference. The center of the operations facility consists of Building 18220 (formerly Building 41-760), Building 18224 (formerly Building 41-755), and a guard building (Figure 1-2). A chain-link fence topped with razor wire surrounds these buildings. A large vehicle parking area is located outside the perimeter fence east of the facility. The land area and buildings within the security fence collectively are referred to as the "Facility" in this report.

The Facility was originally designed to be nearly self-sufficient. During site construction, the topography was altered in order to control surface water runoff. Asphalt-paved driveways surrounding the buildings and paved parking areas are located outside the eastern fence line. An asphalt and gravel roadway provides access from the parking lot on the northeastern corner of the facility to the main antenna array.

Water supply to the Facility is provided through a water main and no domestic or industrial water-supply wells are located within 1 mile of the Facility.

1.3 Site DP98 Facility History of Operations

As shown in Figure 1-2, the Facility is composed of a former garage (Building 18224), a three-story concrete office building (Building 18220), two nearby USTs, and an approximately 27-acre, fan-shaped area of undeveloped woodland extending north and west of the perimeter fence. Figure 1-2 also includes a topographic map of the Facility and surrounding areas of Site DP98. Site DP98 is bounded by undeveloped woodland to the east, the main portion of the Facility and Fairchild Avenue to the south, a ½-acre kettle pond and undeveloped wetland to the north, and the main antenna array to the west. Elevation decreases in a northerly and westerly direction towards the Knik Arm of the Cook Inlet. The center of the Facility is approximately 204 feet above mean sea level (msl). Approximately 300 feet north of the facility topographic lines show a slope with a 20 feet decrease in surface elevation. The wetland extends from the base of the slope to a distance of about 500 feet in a northerly direction, where surface water is impounded in the small kettle pond at an elevation of about 158 feet above msl. Building 18224 and the undeveloped land north and northwest of the Facility are the focus areas of this DP98 RI/FS field investigation. Two USTs used to store diesel fuel were located on the southwest corner of Building 18224. These tanks were removed or abandoned in place in 1995 and are thought to have been the source of fuel contamination at Site DP98.

1.3.1 Building 18224

Building 18224 is a 70-foot-wide by 12-foot-long single-story concrete building with a partial basement constructed to serve as a boiler plant and vehicle maintenance garage. According to Facility personnel, Building 18224 is no longer used for vehicle maintenance. Building 18224 is currently used for a boiler room, electronics room, generator room, carpentry shop, and racquetball court and to support operations of Building 18220. The carpentry shop appears to be used for light hobby manufacturing and painting. This room also contains three fireproof lockers for paint and other general maintenance supplies. Based on chemical use in similar facilities, it is assumed that solvents containing chlorinated hydrocarbons, oil, lubricants, and fuels would have been used in vehicle maintenance activities.

As-built drawings of Building 18224 indicate a former floor drainage network inside the boiler room and former vehicle maintenance garage, connecting to a drainage tile system. Waste liquids entering floor drains, a wash rack, and a grease/oil pit were channeled into an 8-inch-diameter drain tile that encircled the building. Before exiting the building, liquids originating in the vehicle maintenance garage passed through a grease and oil interceptor (i.e., weir-type oil/water separator) situated down-line from the grease/oil pit. The perimeter drain tile discharged via two lateral drain tiles extending from

Building 18224. The long axes of the drainage tiles are shown on Figure 1-2. The first lateral drain tile extended 133 feet in a northerly direction from the northeast corner of the building and discharged to an open ditch. A second lateral drain tile extended 160 feet northwest from the west central portion of the building and discharged onto a sloped embankment. An open drainage ditch ran parallel to the southern, eastern, and northeastern boundaries of the Facility outside the existing fence line, as shown on Figure 1-2. Based on a review of aerial photographs, it appears that the drainage ditch was leveled with fill material prior to 1962. A majority of the property records prior to 1962 were burned in a fire, and therefore, were not available for review.

The oil/grease pit and the connected oil/water separator were abandoned to grade with concrete prior to 1962. The floor drain on the southeast corner of the building currently overflows when storm water pools on the asphalt outside an adjacent door, spilling beneath the doorway and into a catch basin in the floor. Because all the floor drains in the building are interconnected, when sufficient water enters the southeast floor drain, the other floor drains within this building also overflow. A video of the floor drain system at Building 18224 indicated portions of the drainage line were blocked by dirt at the time of inspection.

1.3.2 Building 18220

Building 18220 is a three-level concrete structure formerly used as offices, barracks, and dining facilities and for other support purposes. According to Facility personnel, the building has been used mainly for technical operations associated with the antenna array since the late 1970s to the present and no longer supports personnel living at the Facility.

As-built drawings for the Facility also depict a drainage tile system for Building 18220. Lateral drain tiles extended from the perimeter drainage tile in four directions: one discharged to an open ditch approximately 99 feet southwest of the building; a second pipe discharged to an open ditch approximately 133 feet east of the building; and two additional pipes discharged to the hillside about 100 feet northwest of the building. The current status of the drainage network surrounding Buildings 18220 is not known.

A guard building provides shelter for security forces who limit access inside and outside the compound to essential personnel (Figure 1-2). All non-authorized personnel must be accompanied by a military escort while within the fenced areas or within 30 feet outside of the perimeter fence line.

1.4 Environmental Setting

Elmendorf AFB is located in southcentral Alaska and encompasses approximately 13,103 acres. Elmendorf AFB is bordered by the city of Anchorage to the south, on the east by the U.S. Army's Fort Richardson, and on the north and west by the Knik Arm of Cook Inlet. Wetland, lakes, and ponds cover about 1,592 acres of the base. Land use on Elmendorf AFB includes airfield and base support operations, personnel housing, and recreational facilities. Approximately 1.5 miles south of the base, land use is residential and industrial. Figure 1-1 shows a general location map of Site DP98 as it relates to Elmendorf AFB.

Elmendorf AFB lies within the Lower Matanuska Lowland subunit of the Cook Inlet-Susitna Lowland physiographic subprovince of the Pacific Mountains System. The Lower Matanuska Lowland (sometimes referred to as the Anchorage Lowland or Anchorage Plain) comprises a 35-mile-wide by 50-mile-long, glaciated coastal shelf that is bounded on the west by the Susitna Lowlands subunit, on the north by the Talkeetna Mountains, on the east by the northeast-southwest trending Chugach Mountains, and to the south by Turnagain Arm. Knik Arm, a northern extension of the Cook Inlet marine reentrant, drains the Lower Matanuska Lowland. Elevations in the area range from sea level to nearly 2,000 feet above msl. Slope gradients are generally less than 3 degrees. The following summary of the regional geology and hydrogeology of Elmendorf AFB is based on the works of Cederstrom, Trainer, and Waller (1964); Miller and Dobrovolny (1959); and Schmoll and Dobrovolny (1972). Descriptions of site geology and hydrogeology are presented in Section 4.0.

Figure 1-2. Site DP98 Layout

[This page intentionally left blank.]

1.4.1 Regional Geologic Setting

Elmendorf AFB lies within the Cook Inlet-Susitna Lowland, also referred to as the "Anchorage Plain." The Anchorage Plain is a large alluvial apron extending outward from the Kenai, Chugach, Talkeetna, and Chigmit Mountain fronts, toward Knik Arm. The Anchorage Plain is a tectonically active area with occasional earthquakes. No bedrock exposures exist at Elmendorf AFB.

The topography of the Anchorage Plain is primarily a product of repeated Pleistocene glaciations. Thick sequences of unconsolidated deposits, predominantly glacial drift, underlie the land surface in most of the Anchorage area. The sediments consists of till, outwash-stream deposits, and estuarine and lake sediments. Nonglacial deposits include peat and stream- and wind-laid sediments. Glaciers fed from multiple ice centers in the surrounding mountains deposited a composite system of moraines in the lowlands.

On Elmendorf AFB, the two predominant geological units belong to the pre-Wisconsin age Knik and Wisconsin age Naptowne glacial sequences. An important geologic unit in the Knik glacial sequence is the Bootlegger Cove Formation. The formation also plays an important role as a confining layer in the groundwater system of the region.

The major geological and geomorphological unit on Elmendorf AFB is the Elmendorf End Moraine, which makes up the southwest-trending ridges north of the runways. The Elmendorf End Moraine ranges in width from 0.5 to 1 mile and a linear distance of approximately 10 miles. The Elmendorf End Moraine has been mapped as a glacial end moraine that extends from Elmendorf AFB across Knik Arm from Cairn Point toward the Susitna Lowlands. It is bounded along most of its southern edge by outwash, and its northern edge by ground moraine, kame fields, kame terraces, and abandoned channels.

Surface soils at Site DP98 are dominated by cryorthant (fill material) that is well-drained and characterized as gravely sandy or sandy loam. Kichatna-Porches Variant-Jacobsen complex soil types are prevalent on the sloped embankment north of the facility and consist mostly of poorly drained silt, sand, and gravel mixtures. In the low-lying areas of Site DP98, Doroshin mucky peat is prevalent and includes soils around kettle ponds in the northeastern portion of the site. These soils are made of a silt loam overlain by peat or mucky peat and are poorly drained.

Surface soil layers are formed from loess blown from the floodplains of glacial streams and volcanic ash. Subsurface soil layers are predominantly glacial deposits, and range from gravelly clay loam to a very gravelly sandy loam. Subsurface soil on alluvial terraces and outwash plains are composed mostly of very gravelly sand. Soils in depressions holding fens and bogs are organic and consist mostly of peat. According to the National Wetland Inventory (NWI) Map for the Anchorage area, a wetland exists at the base of the slope within the undeveloped land to the north of the Facility. These wetland maps are constructed from aerial photographs based on topography and vegetative cover and must be confirmed by ground investigation.

1.4.2 Regional Hydrogeology

Deposits of sand and gravel laid down as outwash plains are the most important aquifers and are the only ones that yield large quantities of groundwater. Thin layers of sandy or gravelly material in till in moraine deposits are also important aquifers (both confined and unconfined), although they yield relatively small quantities of water. Unconfined aquifers are extensive, but the permeable saturated units are thin in many places and water supplies available from them are small or undependable. Aquifers that are composed of outwash sand and gravel are as much as several tens of feet thick. The outwash sand and gravel units are moderately to very permeable.

The unconfined aquifers are recharged by the infiltration of precipitation at the land surface and surface water through streambeds. Near the mountains, the artesian-unconfined aquifers are probably recharged in part by percolation from the water-table aquifer. Farther from the mountains, the unconfined aquifer is probably recharged in part by upward flow from the underlying artesian semi-confined aquifers. In several valleys and at a few places in the lowland, artesian wells screened in the unconfined aquifers flow at the ground surface.

Surface runoff and groundwater seepage provide flow to streams in the mountains east of Anchorage. Where they emerge from the mountains onto lower ground, the beds of some streams are higher than the water table nearby; therefore, some of the surface water percolates to groundwater. Most streams that cross the Anchorage Plain between the mountains and Cook Inlet have incised their beds and attain relatively low elevations within rather short distances, from the mountains. Along these incised reaches, the streambeds are lower than the water table nearby; hence in the greater parts of their lower courses, the streams do not contribute to the groundwater reservoir.

Groundwater occurs within saturated intervals of the Elmendorf End Moraine (USAF, 2000a). Groundwater south of the moraine flows south and west towards Ship Creek; groundwater north of the moraine generally flows to the northwest towards the Knik Arm of Cook Inlet.

1.4.3 Ecology

Elmendorf AFB is located within the Cook Inlet Ecoregion; a 10,800-square-mile area dominated by stands of spruce and hardwood species. Needleleaf, broadleaf, and mixed forests are the most widespread. Tall scrub communities form on floodplains, along streambanks, and in drainageways. Poorly drained lowlands support low scrub communities. Tall scrub swamp, low scrub bog, wet forb herbaceous, and wet graminoid herbaceous vegetation colonize wet, low-lying areas.

An ecological inventory was not conducted as part of the RI, however visual observations taken during the field effort and inventories conducted for similar environments on Elmendorf AFB can be used to provide a general idea of type of biota and fauna present in the undeveloped areas of Site DP98.

A slope area creates a buffer zone between the Facility and the wetland area. This slope dips steeply in some places toward the wetland and is dissected by several minor drainage rills (Section 4). The base of the slope becomes a transitional area between what is considered an upland, and a palustrine scrub/shrub wetland (U.S. Fish and Wildlife Service [USFWS], 1979).

A Palustrine system wetland includes nontidal wetlands dominated by trees, shrubs, persistent emergents, and emergent mosses or lichens. Traditionally, such wetland environments may have been called bogs, swamps, fens, or marshes and often includes ponds. Such wetlands are common along lakeshores, river channels, or estuaries, river floodplains, or on slopes. Typical shrub-scrub wetlands include woody vegetation dominated by short young trees and shrubs (less than 6 meters or 20 feet in height), stunted trees or shrubs, and occur in all water regimes except inter-tidal, and are the most common class of wetland in the United States.

A typical assemblage of fauna present in similar environments on Elmendorf AFB include tall shrubs, willows, and low alder growth, gluejoint grass, ferns, horsetail, cow parsnip, yarrow, and devil's club. Though no wildlife was seen during field activities, it could be assumed that moose, small mammals such as fox, shrews, or field mice, and small birds such as the American robin, sparrows, warblers, and thrush's may be present along the slope or in the wetland. A small pond located at the northern edge of the wetland outside the boundary of DP98 may also attract waterfowl such as ducks or geese.

1.4.4 Climate

Average annual precipitation, including snowfall, in the Anchorage area ranges from 15 to 27 inches. Average annual snowfall ranges from 63 to 100 inches. Winter temperatures range from lows of

5°Fahrenheit (F) to highs of 23 °F; temperature inversions are common. Summer temperatures vary from lows of 41 °F to highs of 64 °F.

1.5 Organization of Document

The remainder of this report is organized as follows:

- Section 2 summarizes existing information for Site DP98;
- Section 3 presents a summary of field activities performed in 2002;
- Section 4 provides a site-specific hydrogeologic assessment;
- Section 5 contains an evaluation of site-specific potential ARARs used to establish screening criteria;
- Section 6 includes an evaluation of the data to determine the nature and extent of contamination within soil, sediment, surface water, and groundwater;
- Section 7 contains a description of modeling methodologies, results, and a description of fate and transport of contaminants in groundwater;
- Section 8 presents the results of the human health risk assessment;
- Section 9 provides results of the ecological risk assessment;
- Section 10 is a summary of findings from the remedial investigation phase;
- Section 11 presents the remedial action objectives for the feasibility study;
- Section 12 includes the identification and screening of possible remedial action alternatives;
- Section 13 contains the analysis of alternatives;
- Section 14 presents a detailed description of possible alternatives and selects the most appropriate for the conditions at Site DP98; and
- Section 15 lists references cited within this report.

The following appendices contain supporting documentation:

- Appendix A: Soil Boring and Well Construction Logs, Field Forms and Chains of Custody
- Appendix B: Photo Documentation
- Appendix C: Historical Analytical Data
- Appendix D: QA/QC Summary Report
- Appendix E: Gore Sorber Results
- Appendix F: Aquifer Testing Results
- Appendix G: BIOCHLOR Modeling Output and Max Flux Estimates
- Appendix H: Human Health Risk Assessment
- Appendix I: Ecological Risk Assessment
- Appendix J: Natural Attenuation Evaluation
- Appendix K: Cost Backup for Feasibility Analysis

[This page intentionally left blank.]

Section 2.0
SUMMARY OF EXISTING INFORMATION

This section provides an abbreviated summary of previous investigations performed under the SERA programs, as well as data collected as part of the 2001 EE/CA and the 2001 groundwater sampling.

2.1 Previous Investigations

Building 18224 of Site DP98 was previously referred to as ST423 under the SERA program for investigation of the USTs. Diesel was used to fuel an emergency generator and was stored in a 3,000-gallon tank (UST Air Force Identification Number [AFID] 755) located at the southwest corner of the building. This tank was emptied and removed in 1995, and a new 4,000-gallon capacity UST was installed in the same excavation (USAF, 1995). A 25,000-gallon diesel UST (referred to as AFID 756 and/or STMP458), situated directly northeast of AFID 755, was also emptied and abandoned in place.

Soil samples collected from the UST excavation contained concentrations of diesel-range organics (DRO) above ADEC regulatory criteria in place at that time. For this reason, Site ST423 was included in the SERA Phase IV release investigation performed in 1996. Additional work was also performed at Site ST423 under the SERA programs in 1997 (SERA VI), 1998 (SERA VII), and 1999 (SERA VIII) to delineate the extent of fuel contamination in the soil and groundwater.

During the SERA VI and SERA VIII investigations, soil gas, soil, and groundwater results indicated the presence of volatile organic compound (VOC) contamination. Due to the presence of VOC contamination, the USAF determined a larger scale investigation would be necessary. An EE/CA was performed in 2000 to better delineate the nature and extent of both fuels and VOC contaminants at Site DP98. A detailed evaluation of the nature and extent of contamination at Site DP98 for fuel and VOC contaminants is included in the 2001 EE/CA report (USAF, 2001) as well as in Section 6 of this RI.

2.1.1 1995 UST Decommissioning and Site Assessment

Soil samples collected in 1995 from the excavation of UST AFID 755 indicated DRO at concentrations ranging from 42 to 9,700 milligrams per kilogram (mg/kg), which was above the established ADEC cleanup levels of 200 mg/kg. Approximately 65 cubic yards of contaminated soil was removed and treated offsite. A new 4,000-gallon capacity UST was installed in the same excavation of UST AFID 755 (USAF, 1995). A 25,000-gallon diesel UST (AFID 756), situated directly northeast of AFID 755, was also emptied and abandoned in place.

Because the DRO concentrations exceeded the ADEC cleanup criteria at that time, Site ST423 was included in the SERA program.

2.1.2 1996 SERA Phase IV

As part of SERA IV, 13 soil borings were drilled and converted into either groundwater monitoring wells, groundwater monitoring/air-injection wells, soil gas arrays, or were abandoned. Petroleum hydrocarbons, primarily DRO, were detected in the soil above cleanup criteria. Benzene, toluene, ethylbenzene, and total xylenes (BTEX) and DRO were also detected in groundwater. The sample suite for this investigation did not include VOCs. Due to the presence of contaminated groundwater, the cleanup level was upgraded to a Matrix Score Level A under 18 Alaska Administrative Code (AAC) 75 (USAF, 1996a).

Floating hydrocarbon fuel was detected in one well (41755-WL01) adjacent to the former UST and in a second well (41755-WL03) located approximately 150 feet north-northwest of the former UST. A passive product recovery system was installed in 41755-WL01 and operated from April through December of 1996. Three and a quarter gallons of fuel product were removed from the well during that time (USAF, 1996).

2.1.3 1997 SERA Phase VI

During the 1997 SERA VI investigation, a passive soil gas survey was performed to delineate the extent of fuel constituents in shallow soil. A total of 62 Gore-Sorber® passive sorbents were installed at 3 feet below ground surface (bgs) on a grid with spacing of 50 feet by 50 feet. The sorbers were analyzed for total petroleum hydrocarbon (TPH), BTEX, and tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (DCE); trans-1,2-DCE; and 1,1,1-trichloroethane (TCA). Results indicated two discontinuous areas of possible fuel contamination; one area was approximately 100 feet northwest of Building 18224 and the other area was 430 feet northwest of Building 18224. Measurable concentrations of chlorinated solvents were found at locations approximately 400 feet north-northeast into the area of the suspected former drum and debris disposal area (USAF, 1998).

Following the soil gas survey, four surface and subsurface soil samples were collected to confirm results of the soil gas sampling and extent of contamination. DRO was detected in all samples. Residual-range organics (RRO) were detected in one of the soil boring samples. TPH and gasoline-range organic (GRO) were detected in both surface soil samples; these samples were analyzed for VOCs and semi-volatile organic compounds (SVOCs).

Groundwater samples collected from four downgradient wells (41755-WL06 through 41755-WL09) were analyzed for VOCs. The VOCs cis-1,2-DCE, 1,1,1-TCA, and TCE were all detected in one well, 41755-WL-08; TCE concentrations were measured above ADEC cleanup levels.

One surface water sample (SSW-01) was collected from ponded water and analyzed for VOCs and SVOCs. The only contaminant detected in surface water was cis-1,2-DCE (USAF, 1998).

2.1.4 1998 SERA Phase VII

In 1998, another investigation was conducted as part of SERA VII to fill data gaps left by previous SERA investigations regarding the extent of fuel contamination. Three soil borings were drilled within the Facility around Building 18224, and soil samples were collected and analyzed only for petroleum fuel compounds. DRO, GRO, and total BTEX were detected. DRO was found in concentrations exceeding the cleanup level (USAF, 1999).

2.1.5 1999 SERA Phase VIII

One soil boring (423-BH05) was drilled adjacent to an existing well 41755-WL04. Soil samples were analyzed for fuels and VOCs. Soil collected at 22 bgs contained TCE and cis-1,2-DCE above ADEC cleanup levels (USAF, 2000a).

Groundwater samples were collected from 12 monitoring wells (41755-WL01 through 41755-WL12) and analyzed for DRO, GRO, and VOCs. DRO, GRO, and benzene were found at concentrations exceeding cleanup levels. TCE, cis-1,2-DCE, 1,1-DCE, PCE, and vinyl chloride (VC) were all detected at concentrations above cleanup levels (USAF, 2000a).

2.2 <u>2001 EE/CA</u>

Following the 1999 SERA Phase VIII investigation, it was apparent that an unidentified source for chlorinated solvents existed at Site DP98. A more intrusive and larger scale investigation was necessary to better determine all possible sources of contamination and determine the nature and extent of both fuel and VOC contamination.

The objectives of the 2001 EE/CA were to determine the nature and extent of both chlorinated solvents and fuels in soils, surface water, sediment, and the shallow unconfined aquifer; perform a human health and ecological risk assessment; and select a removal alternative that would be protective of human health and the environment. The field investigation was performed during the summer of 2000.

Results of the 2001 EE/CA field program are summarized in Sections 2.2.1 through 2.2.3 below (USAF, 2001). A more detailed evaluation of the analytical data collected during the 2000 field effort is discussed in conjunction with new data from 2002 in Section 6 of this document.

Two primary sources for contamination were identified in the 2001 EE/CA report: a drainage tile network associated with the former garage (Building 18224) and two former USTs that stored fuel for generators located in the garage. The drainage tile network was identified as the main contributor of chlorinated solvent contaminants and a small amount of fuels. The USTs accounted for the majority of the fuel contamination at Site DP98. A grease oil pit that overflowed into the drain tile network is also thought to have contributed to the fuel contamination.

Analytical and soil gas screening data collected from previous investigations were reviewed and used to determine additional locations for soil gas screening in the 2001 EE/CA report (USAF, 2001). From this information, soil borings, groundwater monitoring wells, surface water, and sediment sample locations were identified to characterize the lateral and vertical extent of contamination. The following sections summarize investigation results according to environmental media.

2.2.1 Soil Results

Following the analyses of 130-soil gas survey point screening results, 16 soil borings were completed. Four additional soil borings were completed at hand auger locations because hand augers could not be drilled to the required depth because of the gravel and compacted fill material at the sample locations. A total of 17 surface soil samples and 39 subsurface samples were collected for analyses. All soil samples were analyzed for DRO, RRO, GRO, VOCs, SVOCs, and metals. In addition, selected soil samples were analyzed for chloride, sulfate, nitrate, phosphate, heterotrophic plate count, sheen screen, and total organic carbon (TOC). Seven of the soil borings were converted to groundwater monitoring wells.

Twenty soil samples exceeded ADEC Method Two cleanup levels for DRO, cis-1,2-DCE, PCE, or TCE. Metals in soil were compared to background levels and determined not to be a risk to human health or the environment. The vertical and aerial extent of fuel-contaminated soil was qualitatively defined northwest of Building 18224, in the vicinity of well 41755-WL07. The vertical and aerial extent of chlorinated solvent-contaminated soil has been qualitatively defined at Site DP98.

2.2.2 Sediment and Surface Water Results

Four sediment samples were collected at coordinating surface water sampling locations and analyzed for DRO, RRO, GRO, VOCs, SVOCs, and metals.

Of the four samples analyzed, two samples and one duplicate sample exceeded the cleanup level for DRO. RRO was detected at three sediment locations and is likely the result of natural, biogenic material. The nature and extent of sediment contamination was not fully delineated. The background samples were only analyzed for Resource Conservation and Recovery Act (RCRA) metals. An evaluation of background metals concentrations was completed as part of the 1994 Operable Unit 6 (OU6) RI/FS (USAF, 1996b), which included sample locations on the Elmendorf Moraine.

Four surface water samples were collected at the same locations as sediment samples and analyzed for the same suite as sediments, with the addition of polynuclear aromatic hydrocarbons (PAHs). RRO was detected above the cleanup level at location DP98-SW02. The nature and extent of surface water contamination was not fully delineated in the 2001 EE/CA report (USAF, 2001).

2.2.3 Groundwater Results

Seven additional monitoring wells were installed in the unconfined aquifer at Site DP98. These seven wells, along with 12 existing monitoring wells, were sampled using a low-flow sampling technique.

Floating product was measured in three monitoring wells (41755-WL01, WL03, and WL11). Groundwater samples were analyzed for DRO, RRO, GRO, VOCs, PAHs, SVOCs, RCRA metals, chloride, sulfate, nitrate/ nitrite, total phosphorus, and TOC. In addition to laboratory analysis, field parameters temperature, pH, conductivity, dissolved oxygen, redox potential, alkalinity, and ferrous iron were also measured.

Samples from nine groundwater wells contained contaminants above ADEC Method Two cleanup levels for GRO, DRO, benzene, 1,1-DCE, cis-1,2-DCE, PCE, TCE, or VC. DRO, GRO, benzene, and BTEX groundwater plumes are centered near Building 18224 and are migrating north-northwest with the prevailing groundwater flow direction. The extent of each of the plumes is defined in all directions except to the northwest. In this direction, the boundaries of the DRO plume were only qualitatively defined.

TCE, PCE, DCE, and VC solvent plumes extended in a north-northwesterly direction following the prevailing groundwater flow from the historic drainage tiles near Building 18224. The TCE plume extended north from the northwest drainage tile slightly past the base of the slope. The PCE plume is centered at the northwest drainage tile and extends north to downgradient well 41755-WL15. The cis-1,2-DCE plume is similar to the TCE plume centering at the terminus of the northwest drainage tile from Building 18224. The downgradient extent of this plume is well 41755-WL16. VC was measured in six wells, but only exceeded screening criteria in one well (41755-WL05).

2.3 2001 Groundwater Monitoring Results

Groundwater samples were collected from 18 monitoring wells at Site DP98 in October 2001. Samples were analyzed for the same contaminants as the 2001 EE/CA (USAF, 2001). These data were collected following the completion of the 2001 EE/CA, and the results were not included in the EE/CA report.

Analytes exceeding cleanup levels were similar to those identified during the 2001 EE/CA (USAF, 2001). A comprehensive water level survey was not conducted. A complete evaluation of the 2001 data is included in the nature and extent section (Section 6) of this RI.

Section 3.0
SUMMARY OF FIELD ACTIVITIES

This section provides a summary of field procedures and activities performed at Site DP98 during the 2002 RI/FS field investigation. Generally, field activities were performed as specified in the workplan addendum (USAF, 2002) unless otherwise noted.

Analytes for each environmental medium were selected based on results from the 2001 EE/CA. A detailed description of field procedures and analytical protocol is provided in the sampling and analysis plan (SAP) contained in Appendix A of the *Site Characterization Investigation at DP98: Final Workplan* (USAF, 2000b). Sample locations for each medium investigated are included on Figure 3-1. The field objectives, activities performed, rationale, and deviations from the workplan addendum are listed in Table 3-1.

3.1 Sediment Sampling

During the 2002 field investigation, six sediment samples (DP98-SD05, SD06, SD07, SD08, SD09, and SD10) were collected from drainages, low-lying areas, and the wetland located topographically downslope of Site DP98 (Figure 3-1). Each sediment sample was collected at the same location as the corresponding surface water sample. Sample locations were chosen to assess whether contaminants found in groundwater were reaching the base of the slope and the wetland. All sediment samples were analyzed for DRO, GRO, RRO, VOCs, PAHs, and metals. Following is a brief description of site locations and conditions at the time of sample collection:

- Sediment sample DP98-SD05 was collected adjacent to standing water near a drainage ditch adjacent to the old landfill access road, and south-east of monitoring well 41755 WL07;
- Sediment sample DP98-SD06 was collected adjacent to standing water between well points WP-2 and WP-3, near the toe of the slope;
- Sediment samples DP98-SD07 and DP98-SD08 were collected near standing water east of samples SD05 and SD06 along the toe of the slope;
- Sediment sample DP98-SD09 was collected at the edge of the wetland, between well points WP-8 and WP-9 and east of SD08; and
- Sediment sample DP98-SD10 was collected near well 41755-WL08 at the edge of the wetland.

3.2 Surface Water Sampling

Six surface water samples (DP98-SW05 through DP98-SW10) were collocated with sediment samples (see Section 3.1). Surface water samples were collected by dipping clean, laboratory-grade sample containers into the water and allowing them to fill. To prevent loss of preservative from the preserved sample containers, surface water was collected in a dedicated laboratory-grade 1-liter glass amber bottle and carefully poured into the preserved containers. Caution was taken to minimize volatilization of contaminants. Samples collected from the ditch (DP98-SW05) were not filtered, and in some cases the water was turbid when collected. All samples were analyzed for DRO, GRO, RRO, VOCs, PAHs, and metals.

3.3 Groundwater Investigation

The following subsections summarize field procedures and activities associated with a site-wide water level survey, completion of pilot borings and monitoring well installation, development of monitoring wells, and groundwater sampling.

Table 3-1

2002 Description of Field Activities

Media	Activity Identified in Work Plan	Rationale
Sediment Sampling	Collect six sediment samples	To better delineate extent of contamination in the wetland downgradient of Site DP98. Six samples were collected at the base of the slope and wetland area.
Surface Water	Collect six surface water samples	To better delineate extent of contamination in the wetlands downgradient of Site DP98. Six surface water samples were collected coordinating with sediment locations at the base of the slope and wetland area.
Groundwater Grab Samples	Install and sample 15 well points	To determine if fuel and/or chlorinated with solvents were seeping out of the base of the slope north of Building 18224 and determine potential risk to human health and the environment. Only 12 locations produced sufficient water to collect analytical samples.
Groundwater Well Installation	Install four deep groundwater wells into the lower confined aquifer to a potential depth of 150 feet bgs	To determine the limits of groundwater contaminant migration. The wells were installed to depths between 55 feet bgs and 85 feet bgs. Well 41755-WL22A was considered a replacement for 41755-WL22 after it was determined well 41755-WL22 was not sealed appropriately to adequately monitor the semi-confined aquifer. Well WL-41755-WL23 was installed in October once groundwater flow direction in the semi-confined aquifer was established. All wells were installed using a hollow-stem drill auger rig.
Develop groundwater monitoring wells	Develop new wells	All of the new wells were developed for sampling.
Groundwater Sampling	Sample new groundwater wells	To determine if contaminants had reached the lower confined aquifer. Each groundwater well was sampled including WL22 prior to being abandoned, which resulted in a total of 5 groundwater samples being collected.
Water Level Survey	Synoptic water level survey of unconfined and semi-confined aquifer	To aid in human health risk assessment and groundwater modeling. Two surveys were completed; during the 17 July water level survey, three wells were not surveyed (WL11, WL12, and WL18). During the 26 August event, two wells were not surveyed (WL01 and WL18); WL01 was being used for fuel recovery treatability study. In November, an additional water level survey was conducted of the four new wells (WL20, WL21, WL 22A, and WL23).
Aquifer Testing	Lower water-bearing unit well	To determine the groundwater flow rate and direction in the semi-confined aquifer and determine if any communication occurs between the unconfined and semi-confined aquifers. A continuous draw-down aquifer test and step down test was conducted in well 41755-WL21.
Product Recovery Testing	Conduct treatment test at well 41755-WL01	To determine feasibility of recovering free product from well 41755-WL01 at practical rates. A Magnum Spillbuster computer monitored recovery system was placed in the well and operated from 23 July through 18 September 2002.
Photo Documentation	Photographs of well points, monitoring wells, product recovery system	A photo documentation log was developed to capture all field tasks completed as part of the RI/FS. Not all tasks were captured due to security conditions at the Facility.
Location Survey	All new sample locations	To determine sample locations, ground elevations, and depth to groundwater.
Waste Management	Characterize drill cuttings and purge water from monitoring well development and sampling	To determine the disposal method necessary for drill cuttings and purge water as outlined in the 2000 DP98 Final Workplan and 2002 Workplan Addendum.

Figure 3-1. 2002 RI/FS Field Activity Locations

[This page intentionally left blank.]

3.3.1 Well Point Installation and Sampling

A total of 12 well points were installed near the edge of the wetland, down-slope of the Facility. Well point locations are included on Figure 3-1. Well points were constructed of 2-inch stainless steel horizontal screens in 3-foot sections; 5-foot stainless steel risers were used at seven locations. All screens and risers were decontaminated prior to use, according to the *Addendum to Site Characterization Investigation at DP98, Final Workplan* (Final Workplan Addendum) (USAF, 2002). A Horiba 10 was used to collect field parameters. Well points were driven using a sledgehammer and modified pounding cap to the termination depth. Total depth ranged from 2.5 feet bgs to 6.5 feet bgs.

Before placement of well points, pilot holes were advanced using a hand auger to predetermine locations for the well point placement in order to establish the depth below the surface of the water table near the toe of the slope. It was noted that 1 to 2-hours elapsed before the holes filled with water. The pilot holes were backfilled with soil from the hole and were not used for the installation of the well points. If the well points were difficult to push or hammer to depth, a decontaminated stainless steel hand auger was used to open the hole prior to installing the well point.

Well points were developed and sampled using a peristaltic pump following the procedures outlined in the 2002 Final Workplan Addendum. Due to slow recharge, only one well volume was purged during well point development. Purge volumes, odors, depth to water, and total depth of each well point were recorded in the field notebook. A summary of well point installation information is included in Table 3-2. Well points were generally sampled within 24 hours of development.

Following sample collection, the well point screen and riser pipe (where applicable) were removed; the holes collapsed on removal of the well points and remaining open space was backfilled with soil removed from the hole during installation.

3.3.2 Pilot Boring DP98-14PB

A pilot boring was completed using an air rotary drill near the security guard shack (Building 18228) adjacent to the playground area at Site DP98 prior to installing monitoring well 41755-WL20. The top 35 feet of lithology in this area had been previously determined using the boring log from monitoring well 41755-WL18, completed as part of the 2001 EE/CA field investigation. For this reason the upper 34 feet of the pilot boring were not sampled. Split spoon samples were collected at 5-foot intervals from 35 feet bgs to 60 feet bgs, and every 10 feet from 60 feet to 150 feet bgs where the borehole was terminated. Clay intervals and a unit of heaving sands hampered the drilling progress on several occasions. The borehole was reamed (cleaned out) between collections of split spoon intervals to ensure that in-situ native soil samples were collected.

3.3.3 Monitoring Well Installation Activities

Following the completion of pilot boring DP98-14PB, four monitoring wells were installed at Site DP98. All wells were to be screened in the lower water-bearing unit. Initially, placement of a conductor casing was to be set from the ground surface into a fine-grained unit to prevent cross-contamination between the water-bearing zones. After the conductor casing was in place, drilling would continue within the casing and into the lower water-bearing zone. Based on the findings of the pilot boring (DP98-14PB), a silty clay stratigraphic unit was identified at a depth of 42 to 53 feet bgs. This unit appeared suitable for placement of the conductor casing.

In the first attempt to install a conductor casing (borehole DW-1A; approximately 10 feet east of pilot boring DP98-14PB) a 6-inch-diameter steel conductor casing was placed into the silty clay unit. This attempt was unsuccessful due to flowing sands just above the silty clay. In a second attempt (borehole DW-1B), 10-inch conductor casing was advanced approximately 20 feet southeast of the pilot boring DP98-14PB. However, the annular bentonite seal between the two casings would not hold. For

Table 3-2

Summary of Well Point Installation

Location	Total Depth (feet)	Depth to Water (feet)	Sample ID	Comments
WP-1	5.8	2.02	DP9802-W-1101/8101	Slow recharge, mildly turbid, hydrocarbon odor
WP-2	6.18	3.76	DP9802-W-1102	Slow recharge, turbid, hydrocarbon odor
WP-3	6.41	1.15	DP9802-W-1103	Turbid, hydrocarbon odor
WP-4	6.38	3.98	DP9802-W-1104	Slow recharge, turbid, hydrocarbon odor
WP-5	5.00	3.1	DP9802-W-1105	Hydrocarbon odor
WP-6	3.15	1.37	DP9802-W-1106	Turbid, hydrocarbon odor
WP-7	2.45	0.1	DP9802-W-1107	Turbid
WP-8	5.35	1.71	DP9802-W-1108/8108	Good recharge
WP-9	3.15	1.59	DP9802-W-1109	Turbid
WP-10	3.15	3.11	DP9802-W-11010	Turbid
WP-11	3.00	2.02	DP9802-W-11011	Slightly turbid
WP-12	5.00	3.94	DP9802-W-11012	Slightly turbid

this reason, the 10-inch conductor casing was sealed within an outer 12-inch conductor casing and left in place to a depth of 47 feet bgs. A hollow-stem auger drill rig was set up on the hole to drill through the 10-inch casing for installation of the well. Several unsuccessful attempts were made to install the well and the hole was eventually abandoned. Based on the information regarding subsurface geology gathered from the pilot boring (SP98-14PB) and difficult site conditions, the planned wells were installed without conductor casings, using a hollow-stem auger drill rig.

The screened intervals for the monitoring wells and boring termination depths were determined by the field geologist and based on the decision-making process outlined in the Final Workplan Addendum (USAF, 2002). Copies of the well installation forms are included in Appendix A. Prepacked screens of 15-foot length were used except for the installation of 41755-WL23, where 15 feet of traditional screen were also used in addition to prepacked screen. The well screens were prepacked Schedule 40, 2-inch inside diameter (ID), 0.01-inch machine-slotted polyvinyl chloride (PVC) casing. Well installation procedures were consistent with the workplan except where noted.

Four wells (41755-WL21, WL22, and WL22A, and WL23) were given aboveground completions with locking steel casing installed around the PVC well casing. Two protective bollards filled with concrete were placed around well 41755-WL21. One monitoring well, 41755-WL20, was completed using a flush mount with a concrete collar due to the location in a heavy traffic area. Newly installed monitoring wells were secured with identically keyed padlocks, and well identification tags were attached to each well.

Drilling operations and well casing installations were hampered by heaving sands encountered in each boring. The heaving sands slowed progress. A description of well completions are discussed in the following subsections.

3.3.3.1 Installation of 41755-WL20

Monitoring well 41755-WL20 is located southeast of the Facility near the security guard shack and near DP98-14PB. The lithologic drill log from the pilot boring (DP98-14PB) was assumed to represent lithology at 41755-WL20. Therefore, it was not necessary to collect split spoon samples and the boring was drilled to the target depth of 85 feet bgs using a wood plug inserted at the bottom of the lead auger. A confining unit was identified from approximately 42-54 feet bgs. The well was set with a 15-foot-prepacked screen. Additional sand was added as the augers were lifted and removed from the string. When the sand pack was in place, bentonite chips were added and hydrated, and the borehole was grouted to the surface using a tremmie pipe.

3.3.3.2 Installation of 41755-WL21

Monitoring well 41755-WL21 is located in the low-laying area northwest of the Facility and south of 41755-WL06 (Figure 3-1). Installation of 41755-WL21 was performed using a hollow-stem auger drill rig. Split spoon samples were collected to a depth of 55 feet bgs. After the bottom depth (55 feet bgs) was reached, the well casing with a 15-foot prepacked screen was installed. Sand was added to bring the open hole up to 34 feet bgs, at which point bentonite chips were added to seal the sand pack, and the hole was grouted to the surface, completing the well installation.

3.3.3.3 Installation of 41755-WL22

Monitoring well 41755-WL22 was drilled north of the security gate crossing the access road north of the Facility (Figure 3-1) using a hollow-stem auger drill rig. Split spoon samples were collected in 5-foot intervals to assess the lithology. At the 35-foot bgs interval, the lower water-bearing unit was identified. The well was set at 55 feet bgs. Additional sand was added when the prepacked screen (15 foot length) was set at 40 to 55 feet bgs. After the augers were above the sand pack, bentonite chips were added, and the borehole was grouted to the surface.

Following the completion and sampling of monitoring wells 41755-WL20, WL21, and WL22, water elevations indicated that well 41755-WL22 may have been screened (between 40 and 55 feet bgs) across both the upper and lower water-bearing zones. Depth to groundwater in wells 41755-WL21 (well screened between 40 and 55 feet bgs) was considerably higher than in well 41755-WL22, suggesting that well 41755-WL22 was not screened appropriately to monitor the lower water-bearing zone. For this reason, 41755-WL22 was replaced with 41755-WL22A. Well 41755-WL-22 was abandoned following the installation of 41755-WL22A.

3.3.3.4 Installation of 41755-WL22A

Replacement well 41755-WL22A was installed approximately 15 feet east of 41755-WL22 using a hollow-stem auger-drilling rig. Starting at 50 feet bgs, split spoon samples were collected every 5 feet to determine lithology. The sample collected at the 75 to 77 feet bgs interval contained dry, silty clay, indicating the bottom of the unconfined aquifer. The monitoring well was set with a prepacked screen at 75 feet bgs. No delays or difficulties occurred with the installation of the well.

3.3.3.5 Installation of 41755-WL23

Once installation of the deep wells was completed, it was determined that wells 41755-WL21 and WL22A were located at cross-gradient locations, and not directly downgradient of the source area. Also, the confining unit identified in well 41755-WL20 from approximately 42 to 54 feet bgs was not identified in these two wells. For this reason, it was decided that a fourth well (WL 22A was considered a replacement well) was installed in the wetland, downgradient and north of wells 41755-WL08 and 41755-WL09. Continuous split spoon sampling was conducted in order to identify the presence of an aquitard. Samples for physical and analytical characteristics were collected. The monitoring well was set at a total depth of 80 feet bgs and a total of 30 feet of screen was used. Of this, 15 feet were prepacked, and 15 feet were conventional schedule 40 PVC with a 0.01-inch slot.

3.3.4 Monitoring Well Development

Groundwater monitoring wells installed in 2002 were developed approximately 2 weeks after completion. The time allowed between installation and development was more than sufficient for the bentonite seal to set.

Well development was conducted following the procedures outlined in the 2000 DP98 Final Workplan. A stainless steel surge block attached to a steel cable and/or a stainless steel bailer was used to surge the wells prior to pumping and remove buildup of silts and sands at the bottom of the wells. Surging was repeated as necessary until sufficient formation material was removed from the well casings. A Grundfos variable rate electronic submersible pump was used to purge the wells. Prior to development of each well, downhole equipment (submersible pump, submersible pump cable, surge block, and water-level meter) was decontaminated to prevent cross-contamination.

Wells were purged until the pH, conductivity, temperature, and turbidity had stabilized to within the acceptable ranges as outlined in the workplan. On average, purge volumes ranged from 115 to 200 gallons per well. Well development logs are presented in Appendix A.

3.3.5 Groundwater Sampling

Wells 41755-WL20, -WL21, -WL22, WL22A, and WL23 were included in the groundwater-sampling program (Figure 3-1). Wells were sampled following well development. Low-flow sampling techniques were used to collect groundwater samples. Samples were collected according to the protocol outlined in the 2002 Final Workplan Addendum and analyzed for GRO, DRO, RRO, VOCs, PAHs, and metals. Equipment included a variable rate Grundfos submersible pump, a peristaltic pump, a Hydrolab water quality meter inline with a flow-through cell, and a Solinst interface probe. Downhole equipment was decontaminated prior to use to prevent cross-contamination.

The submersible pump was set at the mid-screen interval and purging proceeded until the parameter requirements established for traditional purging and sampling were met, as described in the 2000 DP98 Final Workplan. Each monitoring well was purged immediately prior to sample collection. The pumping rate was maintained within the range specified for low-flow sampling (0.1 to 1.0 liter per minute [L/min]), averaging approximately 0.4 L/min. When the parameters had stabilized, a sample was collected through the purge water discharge tubing. Groundwater sampling logs are presented in Appendix A.

3.3.6 Water Level Survey

A groundwater level survey of the unconfined aquifer was completed on 17 July 2002. All monitoring wells sampled as part of the 2000 EE/CA field program and the 2001 groundwater sampling event were included in the survey with the exception of three wells: 41755-WL11, -WL12, and -WL18. The well box enclosure for 41755-WL18 was found to be damaged, and 41755-WL11 and -WL12 were not located. A second water level survey was conducted on 26 August of 2002 and included three of the lower unconfined aquifer wells; however, monitoring wells 41755-WL01 and 41755-WL18 were not measured. At the time, 41755-WL01 contained the free product recovery system (see Section 3.4), and 41755-WL18 had not been repaired.

3.3.7 Aquifer Testing

An aquifer pump test was performed at Site DP98, to determine aquifer parameters and to evaluate whether communication existed between shallow and deep wells located in the immediate vicinity of well 41755-WL21 (Figure 3-1). Table 4-1 list the water-bearing unit in which each well is screened.

Prior to conducting the pump test, a preliminary shakedown test was performed to identify any deficiencies in the test procedures and equipment and to identify a maximum sustainable yield from pumping well 41755-WL-21 without lowering the water level below the depth of the pressure transducers.

For the shakedown and aquifer test, a Grundfos pump was installed in deep well 41755-WL21. The pump was suspended approximately 1 foot from the bottom of the well (54 feet bgs) to minimize water turbulence inside the pump well casing. A pressure transducer was set in well WL21 at approximately 29.50 below the top of the PVC casing to monitor changes in water levels. Pressure transducers were installed in wells 41755-WL21, 41755-WL07, 41755-WL19, 41755-WL06, and 41755-WL05. All pressure transducers were rated for a 10-psi submersion depth (23.1 feet below water surface), and consisted of in situ PDX-260 and -261 type transducers. Transducer-specific quadratic coefficients were entered into a 12-channel Hermit 2000 data-logger unit.

During the course of the shakedown test and aquifer pump test, various measurements were recorded. Groundwater parameters were recorded directly from the discharge hose (prior to treatment) using a Horriba U-22 water quality instrument. Parameters monitored included pH, temperature, conductivity, turbidity, dissolved oxygen, salinity, oxygen reduction potential (ORP), and total dissolved solids. Flow rates were recorded on field forms, in addition to the Grundfos cycle rates (Hz) (Appendix A). All purge water was treated through a granular-activated carbon (GAC) unit and discharged on site during the test. Analytical samples were collected at the start, midpoint, and end of the test to ensure no breakthrough of contaminants had occurred. Results of the pump test are discussed in Section 4.

3.4 Interim Groundwater Remediation Activities

As part of the 2002 RI/FS field program, a product recovery treatment test was conducted at well 41755-WL01. This well has historically contained floating product at a thickness greater than 1 foot since the well was installed in 1995.

3.4.1 Product Recovery System Installation

A self-contained and computer-monitored pump system (Magnum Spillbuster) was installed in the well on 23 July 2002. The entire system, which included a motorized reel, hose, and pump assembly, was placed over the well casing. The computer controls the pump elevation, and at regular intervals the pump is lowered into the well to gauge the thickness of floating product and pumps any product detected to an adjacent 55-gallon drum. The pump cycles every 2 seconds unless no product is detected, then the elapsed time between cycles increases to 20 seconds, 2 minutes, 20 minutes, and then to a maximum of 2 hours. An automatic sensor on the hose discharge monitors the level of product and automatically shuts down the system before the drum is full to prevent spills.

3.4.2 Product Recovery System Evaluation

The product recovery system was checked on regular intervals for the first week of operation. Only small amounts of product were being recovered from the well by the system. After the first week, system checks were performed every few days. After 2 weeks, it was noted that the drum remained mostly empty, and little product had been removed, though the system was operating according to manufacturer specifications. An elapsed time of 14 days was allowed between system checks. After 14 days, the drum container had reached maximum capacity and the discharge monitor had shut down the system. The liquid recovered in the drum was mostly water indicating that a failure in the system had occurred. The drum was transferred to the staging area where it was picked-up by Emerald Environmental Services for disposal.

The system was dismantled and removed from the site on 18 September 2002. At that time, no product or water had been pumped to the new drum; the drum and pump system was brought to the staging area and decontaminated. Analytical results from previous product characterization performed as part of SERA VI were used, and no additional characterization of product was necessary for disposal.

3.5 Topographic Survey

Following the completion of the field investigation, the new monitoring wells, well points, sediments, and surface water locations were surveyed by a professional surveyor certified by the State of Alaska. Elevations were referenced to the U.S. Geologic Survey (USGS) benchmark datum, and coordinates were referenced to the state plane coordinate system using standard measurement units (feet). Survey points were of Third Order Class I with an accuracy of one in 10,000.

3.6 Photodocumentation

Due to the location of some field activities, such as well installation, photographs were not taken for each task conducted during the field investigation. Photographs are presented in Appendix B.

3.7 Waste Management

Investigation-derived waste (IDW) from soil borings and groundwater sampling was containerized in 55-gallon drums in conformance with state, local, and CERCLA requirements as described in the waste management plan (WMP) in the workplan (USAF, 2000b). IDW was transported and staged at the Environmental Restoration Yard (staging area) located at the corner of Arctic Warrior Drive and 9th Street on Elmendorf AFB, pending receipt of analytical results. The supervising rig geologist and groundwater sampling task leader recorded the number of drums, contents, origination of media, and drum contents.

Potentially hazardous IDW liquids consisted of purge water produced during groundwater sampling or rinsate water containing methanol and hexane generated during decontamination of sampling equipment. Due to the limited amount of methanol and hexane-laden rinse water generated during the investigation, water was treated at the wastewater treatment system in the Environmental Restoration Yard staging area. After treatment, the liquid was disposed of on-site through the sanitary sewer system.

Purge water from the pumping test conducted at 41755-WL21 was treated on-site using fabric filters and a portable 55-gallon GAC unit then discharged into the drainage ditch located west of well 41755-WL21. Three analytical samples were collected during the process as well as field parameters to ensure no breakthrough or signs of sheen was present in the water prior to discharge.

Composite samples from drums containing IDW soils were used to characterize the waste. Upon receipt of the analytical results, the proper disposal of the containerized soil was determined by the suite of drums included for each composite sample. Drums were composited according to which soil boring/well installation boring they were derived from. A technical memorandum was submitted to the USAF and ADEC for approval before disposal of the soil cuttings. All drums were disposed of according to the procedures outlined in the 2000 DP98 Final Workplan.

3.8 Record Keeping

Field records were maintained to enable the re-creation of sampling and measurement activities performed during this investigation. Sampling and analysis records were designed to meet the requirements of the Environmental Resources Program Information Management System (ERPIMS).

Section 4.0
HYDROGEOLOGICAL ASSESSMENT

One of the main objectives of the 2002 field investigation was to characterize the geology and hydrogeology of Site DP98 to understand the vertical and lateral distribution and the effect physical characteristics have on the occurrence and movement of contaminants in the subsurface. This section presents an interpretation of the subsurface hydrogeological (physical) characteristics based on site activities since 1996, and integration of mapped geologic units described in regional studies presented in Section 1.3.1.

4.1 Site Physiography

Site DP98 lies on the northwest flank of the northeast trending ridge that cuts Elmendorf AFB diagonally from southwest to northeast. This ridge is made up predominantly of glacial deposits and has been mapped by Miller and Dobrovolny (1959) as the Elmendorf End Moraine (Figure 4-1). Kames and kettles cover most of the surface of this Wisconsin age Naptowne glacial sequence moraine. Many of the kettles contain ponds or lakes, others contain swamp deposits, and still others are unfilled. Small drainage ways locally modify the knob and kettle topography. Based on observations during the 2002 field investigation, sediments of the Elmendorf End Moraine in the area of Site DP98 are underlain by the older (Pre-Wisconsin Knik glacial sequence) Bootlegger Cove Formation. A detailed account of this geologic contact below the southern portion of the Facility is presented in Section 4.4.

Portions of the land surface at Site DP98 have undergone significant modification as part of the original construction of the 381st IS Facility in the early 1950s and the later establishment of earthen pads (fill material) for the antenna arrays. Based on a review of aerial photographs, the site topography beneath the Facility was altered and a former drainage channel was filled to construct the main buildings (18220 and 18224) and the pad for the antenna array (prior to the larger “Elephant Cage”). This antenna pad was located approximately 200 feet north-northwest of Building 18224. A sloped embankment north of the secured-area fence line was elevated with as much as 25 feet of fill material to construct the pad.

4.2 Surface Soils

Surface soils at Site DP98 are described as follows, based on U. S. Department of Agriculture (USDA) classifications (1997):

- **Cryorthents, gravelly, smoothed, 0 to 3 percent slopes –** Characterizes the fill material around the Facility and is typically well-drained gravelly sand or sandy loam.
- **Kichatna-Purches Variant-Jacobsen complex, 0 to 15 percent slopes –** Found on the sloped embankment north of the Facility. Consists of poorly drained silt, sand, and gravel mixtures.
- **Doroshin mucky peat, 0 to 3 percent slopes –** Present within the low-lying area north of the Facility at the base of the slope extending north-northeasterly and includes soils around a kettle pond found north of the parking area. This soil type, consisting of silt loam overlain by peat or mucky peat, is very poorly drained within muskeg borders and moraines. The depth to the seasonally high water table typically ranges from the surface to less than 0.5 feet depth bgs.

4.3 Site Hydrology

The following subsections describe the three areas of surface water drainage in and around Site DP98, the Facility, on the slope, and within the wetland.

4.3.1 Facility Drainage

During site construction, the topography was altered in order to control surface water runoff. Most of the surface soil within the fenced Facility was either paved with asphalt or covered with concrete.

Figure 4-1. Physiographic Features of Elmendorf AFB, Alaska

As a result, the Facility surface water drainage on the west and north sides of Building 18224 follows the topographic contours, which decrease in elevation towards the north-northwest. A natural drainage and sloped embankment occurs outside the fence line on the north side of the Facility and drains the small antenna pad north of Building 18224. An asphalt-paved driveway surrounds the buildings, and paved parking areas are located outside the eastern fence line. An asphalt and gravel roadway provide access from the parking lot on the northeastern corner of the Facility to the main antenna array (Elephant Cage).

4.3.2 Slope Drainage

Surface water runoff has eroded drainage channels into the slope beyond the constructed embankment north of Building 18224. These channels, formed in the fill material, could provide preferential pathways for contaminant migration. As identified in the 2001 EE/CA, three developed rills bifurcate the topography of the slope north of the Facility (Figure 3-1). Only the area between the two western rills contained water during the 2002 field activities. Because this is where groundwater surfaces, all of the surface water samples collected during the field activities were within organic rich peat soil between the two western drainages. All of the well points (WP-1 through WP-12) were also located between the two western drainage rills. From east to west, the slope drainage areas are as follows:

- **Drainage rill 1 –** Located approximately 120 feet west of monitoring well 41755-WL13. No water was observed within this drainage area during the 2002 field activities. The location of surface water sample DP98-SW04 collected in 2000 defines the extent of this drainage.
- **Drainage rill 2 –** Located approximately 100 feet east-northeast of monitoring well 41755-WL04. Surface water sample DP98-SW03 collected in 2000 defines the northern extent of this drainage. Rill 2 made up the eastern boundary of the surface water sample locations and well points collected during the 2002 field investigation. The western and eastern extents of this drainage were defined by surface water samples E02-DP98-SW09 and E02-DP98-SW10, respectively.
- **Drainage rill 3 –** Located approximately 50 feet west of monitoring well 41755-WL05. Surface water sample DP98-SW02 collected in 2000 defines the extent of this drainage. Rill 3 made up the western boundary of the surface water sample locations and well points collected during the 2002 field investigation. The western and eastern extents of this drainage were defined by surface water samples E02-DP98-SW07 and E02-DP98-SW05, respectively.

4.3.3 Wetland Drainage

A pronounced drainage is present at the base of the slope north of the Facility. The NWI map for the Anchorage area has classified this wetland approximately 500 feet north of the Facility at Site DP98 as an SS1/EM5, which is defined as a broad-leaved deciduous, scrub-shrub, emergent wetland (USFWS, 1979). Wetlands are transitional areas between terrestrial and aquatic environments where the water table is usually at or near the surface or the land is covered by surface water. A wetland by definition must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year. Based on general observations, the area at the base of the slope north of the Facility may meet the criteria for SS1/EM5 wetland designation.

EM5 is characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for the most of the growing season in most years. These wetlands are usually dominated by perennial plants. Emergent wetlands are known by many names including marsh, meadow, fen, prairie pothole, and slough.

The SS1 classification is given to areas dominated by woody vegetation less than 20 feet tall. The species include true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions. The wetland north of the Facility has a broad-leaved deciduous subclass. This subclass is typically dominated by alders, willows, buttonbush, red osier dogwood, spirea, bog birch, and young trees of species such as black spruce.

According to lithologies identified during advancement of soil borings 41755-WL15, 41755-WL16, and 41755-WL17, groundwater occurs just below a mat of organic peat approximately 1 to 2 feet bgs. When surface water runoff reaches the base of the slope, the surface water apparently follows a topographic low north-northeast towards an open kettle pond. The surface water in this area appears to be a result of both direct runoff of precipitation and from groundwater discharge at the base of the slope. The potentiometric surface of unconfined groundwater intersects topographic contours at the base of the slope.

Within the wetland, the surface elevation drops 8 feet over a distance of approximately 800 feet (0.01 gradient), in a northeasterly direction. Most surface water flows northeast towards the kettle pond, and a small percentage of the water appears to flow northwesterly towards a small knoll.

In the wetland, the movement of water is the primary vehicle for inorganic and organic chemical processes. The flow of groundwater and surface water acts to transport dissolved and suspended organic and inorganic constituents. Surface and groundwater also mediate inorganic and biochemical reactions.

4.4 Site Geology

The following description of subsurface geology is based on review of boring logs from soil borings and well installations conducted at the site since 1996, and the 2002 field activities. In general, four main geologic units occur in the subsurface below Site DP98. Three of the four units have been interpreted to be sediments of the Elmendorf End Moraine. The fourth unit has been interpreted to be sediments of the Bootlegger Cove Formation that occurs below the Elmendorf End Moraine sediments.

The general subsurface geology below Site DP98 is depicted in seven geologic cross-sections constructed from the boring logs. The locations of each geologic cross-section are presented in Figure 4-2. Three south to north geologic cross-sections (A-A′, B-B′, and C-C′), and four east to west geologic cross-sections (D-D′, E-E′, F-F′, and G-G′) are shown in Figures 4-3 through 4-9.

Based on our interpretation of the boring logs and geologic cross-sections, the following generalized stratigraphic sequence occurs from surface level to approximately 120 feet bgs at Site DP98:

- **Imported Fill Material –** 10 to 16 feet thick below the southern portions of the Facility, and 1 to 8 feet thick below the slope portions of the site.
- **Clayey Gravelly Silt and Gravelly Sand –** 5 to 25 feet thick below the southern portions of the Facility, 10 to 30 feet thick below the slope portions of the site, 15 to 35 feet thick below the northern portions beyond the slope, and 5 to 35 feet thick below the wetland portion of the site. This material represents the uppermost geologic unit of the Elmendorf End Moraine (mapped unit Qey of Cederstrom, Trainer, and Waller [1964]) sediments.
- **Silty Clay** – 10 to 12 feet of silty clay was found to occur locally below the southern portion of the Facility and in the central portion of the wetlands area. Up to 5 feet of the silty clay was penetrated in well boring 41755-WL23 in the wetlands at a depth of 18 to 23 feet. This material comprises the second geologic unit of Qey sediments.
- **Gravelly Silty Sand –** 30 to 35 feet thick below the southern portions of the Facility; 18 to 25 feet thick below the slope portions of the site; and up to 65 feet thick below the northern and wetlands portions of the site beyond the slope. This material comprises the lowermost geologic unit of Qey sediments.

- **Silty Clay –** up to 30 feet thick below the southern portions of the Facility. This material represents the Bootlegger Cove Formation (mapped unit Qeo of Cederstrom, Trainer, and Miller [1964]). The geologic contact between the younger Qey sediments and older silty clay facies of Qeo was penetrated only in pilot boring (DP98-PB14) at an approximate elevation of 90 feet above msl during the 2002 field investigation.

  A brief description of soils and sediments within each of the stratigraphic sequences follows.

4.4.1 Imported Fill Material

The thickness of the imported fill material decreases from south to north below the Facility (Figures 4-3, 4-4, and 4-5) and consists of light brown to brown-colored, loose, silty gravel to a medium-grained gravelly sand.

4.4.2 Clayey Gravelly Silt and Gravelly Sand

The first native soil that underlies the imported fill material consists of a tan-colored, firm to stiff, clayey gravelly silt with small- to medium-sized subrounded gravel and a moderate clay component. The clayey gravelly silt is interlayered locally with lenses of gray-colored, medium-dense to hard, gravelly, fine- to medium-grained sand, with medium to large-sized subrounded gravel. The sand lenses usually have a higher moisture content than the clayey gravelly silt. The gravelly sand is the most variable in occurrence across the site. In the southeastern portion of the Facility, the clayey gravelly silt is interlayered with lenses of a grayish-brown, medium-dense silty sand and clayey silty sand.

4.4.3 Silty Clay

In the southern portion and central wetland areas of the site, the clayey gravelly silt and gravelly sand is underlain by a gray-colored, firm to stiff, dry, silty clay. This silty clay has not been observed in boring logs below the main Facility, the slope, and north portions of the site (Figure 4-4). A brownish-gray colored, firm, moist to very moist, clayey silt was observed in the two 2002 well borings (41755-WL21 and 41755-WL22A) on the slope portion of the site. The clayey silt is more widespread below the Facility and may be a transitional facies of the silty clay at depth.

4.4.4 Gravelly Silty Sand

The lowermost geologic unit interpreted as Qey sediments is a gray-colored, medium-dense to dense, gravelly silty sand that is intercalated with medium- to coarse-grained gravelly sand. In pilot boring DP98-PB14 in the southern portion of the site, this lowermost Qey unit was bounded by impermeable silty clay sediments, below and above it. In well boring 41755-Wl23 in the wetlands area, the gravelly silty sand extended from depths of 25 to 89 feet bgs below the younger silty clay. In all other portions of the site, the gravelly silty sand underlies the clayey gravelly silt and gravelly sand unit with no fine-grained sediment layer separation.

4.4.5 Silty Clay

During the advancement of pilot boring DP98-PB14 sediments at depths beyond 120 feet bgs in the southern portion of the site, were interpreted as Bootlegger Cove Formation (Qeo). The sediment observed at an elevation of approximately 90 feet above msl was blue-gray colored, stiff, dry, silty clay with moderate plasticity. In pilot boring DP98-14PB, up to 30 feet of Qeo was penetrated to a depth of approximately 150 feet (60 feet above msl). At depth, the sediments ranged from gray-colored, firm to stiff, dry, sandy clay to stiff, dry sandy silty clay. From depths of 140 to 150 feet bgs in DP98-14PB, a gray-colored, very stiff, dry, silty clay with thin silty sand lenses was observed. The silty sand lenses usually exhibited a higher moisture content than the surrounding silty clay. Based on observations during the 2002 field investigation, up to three of the cohesive facies of Qeo designated by Updike and Carpenter (1986) and Ullery and Updike (1983) were found in pilot boring DP98-14PB.

4.5 Site Hydrogeology

During the 2002 field activities, the physical characteristics at Site DP98 were evaluated to help assess the vertical and lateral distribution and movement of contaminants in the subsurface. This section provides a synthesis of physical characteristics–specifically, hydrostratigraphic units and groundwater flow properties that are important for evaluating the subsurface environment at the site. The objective of the hydrogeological evaluation was to identify the major water-bearing units, assess the groundwater flow regime, and identify (where present) preferential pathways of groundwater flow. An understanding of the hydrogeologic setting below Site DP98 is important to the understanding of the extent of contamination and the evaluation of possible routes for contaminant migration. The geologic units identified in Section 4.4 play an important role for defining the hydrostratigraphy below the site.

4.5.1 Hydrostratigraphy

The evaluation of the groundwater conditions at Site DP98 was based on information regarding well location, well construction, vertical survey data, depth-to-groundwater measurements, and subsurface geology. Groundwater elevation data and subsurface soil types were both used to evaluate the aquifer characteristics below the Facility. Two of the geologic units described in Section 4.4 have been interpreted as the primary water-bearing zones at Site DP98. From top to bottom, they are:

- Clayey gravelly silt and gravelly sand unit; and
- Gravelly silty sand unit.

Saturated sand lenses within the clayey gravelly silt and gravelly sand unit were found to be the main source beds for an unconfined aquifer below Site DP98. In two locations (well 41755-WL20 and well 41755-WL23), the unconfined aquifer may be under semi-confined conditions. The presence of the shallow, silty clay unit dictated the potential for semi-confined conditions within the lower, gravelly silty sand unit. Based on the subsurface geology and hydrogeological conditions, Site DP98 is underlain by an unconfined (water table) aquifer.

A significant transition in the site's underlying geology occurs from the higher surface elevations of Buildings 18220 and 18224, onto the slope and northern portions of the Facility, and further north toward the wetlands. The southern portion of the Facility in the area of pilot boring DP98-PB14 is underlain by 10 feet of aquitard material from 155 to 164 feet above msl that separates the clayey gravelly silt and gravelly sand unit with the lower gravelly silty sand unit and appears to be discontinuous to the north, as shown in north-south geologic cross-sections B-B' and C-C' (Figures 4-4 and 4-5, respectively). This impermeable layer appears to be "leaky" upon thinning northward and changes in composition laterally east and west from silty clay to a clayey silt. The apparent thinning and discontinuous nature of the impermeable unit northward and laterally suggests that the two water-bearing zones are hydrologically connected. The total saturated thickness of the unconfined aquifer below Site DP98 ranges from 5 to 65 feet.

Four samples collected from well boring 41755-WL23 were submitted to Shannon and Wilson, Inc. of Anchorage, Alaska for grain-size (sieve analysis) by ASTM Method C136, bulk density measurements by procedures outlined in ASTM D 2937, and falling head permeability analyses by ASTM Method D 5084. Grain size analysis (sieve with hydrometer) was conducted on one sample (DP98-WL23-PHYS04) using ASTM Method D422.

Sample number DP98-WL23-PHYS01 was collected from a depth of 6.5 feet bgs. Grain size analysis of sample PHYS01 classified the sample as a silt with sand. The bulk density of sample PHYS01 was calculated at 1,941 kilogram per cubic meter ($Kg/m^{3)}$ and the average hydraulic conductivity based on three falling head permeability tests was 3.8 x 10^{-7} centimeters per second (cm/s).

Sample number DP98-WL23-PHYS02 was collected from a depth of 9 feet bgs. Grain size analysis of sample PHYS02 classified the sample as a silt with sand (slightly gravelly, sandy silt). The bulk density of sample PHYS02 was calculated at 2,011 Kg/m^3 and the average hydraulic conductivity of 2.6 x 10^{-6} cm/s. Sample PHYS03 was collected from a depth of 27 feet bgs. Sieve analysis of sample PHYS03 classified the sample as a silty sand with gravel. The bulk density of sample PHYS03 was calculated at 2,334 Kg/m^3 and an average hydraulic conductivity of 5.2 x 10^{-7} cm/s. Sample PHYS04 was collected from a depth of 55 feet bgs. Sieve with hydrometer analysis of sample PHYS04 classified the sample as a silty sand with gravel. The bulk density of sample PHYS04 was calculated at 2,107 Kg/m^3 and an average hydraulic conductivity of 6.0 x 10^{-7} cm/s.

4.5.2 Aquifer Pumping Test Analysis

URS conducted an aquifer pumping test at Site DP98 to acquire data in determining aquifer parameters and to evaluate whether communication existed between the clayey gravelly silt and gravelly sand unit and the lower gravelly silty sand unit in the immediate vicinity of well 41755-WL21. Well 41755-WL21 was chosen because of its location within the slope portion of the Facility. A 24-hour continuous step draw-down test began on 31 October 2002.

On 30 October 2002, a preliminary shakedown test was conducted to identify any deficiencies in the test procedures and equipment, to identify a maximum sustainable yield from well 41755-WL21 to determine depth placement of aquifer head monitoring equipment (pressure transducers), and to conduct a pilot test of a portable treatment system for the discharged water.

The following equipment was utilized during the aquifer pumping test:

- Two-inch-diameter Grundfos RediFlow-2 submersible pump;
- Twelve-channel Hermit SE2000 Data Logger; and
- Six PXD 261 pressure transducers rated at 10 psi.

4.5.2.1 Test Configuration and Monitoring

The pump was suspended approximately 1 foot from the bottom of the well (54 feet bgs) to minimize water turbulence inside the well casing. A pressure transducer was set in well 41755-WL21 at approximately 29.50 below the top of the well casing (btoc) near the maximum allowable submersion depth of the instrument (10 psi). A check valve was placed above the inlet port of the pump to prevent backflow into the well during the recovery portion of the test. Water flow from the discharge hose in well 41755-WL21 passed through a flow-meter at ground surface, which was immediately followed by an in-line ball valve to control flow rates prior to emptying into a 250-gallon container. The flow meter was graduated in 0.1-gallon increments and also measured the cumulative total volume of water discharged. The water contained within the poly tank was gravity fed into a GAC unit prior to being discharged into a drainage swale culvert located west of well 41755-WL21.

Pressure transducers were installed in wells 41755-WL21, 41755-WL07, 41755-WL19, 41755-WL06, and 41755-WL05. All pressure transducers were rated for a 10-psi submersion depth (23.1 feet below water surface). Transducer-specific quadratic coefficients were entered into the 12-channel Hermit 2000 data logger unit. Prior to installation of the transducers, depth to water measurements were manually measured with water level sounders. The test set-up included a logarithmic sampling frequency for each pressure transducer. All watches used on-site were synchronized to the Hermit 2000 data logger internal clock.

During the course of the shakedown test and aquifer pumping test, various measurements were recorded. Groundwater parameters were recorded directly from the discharge hose (prior to treatment) using a Horriba U-22 water quality instrument. Parameters monitored included pH, temperature, conductivity, turbidity, dissolved oxygen, salinity, ORP, and total dissolved solids. Pressure transducer readings from the Hermit 2000 data logger were also recorded on field forms during the shakedown and aquifer pumping tests.

Flow rates were also recorded every 5 minutes after the start of the test or subsequent steps in flow rates, and adjustments were made as necessary to establish flow consistency. After the first 20 minutes of the test start or subsequent step, the flow rate sampling frequency was increased to 20- to 30-minute intervals. Flow rates on a gallon-per-minute (gpm) and gallon-per-second basis were recorded on field forms, in addition to the pump cycle rates that were measured in hertz (Hz). Observations were also made regarding whether hydrocarbon odors or sheens were observed in purge water prior to GAC treatment. No hydrocarbon odors or sheen were observed in either the shakedown test or aquifer pumping test.

4.5.2.2 Initial Shakedown Test

The initial shakedown test was started at 1901 on October 30, 2002 at a flow rate of 1 gpm. The shakedown test was stepped to an increased flow rate of 2 gpm at 21:44. The test was stepped again at 2206 when the pump was shut off for recovery. The shakedown test was stopped at 0917 on 2 October 2002.

Shakedown Test Results:

- It was determined that a sustainable flow rate of 1 gpm could be maintained on a long-term basis. It was also determined that a sustained flow rate of 2 gpm may jeopardize exposing the transducer in the test pumping well (41755-WL21).
- The ball valve at ground surface was not adequate in preventing back-flow of groundwater in the discharge hose from gravity feeding back into the well. Therefore, recovery rates were skewed high as a result. A check valve was added to the pump configuration for the aquifer test.
- A total of 235 gallons was purged from well 41755-WL21 during the shakedown test. Specific flows rates could easily be established within 1 minute of test steps.
- No definitive drawdown was noted in nearby observation wells.

4.5.2.3 Aquifer Pumping Test

Immediately prior to the start of the aquifer pumping test, the test setup and transducer settings were checked and verified. The test setup included a logarithmic sampling frequency for each pressure transducer. Water levels in the test well and observation wells were measured immediately prior to the start of the test. The measurement reference point for each transducer was set at zero, providing negative or positive measurements of head change in regards to the manual water level measurements collected immediately prior to the start of the test. Copies of the raw data and water level measurements from the aquifer pumping test are provided in Appendix F.

The test was started at 1902 on 31 October 2002. An approximate flow rate of 1 gpm was established at 1903 and a firm flow rate of 1 gpm was established at 1905. The first minute of the test had a flow rate of approximately 1.5 to 2 gpm. After the head in well 41755-WL21 became relatively stable (a decrease in head of 9.71 feet), the test was stepped at 0141 on 1 November 2002 when the flow was increased to 1.5 gpm. The flow rate transition from 1 to 1.5 gpm was established within seconds of the test step.

The flow rate during the second step was continued for a longer duration than the first step since a decrease in head was initially observed in well 41755-WL06 at approximately 0500 on 1 November 2002, and it was not known whether a flow rate of 2 gpm would expose the transducer in well 41755-WL21.

The decrease in head in well 41755-WL06 from the second step to the start of the third step was 1.06 feet. The drop in head in well 41755-WL21 over the course of the second step was 6.05 feet.

The test was stepped a third time at 1435 on 1 November 2002 when groundwater levels stabilized in wells 41755-WL21 and 41755-WL06. The flow rate was increased to 2 gpm. A flow rate of 2 gpm was firmly established at 1436. The test was stepped again at 1903 when the pump was shut off at the completion of the test and water level recovery was monitored. Prior to shutting off the pump, the transducer in well 41755-WL21 had 1.37 feet of available head and was still falling approximately 0.15 feet every 30 minutes. Increasing and decreasing head measurements were observed in well 41755-WL06. All four-observation wells returned to their static water levels at 1125 on 2 November 2002 (Appendix F).

Based on the pump test results, it appears that there is some degree of groundwater communication between the clayey gravelly silt and sandy gravel unit and the lower gravelly silty sand unit. No significant reductions in head were noted in any of the other observation wells. It is suspected that the observed minimal changes in head in observation wells could be considerably greater (or more laterally apparent) if higher rates of discharge were possible.

4.5.3 Hydraulic Gradient, Groundwater Flow Direction, and Groundwater Velocity

As part of the 2002 field activities, synoptic water level surveys were conducted on 17 July, 26 August, and 19 September 2002 to assess the potentiometric surface of the unconfined aquifer. During each event, several monitoring wells were not accessible and therefore not measured. The 17 July event was conducted during a dry period that experienced record high temperatures in Anchorage. The 26 August and 19 September events were conducted after the wet season began. The 19 September event included three of the four wells installed during the 2002 field activities. The 19 September event potentiometric surface is presented in Figure 4-10. An increase in hydraulic head of approximately 1 to 1.5 feet was measured between the 17 July and 26 August events. The depth to groundwater ranged from 3 to 8 feet bgs below the Facility, 5 to 13 feet bgs below the slope portion, and less than 0.5 foot above ground surface to 2 feet bgs within the wetland during the 26 August event (Table 4-1).

The groundwater flow direction across the site ranged from north-northeast to northwest during the 19 September event. The calculated hydraulic gradient for the 19 September event was 8.61×10^{-2} feet per foot (ft/ft). Based on observations during the 2002 field activities, results from the pumping test, and soil characteristic results presented in Section 4.5.1, the hydraulic conductivity for the gravelly silty sand hydrostratigraphic unit below Site DP98 is approximately 5.6×10^{-7} cm/s. Utilizing a Darcian pore factor (0.25 effective porosity) and the 19 September gradient, the average linear groundwater velocity at Site DP98 is approximately 0.061 meters per year (0.20 feet/year). Based on the length of the existing contaminant plume, this calculated velocity is a contradiction. The hydraulic conductivity value used in the calculation is from soil encountered during installation of well 41755-WL23 located in the wetlands area of the site, which may not be a true representation of the complete hydrogeologic conditions below the site.

To better quantify the heterogeneous subsurface characteristics at Site DP98, a range of hydraulic conductivities based on soil types was used to calculate the average linear velocity. The hydraulic conductivities are based on published data for clayey silts and sands and gravelly sands (Table 4-5, in Fetter, 1988). Conservative hydraulic conductivities of 10^{-4} to 10^{-6} cm/s and an effective porosity of 0.20 were used to calculate the average linear velocities at the site. Based on these values, and the 19 September gradient, the average linear groundwater velocity at Site DP98 ranges from 0.136 meters per year (m/year) (0.446 ft/year) to 13.6 m/year (44.5 ft/year).

Figure 4-2. Geologic Cross-Section Location Map

[This page intentionally left blank.]

Figure 4-3. Geologic Cross-Section A-A'

[This page intentionally left blank.]

Figure 4-4. Geologic Cross-Section B-B’

[This page intentionally left blank.]

Figure 4-5. Geologic Cross-Section C-C’

[This page intentionally left blank.]

Figure 4-6. Geologic Cross-Section D-D’

[This page intentionally left blank.]

Figure 4-7. Geologic Cross-Section E-E’

[This page intentionally left blank.]

Figure 4-8. Geologic Cross-Section F-F’

[This page intentionally left blank.]

Figure 4-9 Geologic Cross-Section G-G’

[This page intentionally left blank.]

Figure 4-10. Potentiometric Surface (September 19, 2002)

[This page intentionally left blank.]

Figure 4-xx. xxxxxx

[This page intentionally left blank.]

Figure 4-xx. xxxx

[This page intentionally left blank.]

Figure 4-xx. xxxxxx

[This page intentionally left blank.]

Figure 4-xx. xxxxxx

[This page intentionally left blank.]

Figure 4-xx. xxxxxx

[This page intentionally left blank.]

Figure 4-xx. xxxxxx

[This page intentionally left blank.]

Section 5.0
NATURE AND EXTENT

This section describes the type, concentration, and distribution of contaminants at Site DP98. All data collected at the site through the 2002 RI field program are considered in this section. The purpose of this evaluation is to determine the nature and extent of contamination in all environmental media and develop a list of contaminants of potential concern (COPCs). A complete set of historical Site DP98 analytical data for soil groundwater, sediment, and surface water is provided in Appendix C. A summary of the data QA/QC activities for the 2002 RI field program phase of investigation is included in Appendix D.

5.1 Data Evaluation

The following sections discuss the methodology and results of a preliminary data assessment conducted for the field portion of the 2001 EE/CA at Site DP98, including the data quality assessment and statistical evaluation. All data collected for the field portion of the 2001 EE/CA were first evaluated against data quality objectives and quality assurance/quality control (QA/QC) criteria. Following the quality assessment, criteria for evaluating the data against regulatory criteria were established. An assessment of the contamination for natural attenuation was also performed. Finally, metals were statistically evaluated against background concentrations. Each of these data evaluation procedures is discussed in the following subsections.

5.1.1 Assessment of Data Quality

An assessment of the data quality for the analytical data was performed and the data met the acceptance criteria as outlined in the quality assurance project plan (QAPP) for each investigation. Non-conformances of this data set are identified, discussed, and qualified in a QA/QC Summary Report (Appendix D). QA/QC summary reports for data from 2000 and 2001 were included in a previous investigation reports. The QA/QC Summary Report 2002 data set is included in this report as Appendix D.

A typical data quality assessment includes the following: a review of field records for completeness; sample identification; correlation of field test data; identification of anomalous data; and an assessment of the accuracy and precision of data consistent with the QAPP. The QAPP for the Site DP98 2001 EE/CA and additional detail on the methodology for assessing data quality is located in Appendix C of the workplan (USAF, 2000b).

Sampling and analytical activities were conducted following the procedures and requirements described in the Elmendorf AFB DP98 TCE Investigation Workplan, May 2000 and the 2002 Addendum to the Workplan. URS performed a QA/QC review of the analytical data provided by the contract laboratory, Columbia Analytical Services, Inc. The review included an evaluation of sample handling, holding times, field and laboratory blanks, field duplicates, laboratory control samples (LCS), matrix spikes, initial and continuing calibration, and surrogate recoveries. Data have been qualified in accordance with the current Air Force Center for Environmental Excellence (AFCEE) Quality Assurance Project Plan (QAPP) Version 3.1 and the approved variances for projects this year. Nonconformances of the 2002 data set are identified, discussed, and qualified in the QA/QC Summary Report in Appendix D.

Completeness goals were 95 percent for water samples and 90 percent for sediment and soil samples. For the lower semi-confined aquifer groundwater samples collected in 2002, completeness goals were not met for m,p-xylenes and polynuclear aromatic hydrocarbons. For the surface water samples collected in 2002, completeness goals were not met for acetone. For the sediment samples collected in 2002, completeness goals were not met for volatile organic compounds and gasoline range organics. A complete discussion is included in Appendix D.

5.1.2 Screening Criteria by Media

Potential applicable or relevant and appropriate requirements (ARARs) and to-be-considered criteria, advisories, and guidance documents (TBCs) were identified during the 2001 EE/CA (USAF, 2001). Following USEPA guidance, potential ARARs and TBCs that may apply to a site and its remedial action were identified at multiple points in the remedy selection process (USEPA, 1988). For Site DP98, identification of potential ARARs began in the site characterization phase during the 2001 E/CA, when sufficient data was developed so that initial judgments could be made about the chemicals present and any special characteristics of the site location could be taken into account.

These preliminary ARARs are used as the screening criteria in this section to determine the nature and extent of contaminants at Site DP98. The preliminary ARARs used as the screening criteria are based on ADEC human health goals and on federal drinking water standards (MCLs) and are considered to be protective of human health and are discussed in more detail in Section 9 of this document. For this reason, contaminants that exceed the screening criteria are considered COPCs. These COPCs are carried forward and included in development of remedial action objectives in Section 10 of the RI and the Feasibility Study. The screening criteria are selected in the following subsections based on a comparison of the preliminary ARARs by media for like compounds or analytes.

5.1.2.1 Soil Screening Criteria

Soil screening values are based on ADEC 18 AAC 75 Method Two Soil Regulatory Criteria (summarized in Table 9-1) for sites with under 40 inches of annual precipitation (ADEC, 2003). The selected screening criteria were used as a tool to evaluate the nature and extent of soil contamination at Site DP98, and identify COPCs that may require action. Potential remedial action objectives for soils are discussed in Section 10.

5.1.2.2 Groundwater Screening Criteria

Potential and selected groundwater screening criteria are summarized in Table 5-1. Potential groundwater screening criteria (summarized in Section 9) included the preliminary ARARs; ADEC 18 AAC 75 Table C (ADEC, 2003), National MCLs (primary drinking water standards), National MCLGs, and Alaska primary and secondary MCLs (18 AAC 80.300). The screening criteria were evaluated on an analyte- or chemical-specific basis with the selected level being the most conservative of the potential screening criteria for each analyte. A majority of the selected groundwater screening criteria were MCLs. In most cases MCLs are equivalent to the ADEC 18 AAC 75 Table C values. The selected screening criteria were used only to evaluate the nature and extent of groundwater contamination at Site DP98 and determine COPCs. Proposed remedial action objectives for groundwater are discussed in Section 10.

5.1.2.3 Sediment Screening Criteria

Due to the absence of numerical freshwater sediment criteria, freshwater sediment data from the wetland and onsite drainage were compared to the preliminary ARARs identified in the 2001 EE/CA and those identified for this RI/FS (Table 9-1). The selected screening criteria were used to evaluate the nature and extent of sediment contamination at the site that may require action. The upper effects threshold values for freshwater sediment provided in the NOAA Screening Quick Reference Tables (values in these tables are TBCs and are used for screening purposes only) were also compared to the sediment sample results.

5.1.2.4 Surface Water Screening Criteria

The groundwater screening criteria summarized in Table 5-1 represent the preliminary ARARs for drinking water with the most stringent of these identified as the selected screening criteria for surface water. This set of screening criteria was also used to evaluate the nature and extent of surface water contamination at Site DP98.

Table 5-1

Groundwater Screening Criteria

Analyte	ADEC (mg/L)	National Primary MCLs (mg/L)	National MCLGs (mg/L)	Alaska Primary MCLs (mg/L)	Alaska Secondary MCLs (mg/L)	Selected Screening Criteria (mg/L)	Screening Criteria Source
Hydrocarbons							
GRO	1.3	NE	NE	NE	NE	1.3	ADEC
DRO	1.5	NE	NE	NE	NE	1.5	ADEC
RRO	1.1	NE	NE	NE	NE	1.1	ADEC
Volatile and Semivolatile Organics							
Benzene	0.005	0.005	0	0.005	NE	0.005	MCL
Bromodichloromethane	0.1	0.08	0	NE	NE	0.08	MCL
Bromoform	NE	0.08	0	NE	NE	0.08	MCL
Carbon tetrachloride	0.005	0.005	0	0.005	NE	0.005	MCL
Chlorobenzene	0.1	NE	NE	NE	NE	0.1	ADEC
Chlorodibromomethane	NE	0.08	0	NE	NE	0.08	MCL
Chloroform	0.1	0.08	0	NE	NE	0.08	MCL
Dichlorobromopropane	NE	0.0002	0	0.0002	NE	0.0002	MCL
1,2-Dichlorobenzene	0.6	0.6	0.6	0.6	NE	0.6	MCL
1,3-Dichlorobenzene	NE	0.6	0.6	NE	NE	0.6	MCL
1,4-Dichlorobenzene	0.075	0.075	0.075	0.075	NE	0.075	ADEC
1,1-Dichloroethane	3.65	NE	NE	NE	NE	3.65	ADEC
1,2-Dichloroethane	0.005	0.005	0	0.005	NE	0.005	MCL
1,1-Dichloroethylene	0.007	0.007	0.007	0.007	NE	0.007	MCL
cis-1,2-Dichloroethylene	0.07	0.07	0.07	0.07	NE	0.07	MCL
trans-1,2-Dichloroethylene	0.1	0.1	0.1	0.1	NE	0.1	MCL
1,2-Dichloropropane	0.005	0.005	0	0.005	NE	0.005	MCL
1,3-Dichloropropene	0.005	NE	NE	NE	NE	0.005	ADEC
Di(2-ethylhexyl)adipate	NE	0.4	0.4	0.4	NE	0.4	MCL
Di(2-ethylhexyl)phthalate	NE	0.006	0.006	0.006	NE	0.006	MCL
Ethylbenzene	0.7	0.7	0.7	0.7	NE	0.7	MCL
Hexachlorobenzene	NE	0.001	0	0.001	NE	0.001	MCL
Hexachlorobutadiene	NE	Under Review	Under Review	Under Review	NE	Under Review	
Hexachloro-1,3-butadiene	0.01	NE	NE	NE	NE	0.01	ADEC
Hexachlorocyclopentadiene	NE	0.05	0.05	0.05	NE	0.05	MCL
Methylene Chloride	0.005	0.005	0	0.005	NE	0.005	MCL
Monochlorobenzene	NE	0.1	0.1	0.1	NE	0.1	MCL
Pentachlorophenol	NE	0.001	0	0.001	NE	0.001	MCL
Styrene	0.1	0.1	0.1	0.1	NE	0.1	MCL
1,1,2,2-Tetrachloroethane	0.004	NE	NE	NE	NE	0.004	ADEC
Tetrachloroethylene	0.005	0.005	0	0.005	NE	0.005	MCL
Toluene	1	1	1	1	NE	1	MCL
Toxaphene	NE	0.003	0	0.003	NE	0.003	MCL
1,2,4-Trichlorobenzene	0.07	0.07	0.07	0.07	NE	0.07	MCL
1,1,1-Trichloroethane	0.2	0.2	0.2	0.2	NE	0.2	MCL

Table 5-1 (Continued)

Analyte	ADEC (mg/L)	National Primary MCLs (mg/L)	National MCLGs (mg/L)	Alaska Primary MCLs (mg/L)	Alaska Secondary MCLs (mg/L)	Selected Screening Criteria (mg/L)	Screening Criteria Source
1,1,2-Trichloroethane	0.005	0.005	0.003	0.005	NE	0.005	MCL
Trichloroethylene	0.005	0.005	0	0.005	NE	0.005	MCL
Vinyl Chloride (Chloroethene)	0.002	0.002	0	0.002	NE	0.002	MCL
Xylenes (total)	10.0	10	10	10	NE	10	MCL
Acenaphthene	2.2	NE	NE	NE	NE	2.2	ADEC
Anthracene	11.0	NE	NE	NE	NE	11	ADEC
Benzo(a)anthracene	0.001	NE	NE	NE	NE	0.001	ADEC
Benzo(b)fluoranthene	0.001	NE	NE	NE	NE	0.001	ADEC
Benzo(k)fluoranthene	0.01	NE	NE	NE	NE	0.01	ADEC
Benzo(a)pyrene	0.0002	0.0002	0	0.0002	NE	0.0002	MCL
Chrysene	0.1	NE	NE	NE	NE	0.1	ADEC
Dibenzo(a,h)anthracene	0.0001	NE	NE	NE	NE	0.0001	ADEC
Fluorene	1.46	NE	NE	NE	NE	1.46	ADEC
Indeno(1,2,3-c,d)pyrene	0.001	NE	NE	NE	NE	0.001	ADEC
Naphthalene	1.46	NE	NE	NE	NE	1.46	ADEC
Pyrene	1.1	NE	NE	NE	NE	1.1	ADEC
Inorganics							
Antimony	NE	0.006	0.006	0.006	NE	0.006	MCL
Arsenic	0.05	0.01	0	0.05	NE	0.01	MCL
Barium	2	2	2	2	NE	2	MCL
Beryllium	NE	0.004	0.004	0.004	NE	0.004	MCL
Cadmium	0.005	0.005	0.005	0.005	NE	0.005	MCL
Chloride	NE	NE	NE	NE	250	250	State Secondary MCL
Chromium (total)	0.1	0.1	0.1	0.1	NE	0.1	MCL
Copper	NE	1.3	1.3	NE	1	1	State Secondary MCL
Cyanide	NE	0.2	0.2	0.2	NE	0.2	MCL
Fluoride	NE	4	4	4	2	2	State Secondary MCL
Iron	NE	NE	NE	NE	0.3	0.3	State Secondary MCL
Lead	0.015	0.015	0	NE	NE	0.015	MCL
Manganese	NE	NE	NE	NE	0.05	0.05	State Secondary MCL
Mercury	0.002	0.002	0.002	0.002	NE	0.002	MCL
Nickel	NE	NE	NE	0.1	NE	0.1	Alaska MCL
Nitrate (as nitrogen)	NE	10	10	10	NE	10	MCL
Nitrite (as nitrogen)	NE	1	1	1	NE	1	MCL
Total nitrate and nitrite (as nitrogen)	NE	10	10	10	NE	10	MCL
Selenium	0.05	0.05	0.05	0.05	NE	0.05	MCL
Silver	0.018	NE	NE	NE	0.1	0.018	ADEC
Sodium	NE	NE	NE	NE	250	250	State Secondary MCL

Table 5-1 (Continued)

Analyte	ADEC (mg/L)	National Primary MCLs (mg/L)	National MCLGs (mg/L)	Alaska Primary MCLs (mg/L)	Alaska Secondary MCLs (mg/L)	Selected Screening Criteria (mg/L)	Screening Criteria Source
Sulfate	NE	NE	NE	NE	250	250	State Secondary MCL
Total Dissolved Solids	NE	NE	NE	NE	500	500	State Secondary MCL
Thallium	NE	0.002	0.0005	0.002	NE	0.002	MCL
Zinc	NE	NE	NE	NE	5	5	State Secondary MCL
Pesticides and Aroclors							
4,4-DDD	0.0036	NE	NE	NE	NE	0.0036	ADEC
4,4-DDE	0.0025	NE	NE	NE	NE	0.0025	ADEC
4,4-DDT	0.0025	NE	NE	NE	NE	0.0025	ADEC
Aldrin	0.00005	NE	NE	NE	NE	0.00005	ADEC
alpha-BHC	0.0001	NE	NE	NE	NE	0.0001	ADEC
alpha-Chlordane	0.002	0.002	0	0.002	NE	0.002	MCL
Aroclor 1016	0.005	0.0005	0	0.005	NE	0.0005	MCL
Aroclor 1221	0.005	0.0005	0	0.005	NE	0.0005	MCL
Aroclor 1232	0.005	0.0005	0	0.005	NE	0.0005	MCL
Aroclor 1242	0.005	0.0005	0	0.005	NE	0.0005	MCL
Aroclor 1248	0.005	0.0005	0	0.005	NE	0.0005	MCL
Aroclor 1254	0.005	0.0005	0	0.005	NE	0.0005	MCL
Aroclor 1260	0.005	0.0005	0	0.005	NE	0.0005	MCL
beta-BHC	0.00047	NE	NE	NE	NE	0.00047	ADEC
delta-BHC	NE	NE	NE	NE	NE	NE	NA
Dieldrin	0.00005	NE	NE	NE	NE	0.00005	ADEC
Endosulfan I	0.2	NE	NE	NE	NE	0.2	ADEC
Endosulfan II	0.2	NE	NE	NE	NE	0.2	ADEC
Endosulfan sulfate	NE	NE	NE	NE	NE	NE	NA
Endrin	.002	NE	NE	.002	NE	.002	ADEC
Endrin aldehyde	NE	NE	NE	NE	NE	NE	NA
gamma-Chlordane	0.002	0.002	0	0.002	NE	0.002	MCL
Heptachlor	0.0004	0.0004	0	0.0004	NE	0.0004	MCL
Heptachlor epoxide	0.0002	0.0002	0	0.0002	NE	0.0002	MCL
Lindane	0.0002	0.0002	0.0002	0.0002	NE	0.0002	MCL
Methoxychlor	0.04	0.04	0.04	0.04	NE	0.04	MCL
Toxaphene	0.003	0.003	0	0.003	NE	0.003	MCL

ADEC – Alaska Department of Environmental Conservation Groundwater Cleanup Levels – 18 Alaska Administrative Code 75.345 Table C 30 January 2003.
Alaska primary MCLs and State Secondary MCLs – Alaska Administrative Code 80.300
MCLs – Maximum contaminant levels – 40 CFR, Ch.1. Part 141, Subpart B
MCLGs – Maximum contaminant level guidelines – 40 CFR Ch.1. Part 141, Subpart G
mg/L – Milligram per liter

In addition, surface water must meet the Alaska Water Quality Standards outlined in 18 AAC 70. Surface waters are monitored for total aromatic hydrocarbons (TAH) and total aqueous hydrocarbons (TAqH). TAH is quantified using EPA Method 8021B or 8260B for total BTEX. TAqH is quantified using the sum of results for total BTEX and polynuclear aromatic hydrocarbons (PAHs) using EPA Method 8310, 8270C, or 8270SIMS. Surface water samples were collected to determine whether runoff from the Facility was introducing contaminants into downslope surface water.

5.2 Physical Conceptual Site Model and Summary

A block diagram showing the physical site conceptual model is provided as Figure 5-1. Site history and physical characteristics are previously discussed in Sections 1 through 4 of this document.

Soil, groundwater, sediment, and surface water samples were analyzed for a variety of potential contaminants including petroleum hydrocarbons, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), inorganics (metals), and some physical parameters.

Results of these analyses indicate that DRO is the primary fuel contaminant observed at the site and TCE is the primary VOC contaminant observed at the site. Lesser volumes and concentrations of GRO, RRO, and TCE breakdown products were also detected at the site in both soil and groundwater. In addition, arsenic, lead, and selenium were found to exceed the selected screening criteria in soil. Cadmium and selenium exceeded the selected screening criteria in groundwater.

There are two distinct and separate areas of elevated DRO impacts to soil both above and below the zone of saturation in soils with lower concentrations tying the two areas of higher concentrations together. The first area is located approximately 600 feet north-northwest of the former UST area at the southwest corner of building 18224. Groundwater is shallow in this area and most of the soil impacts are below the saturation zone. DRO is present in soil at concentrations up to 42,000 mg/kg. DRO is observed in soil to depths of 5 to 10 feet bgs in this area. The other area, located beneath building 18224, has soil DRO concentrations in soil up to 37,100 mg/kg. DRO is observed in soil to depths of at least 26 feet bgs in this area. Free-product has been observed on the groundwater surface in the area beneath and around Building 18224 at thicknesses ranging from a thin sheen to over 3 feet. Product thickness has decreased since the maximum of 3.26 feet was measured in well 41755-WL01 in 1998. GRO and RRO concentrations were measured in soil samples from the same area with lower frequency and lower concentrations. TCE was measured in soil samples at concentrations up to approximately 60 mg/kg, which is commingled with the DRO contamination observed beneath Building 18824.

Dissolved DRO concentrations were observed in groundwater at concentrations up to 1,300 mg/L. Dissolved DRO concentrations were also observed in the same area as the soil impacts with the highest concentrations observed approximately 300 feet north-northwest of the northern extension of Building 18220. Dissolved DRO in groundwater extends approximately 600 feet north-northwest of Building 18224 with a width of approximately 300 feet. Dissolved GRO and RRO concentrations were measured in groundwater samples from the same area with lower frequency and lower concentrations. TCE was observed in groundwater at concentrations up to 5,000 µg/L. The distribution of TCE in groundwater is less extensive than DRO and is centered at the end of the building drain tile system.

Based on historical site operations and the observed contaminant distributions, it is inferred that the DRO distribution at the site is a result of releases from the former USTs and vehicle maintenance operations in Building 18224. A portion of the released DRO migrated vertically through unsaturated soil and dispersed laterally resulting in the distribution observed under Building 18224. A portion of the released DRO also appears to have preferentially migrated through the western Building 18224 drain tile.

Figure 5-1. Physical Conceptual Site Model

[This page intentionally left blank.}

This portion of the release would have been discharged near the surface at the base of the slope where it then migrated and infiltrated into the subsurface to produce the distribution observed north of Building 18220. The two resulting plumes then combined via groundwater transport mechanisms. The distribution of GRO, RRO, and TCE are inferred to be a result of vehicle maintenance activities conducted at Building 18224 with minor releases to floor drains and the drain tile resulting in the observed distribution.

5.3 Soil Analytical Results

During all phases of investigation at Site DP98, 100 soil samples were collected and analyzed for one or more of the following:

- Petroleum hydrocarbons;
- VOCs;
- SVOCs;
- Total inorganics (metals); and
- Physical parameters.

Soil samples were collected from 43 soil boring, monitoring well, and piezometer locations at the site to provide a lateral and vertical evaluation of site conditions. Locations were selected in a phased approach based on known historical and current site operations, soil gas survey results, and results of preceding investigative phases. Results of soil sample analyses are summarized and compared to screening criteria in Table 5-2.

5.3.1 Petroleum Hydrocarbons in Soil

A summary of DRO, GRO, RRO, and TCE by location is provided in Table 5-3. DRO was the most frequently detected petroleum hydrocarbon in soil at the site (Table 5-2). DRO was detected in 89 of the 103 analyzed soil samples at concentrations ranging from 1.66 to 42,000 mg/kg. The average DRO detection in soil was approximately 1,750 mg/kg. DRO was detected in 31 soil samples at concentrations above the screening level of 250 mg/kg and depths ranging from 0 to 28 feet bgs. The locations and depths of fuel compounds in soil are presented on Figure 5-2. Figure 5-3 presents an estimated distribution of DRO in soil at concentrations above 250 mg/kg. DRO is inferred to be present (via interpolation) in soil at concentrations greater than 250 mg/kg in an area that extends approximately 600 feet north-northwest from the former UST area and is approximately 300 feet wide (Figure 5-3).

5.3.1.1 DRO

There are two distinct and separate areas of elevated DRO impacts to soil both above and below the zone of saturation with lower concentrations tying the two areas of higher concentrations together. The highest DRO concentration was detected in a soil sample collected just below saturation in the wetland area from location HB-F at a depth of 5 to 5.5 feet bgs. Based on these results, DRO extends to a depth of at least 5.5 feet bgs in this area. DRO was detected in soil samples at various depths in this area ranging from 3,400 mg/kg to 42,000 mg/kg. The majority of the DRO mass in this area appears to be at or below the groundwater surface or at least the piezometric surface in this area.

The second elevated DRO concentration area is present below and north of Building 18224 (Figure 5-3). The highest measured concentration in this area was 37,100 mg/kg in the soil sample from well 41755-WL03 at a depth of approximately 28 feet bgs. DRO concentrations in this area ranged from 390 to 31,700 mg/kg with the highest concentrations below the groundwater surface or at least the piezometric surface in this area.

Table 5-2

Summary of Soil Analytical Results

Analyte	Unit	No. Tested	No. Detected	Minimum Detected Concentration	Average Detected Concentration	Maximum Detected Concentration	Screening Criteria	Maximum Reporting Limit	No. of Detections Greater than Screening Level
Petroleum Hydrocarbons									
Diesel range organics	mg/kg	103	89	1.66	1744	42000	250	20	31
Gasoline range organics	mg/kg	102	53	0.24	61.40	616	300	33	1
Residual range organics	mg/kg	75	62	4	244	10000	10000	220	1= 10000
Volatile Organics									
1,1,1,2-Tetrachloroethane	mg/kg	62	0	NA	NA	NA	NE	0.175	NE
1,1,1-Trichloroethane	mg/kg	62	0	NA	NA	NA	1	0.19	0
1,1,2,2-Tetrachloroethane	mg/kg	62	0	NA	NA	NA	0.017	0.189	0
1,1,2-Trichloroethane	mg/kg	62	0	NA	NA	NA	0.017	0.21	0
1,1-Dichloroethane	mg/kg	62	0	NA	NA	NA	12	0.213	0
1,1-Dichloroethene	mg/kg	62	1	0.058	0.06	0.058	0.03	0.21	1
1,1-Dichloropropene	mg/kg	62	0	NA	NA	NA	NE	0.21	NE
1,2,3-Trichlorobenzene	mg/kg	62	0	NA	NA	NA	NE	0.2	NE
1,2,3-Trichloropropane	mg/kg	62	0	NA	NA	NA	NE	0.21	NE
1,2,4-Trichlorobenzene	mg/kg	62	0	NA	NA	NA	2	0.2	0
1,2,4-Trimethylbenzene	mg/kg	62	5	0.057	0.30	0.84	NE	0.2	NE
1,2-Dibromo-3-chloropropane	mg/kg	62	0	NA	NA	NA	NE	0.66	NE
1,2-Dibromoethane	mg/kg	62	0	NA	NA	NA	NE	0.2	NE
1,2-Dichlorobenzene	mg/kg	62	0	NA	NA	NA	7	0.203	0
1,2-Dichloroethane	mg/kg	62	0	NA	NA	NA	0.015	0.2	0
1,2-Dichloropropane	mg/kg	62	0	NA	NA	NA	0.017	0.18	0
1,3,5-Trimethylbenzene	mg/kg	62	5	0.0242	0.30	0.837	NE	0.2	NE
1,3-Dichlorobenzene	mg/kg	62	0	NA	NA	NA	NE	0.23	NE
1,3-Dichloropropane	mg/kg	62	0	NA	NA	NA	NE	0.206	NE
1,4-Dichlorobenzene	mg/kg	62	0	NA	NA	NA	0.8	0.218	0
1-Chlorohexane	mg/kg	58	0	NA	NA	NA	NE	0.205	NE
2,2-Dichloropropane	mg/kg	62	0	NA	NA	NA	NE	0.27	NE
2-Butanone	mg/kg	7	1	0.003	0.00	0.003	NE	0.2	NE

Table 5-2 (Continued)

Analyte	Unit	No. Tested	No. Detected	Minimum Detected Concentration	Average Detected Concentration	Maximum Detected Concentration	Screening Criteria	Maximum Reporting Limit	No. of Detections Greater than Screening Level
2-Chlorotoluene	mg/kg	62	0	NA	NA	NA	NE	0.216	NE
2-Hexanone	mg/kg	2	0	NA	NA	NA	NE	0.2	NE
4-Chlorotoluene	mg/kg	62	0	NA	NA	NA	NE	0.21	NE
4-Isopropyltoluene	mg/kg	62	6	0.034	1.27	3.15	NE	0.2	NE
4-Methyl-2-pentanone	mg/kg	6	0	NA	NA	NA	NE	0.2	NE
Acetone	mg/kg	6	0	NA	NA	NA	NE	0.5	NE
Benzene	mg/kg	103	3	0.13	0.19	0.3	0.02	0.48	3
Bromobenzene	mg/kg	62	0	NA	NA	NA	NE	0.204	NE
Bromochloromethane	mg/kg	62	0	NA	NA	NA	NE	0.194	NE
Bromodichloromethane	mg/kg	62	0	NA	NA	NA	0.35	0.2	0
Bromoform	mg/kg	62	0	NA	NA	NA	NE	0.17	NE
Bromomethane	mg/kg	62	0	NA	NA	NA	NE	0.21	NE
Carbon disulfide	mg/kg	2	0	NA	NA	NA	NE	0.05	NE
Carbon tetrachloride	mg/kg	62	0	NA	NA	NA	0.03	0.19	0
Chlorobenzene	mg/kg	62	0	NA	NA	NA	0.6	0.216	0
Chloroethane	mg/kg	62	0	NA	NA	NA	NE	0.17	NE
Chloroform	mg/kg	62	42	0.0211	0.09	0.53	0.34	0.05	4
Chloromethane	mg/kg	62	0	NA	NA	NA	NE	0.74	NE
cis-1,2-Dichloroethene	mg/kg	62	12	0.049	0.80	2.084	0.2	0.2	10
cis-1,3-Dichloropropene	mg/kg	62	0	NA	NA	NA	NE	0.21	NE
Dibromochloromethane	mg/kg	62	0	NA	NA	NA	NE	0.179	NE
Dibromomethane	mg/kg	62	0	NA	NA	NA	NE	0.17	NE
Dichlorodifluoromethane	mg/kg	62	0	NA	NA	NA	NE	0.2	NE
Ethylbenzene	mg/kg	103	20	0.0398	1.19	4.87	5.5	0.19	0
Hexachlorobutadiene	mg/kg	62	2	0.018	0.02	0.024	8	0.24	0
Isopropylbenzene	mg/kg	62	6	0.0907	0.51	1.204	NE	0.2	NE
m,p-Xylene	mg/kg	70	7	0.042	0.60	2.65	NE	0.44	NE
Methyl Tert-Butyl Ether	mg/kg	56	0	NA	NA	NA	NE	0.19	NE
Methylene chloride	mg/kg	63	3	0.018	0.028	0.038	0.015	0.286	3
Naphthalene	mg/kg	62	10	0.0365	5.77	34.56	NE	0.2	NE

Table 5-2 (Continued)

Analyte	Unit	No. Tested	No. Detected	Minimum Detected Concentration	Average Detected Concentration	Maximum Detected Concentration	Screening Criteria	Maximum Reporting Limit	No. of Detections Greater than Screening Level
n-Butylbenzene	mg/kg	62	3	0.2	0.90	2.123	NE	0.21	NE
n-Propylbenzene	mg/kg	62	6	0.0305	0.80	1.97	NE	0.2	NE
o-Xylene	mg/kg	62	3	0.0625	0.42	0.71	NE	0.21	NE
sec-Butylbenzene	mg/kg	62	8	0.018	0.75	2.01	NE	0.2	NE
Styrene	mg/kg	62	0	NA	NA	NA	1.3	0.218	0
tert-Butylbenzene	mg/kg	62	2	0.017	0.03	0.039	NE	0.2	NE
Tetrachloroethene	mg/kg	62	3	0.016	0.06	0.095	0.03	0.22	2
Toluene	mg/kg	103	9	0.013	0.16	0.416	5.4	0.48	0
trans-1,2-Dichloroethene	mg/kg	62	2	0.0164	0.06	0.1031	0.4	0.2	0
trans-1,3-Dichloropropene	mg/kg	62	0	NA	NA	NA	NE	0.18	NE
Trichloroethene	mg/kg	62	21	0.02	3.74	59.63	0.027	0.2	16
Trichlorofluoromethane	mg/kg	62	0	NA	NA	NA	NE	0.25	NE
Vinyl chloride	mg/kg	62	0	NA	NA	NA	0.009	0.24	0
Xylenes	mg/kg	33	19	0.023	2.49	15.1	78	0.19	0
Semivolatile Organics									
2-Methylnaphthalene	mg/kg	56	6	0.784	15.56	76.4	NE	0.48	NE
Acenaphthene	mg/kg	59	4	0.182	0.44	1.06	210	0.8	0
Acenaphthylene	mg/kg	59	2	0.00848	0.60	1.19	NE	0.43	NE
Anthracene	mg/kg	59	2	0.00186	0.02	0.032	4300	0.39	0
Benzo(a)anthracene	mg/kg	59	1	0.00712	0.01	0.00712	6	0.47	0
Benzo(a)pyrene	mg/kg	59	2	0.00166	0.03	0.066	1	0.19	0
Benzo(b)fluoranthene	mg/kg	59	1	0.434	0.43	0.434	11	0.49	0
Benzo(g,h,i)perylene	mg/kg	59	1	0.00227	0.00	0.00227	NE	0.35	NE
Benzo(k)fluoranthene	mg/kg	59	0	NA	NA	NA	110	0.52	0
Chrysene	mg/kg	59	2	0.00371	0.30	0.598	620	0.36	0
Dibenz(a,h)anthracene	mg/kg	59	0	NA	NA	NA	1	0.32	0
Fluoranthene	mg/kg	59	2	0.00965	0.88	1.75	NE	0.29	NE
Fluorene	mg/kg	59	4	0.014	0.97	2.29	270	0.44	0
Indeno(1,2,3-cd)pyrene	mg/kg	59	0	NA	NA	NA	11	0.39	0
Naphthalene	mg/kg	59	8	0.0937	6.32	27	43	0.49	0

Table 5-2 (Continued)

Analyte	Unit	No. Tested	No. Detected	Minimum Detected Concentration	Average Detected Concentration	Maximum Detected Concentration	Screening Criteria	Maximum Reporting Limit	No. of Detections Greater than Screening Level
Phenanthrene	mg/kg	59	3	0.00853	0.49	1.15	NE	0.8	NE
Pyrene	mg/kg	59	3	0.00553	0.43	1.25	1500	0.62	0
Total Inorganics									
Arsenic	mg/kg	56	56	2.9	6.58	32.1	2	NA	56
Barium	mg/kg	56	56	32	64.16	140	1100	NA	0
Cadmium	mg/kg	56	56	0.38	0.51	0.65	5	NA	0
Chromium	mg/kg	56	56	6.6	24.90	36.5	26	NA	22
Lead	mg/kg	56	56	3.6	10.57	215	400	NA	0
Mercury	mg/kg	56	54	0.02	0.08	0.73	1.4	0.02	0
Selenium	mg/kg	56	10	0.25	0.81	2.9	3.5	0.35	0
Silver	mg/kg	56	12	0.32	0.41	0.48	21	0.3	0
Physical Parameters									
Total Organic Carbon	%	1	1	0.24	0.24	0.24	NA	NA	NA
Total Organic Carbon	mg/kg	8	8	3200	8287.5	29400	NA	NA	NA

mg/kg – Milligram per kilogram
NA – Not applicable
NE – Not established

Table 5-3

Summary of Petroleum Hydrocarbons and TCE in Soil by Location

Sample Location	Sample Type	Sample Date	Sample Depth (ft bgs)	DRO mg/kg	GRO mg/kg	RRO mg/kg	TCE mg/kg
41755-WL01-GRND	ES	07/08/96	11	1700	616	NS	NS
41755-WL01-GRND	ES	07/08/96	16.5	23	8	NS	NS
41755-WL02-GRND	ES	07/18/96	16.5	10 U	5 U	NS	NS
41755-WL02-GRND	ES	07/18/96	18.5	3050	5 U	NS	NS
41755-WL03-GRND	ES	07/18/96	16.5	2260	47	NS	NS
41755-WL03-GRND	ES	07/18/96	21	18	5 U	NS	NS
41755-WL03-GRND	ES	07/19/96	28	37100	200	NS	NS
41755-WL04-GRND	ES	08/16/96	21.5	196	18.5	NS	NS
41755-WL04-GRND	ES	08/16/96	31.5	23	5 U	NS	NS
41755-WL05-GRND	ES	08/16/96	11.5	4200	201	NS	NS
41755-WL05-GRND	ES	08/16/96	19	3400	242	NS	NS
41755-WL06-GRND	ES	08/23/96	6	10 U	5 U	NS	NS
41755-WL06-GRND	ES	08/23/96	10	10 U	5 U	NS	NS
41755-WL07-GRND	ES	08/23/96	6	139	5 U	NS	NS
41755-WL07-GRND	ES	08/23/96	11	72	33 U	NS	NS
41755-WL10-GRND	ES	07/28/97	6	58	7 U	239	NS
41755-WL10-GRND	ES	07/28/97	9	2200	190	105	NS
41755-WL11-GRND	ES	07/28/97	5.5	205	7 U	512	NS
41755-WL11-GRND	ES	07/28/97	14.5	5600	100	40 U	NS
41755-WL12-GRND	ES	08/15/97	8	20 U	1.4 U	99 U	NS
41755-WL13-GRND	ES	08/27/00	1.5	39.4	0.32 U	257	0.032 U
41755-WL13-GRND	ES	08/27/00	11	3.6 F	0.19 U	9.1 F	0.019 U
41755-WL13-GRND	ES	08/27/00	23.5	5.6	0.18 U	14	0.018 U
41755-WL14-GRND	ES	08/29/00	1.5	42.5	0.34 U	234	0.028 U
41755-WL14-GRND	ES	08/29/00	6	9.9	0.18 U	45.8	0.025 U
41755-WL14-GRND	ES	08/29/00	19	5.2	0.26 U	20.7	0.021 U
41755-WL15-GRND	ES	08/29/00	1.5	40.5	1.2 U	218	0.109 U
41755-WL15-GRND	ES	08/29/00	11	2.0 F	0.21 U	7.3 F	0.021 U
41755-WL15-GRND	ES	08/29/00	19	2.5 F	0.15 U	8.5 F	0.012 U
41755-WL16-GRND	ES	08/30/00	1.5	213	1.9 U	742	0.18 U
41755-WL16-GRND	ES	08/30/00	11	110	3.1 U	1089	0.2 U
41755-WL16-GRND	ES	08/30/00	21	4.2	0.21 U	11.3	0.019 U
41755-WL17-GRND	ES	08/30/00	1.5	84	2.1 Y	339	0.2 U
41755-WL17-GRND	ES	08/30/00	11	3.3 F	0.24 U	12.7	0.016 U
41755-WL17-GRND	ES	08/30/00	21	3.2 F	0.25 Y	8.8 F	0.018 U
41755-WL18-GRND	ES	08/31/00	1.5	2.7 F	0.23 U	14.7	0.022 U
41755-WL18-GRND	ES	08/31/00	13.5	3.8 F	0.3 Y	12.5	0.02 F
41755-WL18-GRND	ES	08/31/00	26	3.7 F	0.26 Y	10.4	0.02 U
41755-WL19-GRND	ES	08/31/00	1.5	4.4	0.15 U	18.2	0.018 U
41755-WL19-GRND	ES	08/31/00	18.5	2.0 F	0.14 U	5.5 F	0.015 U
41755-WL19-GRND	ES	08/31/00	31	3.3 F	0.16 U	7.6 F	0.014 U
DP98-SB01	ES	08/23/00	1.5	2.6 F	0.27 F	10.6	0.061 F
DP98-SB01	ES	08/23/00	8.5	3.0 F	3.09 F	15.6	3.91
DP98-SB01	ES	08/23/00	28.5	2.6 F	23.6	6.6 F	59.6
DP98-SB01	FD	08/23/00	28.5	3.18 Y	32.5	8 Y	43.56
DP98-SB01	ES	08/23/00	41	3.2 F	0.29 F	8.6 F	0.079 F
DP98-SB02	ES	08/24/00	1.5	46	1.26 F	406	1.687

Table 5-3 (Continued)

Sample Location	Sample Type	Sample Date	Sample Depth (ft bgs)	DRO mg/kg	GRO mg/kg	RRO mg/kg	TCE mg/kg
DP98-SB02	ES	08/24/00	13.5	369	21.7	6 F	1.148
DP98-SB02	ES	08/24/00	24	5090	280	11.7	0.31 U
DP98-SB02	FD	08/24/00	24	4621.4	267	11	0.39 Y
DP98-SB03	ES	08/24/00	1.5	79	1.78 F	558 J	0.362
DP98-SB03	ES	08/24/00	13.5	1635	80.4	7 F	0.173
DP98-SB03	ES	08/24/00	26	1128	69.7 J	7.3 F	0.158
DP98-SB04	ES	08/25/00	1.5	13.3	0.56 F	90.5	0.024 F
DP98-SB04	ES	08/25/00	19	2.8 F	0.3 F	4.9 F	0.086 F
DP98-SB04	ES	08/25/00	31	2.8 F	0.45 F	4.9 F	0.015 U
DP98-SB05	ES	08/26/00	1.5	43.0	0.28 U	348	0.038 U
DP98-SB05	ES	08/26/00	18.5	106 F	3.47	4.8 F	0.019 U
DP98-SB05	ES	08/26/00	26	2.6 F	0.16 U	4.3 F	0.016 U
DP98-SB05	ES	08/26/00	36	3.1 F	0.17 U	6.1 F	0.021 U
DP98-SB06	ES	08/27/00	1.5	8.1	0.23 U	53.6	0.022 U
DP98-SB06	ES	08/27/00	11	8.7	3.8 F	47.2	0.028 U
DP98-SB06	ES	08/27/00	16	1205.7	47.5 J	17.4	0.02 U
DP98-SB06	FD	08/27/00	16	1033	70.7 J	24.1	1.701
DP98-SB06	ES	08/27/00	31	4.0	4.2	12.2	6.68
DP98-SB07	ES	08/28/00	1.5	127	1.33 F	43.6	0.021 F
DP98-SB07	ES	08/28/00	4.5	1088	82.4 J	11	0.11 F
DP98-SB07	FD	08/28/00	4.5	622.4	64.9 J	7.6 Y	0.079 Y
DP98-SB07	ES	08/28/00	22	5.0	0.37 F	12.6	0.018 U
DP98-SB08	ES	08/28/00	1.5	3.0 F	0.24 F	8.3 F	0.127 F
DP98-SB08	ES	08/28/00	11	6.7	0.59 F	13	0.727
DP98-SB08	ES	08/28/00	24	5.6	0.31 F	11.4	0.016 U
DP98-SB09	ES	09/01/00	1.5	1.6 U	0.18 U	2.6 U	0.014 U
DP98-SB09	ES	09/01/00	11	1.6 U	0.17 U	3.1 F	0.016 U
DP98-SB09	FD	09/01/00	11	1.55 U	0.35 Y	4 Y	0.015 U
DP98-SB09	ES	09/01/00	21	1.7 F	0.19 U	4.4 F	0.034 U
DP98-SB10	ES	08/27/00	11	9.2	0.31 F	50.8	0.015 U
DP98-SB11	ES	09/01/00	11	2.6 F	0.27 U	16.6	0.02 U
DP98-SB12	ES	09/04/00	6	2.4 F	0.25 F	5.2 F	0.06 F
DP98-SB13	ES	09/01/00	17	3.3 F	0.47 F	12.5	0.037 U
DP98-SS01	ES	09/01/00	1.5	7.8	0.13 U	50.4	0.012 U
41755-BH01	ES	07/19/96	5	32	5 U	NS	NS
41755-BH01	ES	07/19/96	11	18	5 U	NS	NS
41755-BH01	FD	07/19/96	11	13	5 U	NS	NS
423BH02	ES	06/25/98	15	388	22.8	17.6 U	NS
423BH02	ES	06/25/98	26.5	12700	272	18.3 U	NS
423BH02	ES	06/25/98	40	34.3	1.24 U	17.5 U	NS
423BH02	FD	06/25/98	40	NS	1.34 U	NS	NS
423BH03	ES	06/25/98	15	4.35 U	1.87 U	17.9 U	NS
423BH03	ES	06/25/98	30.7	4.26 U	1.17 U	17.6 U	NS
423BH04	ES	07/20/98	20	4.44 U	1.84 U	18.3 U	NS
423BH04	FD	07/20/98	20	5.16	1.42 U	NS	NS
423BH04	ES	07/20/98	25.5	190	10.2	17 U	NS
423BH04	FD	07/20/98	25.5	217	15.4	18.5 U	NS
423BH04	ES	07/20/98	40	8.56	1.23 U	18.2	NS
423BH05	ES	10/21/99	22	240	15	NS	1.1

Table 5-3 (Continued)

Sample Location	Sample Type	Sample Date	Sample Depth (ft bgs)	DRO mg/kg	GRO mg/kg	RRO mg/kg	TCE mg/kg
423BH05	FD	10/21/99	22	250	31	NS	1.4
423BH05	ES	10/21/99	28	6 J	5 U	NS	0.05 U
41755-PZ01	ES	07/08/96	11.5	660	119	NS	NS
41755-PZ01	FD	07/08/96	11.5	660	119	NS	NS
41755-PZ02	ES	07/08/96	6	5900	60	NS	NS
41755-PZ02	ES	07/08/96	10.5	6800	30	NS	NS
41755-PZ02	FD	07/08/96	10.5	4750	270	NS	NS
41755-PZ03	ES	07/09/96	10.5	10 U	5 U	NS	NS
41755-PZ03	ES	07/09/96	16	390	14	NS	NS
SB423-01	ES	09/22/97	4.5	1600	2.4	11 U	NS
SB423-01	FD	09/22/97	4.5	1700	4.4	41	NS
SB423-01	ES	09/22/97	11	710	33	11 U	NS
SB423-02	ES	09/23/97	2	4500	4.9	10000	NS
SB423-02	ES	09/23/97	12	4.5 U	1.3 U	11 U	NS
HB-F	ES	10/13/97	5.5	42000	19	1000	NS
HB-E	ES	10/13/97	5	7500	75	220 U	NS

DRO – Diesel range organics
ES – Environmental sample
FD – Field duplicate
Ft bgs – Feet below ground surface
GRO – Gasoline range organics
J – Associated value is an estimate
mg/kg – Milligrams per kilogram
NS – Not sampled for specified analyte
RRO – Residual range organics
TCE – Trichloroethene
U – Analyte not detected at specified reporting limit
Y – The chromatographic fingerprint of the sample resembles a petroleum product eluting in approximately the correct carbon range, but the elution pattern does not match the calibration standard

Figure 5-2. Soil Analytical Data for Fuel Compounds

[This page intentionally left blank.]

Figure 5-3. Interpolated Extent of DRO in Soil Greater Than 250 mg/kg

[This page intentionally left blank.]

Figure 5-4. Soil Analytical Data for BTEX

[This page intentionally left blank.]

The total volume of soil (both saturated and unsaturated) with DRO greater than 250 mg/kg is approximately 360,000 cubic yards, which was estimated using the computer model Groundwater Modeling System (GMS). The volume of unsaturated soil with DRO greater than 300 mg/kg is approximately 107,000 cubic yards, as estimated using GMS.

5.3.1.2 GRO

GRO was detected in 53 of the 102 analyzed soil samples at concentrations ranging from 0.24 to 616 mg/kg. The average GRO concentration detected in soil was approximately 61 mg/kg. One soil sample (from location WL01 at approximately 11 ft bgs) contained GRO at a concentration greater than the screening level of 300 mg/kg. The volume of unsaturated soil with GRO greater than 300 mg/kg is approximately 4,500 cubic yards, as estimated using GMS. In general, the GRO distribution in soil at the site is coincident with the DRO detections indicating similar release mechanisms.

5.3.1.3 RRO

RRO was detected in 62 of the 75 soil samples collected from the site at concentrations ranging from 4 to 10,000 mg/kg. The average RRO concentration detected in soil was approximately 244 mg/kg. One soil sample (collected from location SB423-02 at a depth of approximately 2 feet bgs) contained RRO at a concentration equal to the screening criteria of 10,000 mg/kg. All other RRO detections in soil were at concentrations at least an order of magnitude lower than the screening criteria. In general, the RRO distribution in soil at the site is also coincident with the DRO detections indicating similar release mechanisms.

5.3.1.4 Benzene

Benzene was detected in 3 of 103 samples at concentrations ranging from 0.13 to 0.3 mg/kg. All three benzene soil detections were greater than the screening criteria of 0.02 mg/kg. The three benzene detections were from samples collected from well 41755-WL01, WL11, and PZ01 from depths of 11 to 14.5 feet bgs. These sample locations are positioned immediately adjacent to Building 18224 and are coincident with DRO, GRO, and RRO occurrences. Toluene, ethylbenzene, and xylenes were not detected at concentrations above the screening criteria (Table 5-2). The distribution of benzene, toluene, ethylbenzene, and xylenes (BTEX) is provided in Figure 5-4.

5.3.2 VOCs in Soil

Up to 58 soil samples were collected and analyzed for VOCs. Excluding BTEX, six VOC analytes (tetrachloroethene, trichloroethene, cis-1,2-dichloroethene, 1,1-dichloroethene, chloroform, and methylene chloride) were detected in soil at concentrations greater than their respective screening criteria.

5.3.2.1 TCE

TCE was detected in 21 of the 62 analyzed samples at concentrations ranging from 0.02 to 59.6 mg/kg. TCE was detected in 16 soil samples at concentrations greater than the screening criteria of 0.027 mg/kg (Table 5-2). The average TCE concentration detected was 3.74 mg/kg. Soil analytical data for selected VOCs (including TCE) is provided on Figure 5-5. Figure 5-6 presents the interpolated distribution of TCE in soil at concentrations above 0.027 mg/kg. The highest TCE concentration in soil was measured in boring DP98-SB01, located immediately adjacent to the outlet of the western drain tile for Building 18224, at a depth of approximately 28 feet bgs. An estimated volume of contaminated soil with TCE concentrations greater than the screening level, which is above the saturated zone, is approximately 127,000 cubic yards. The areal extent of TCE in soil at concentrations greater than the screening criteria extends approximately 400 feet north-northwest of Building 18224.

5.3.2.2 Cis-1,2-DCE

Cis-1,2-DCE was detected in 12 of the 62 analyzed soil samples at concentrations ranging from 0.049 to 2.08 mg/kg. The average detected cis-1,2-DCE concentration in soil was 0.8 mg/kg. Cis-1,2-DCE was detected in 10 soil samples at concentrations greater than the screening criteria of 0.2 mg/kg (Table 5-2). The highest cis-1,2-DCE concentration was measured in the soil sample from DP98-SB06 at a depth of approximately 31 feet bgs (Figure 5-5). DP98-SB06 is located approximately 100 feet north-northwest (downgradient), and at a surface lower elevation, than DP98-SB01 where the highest TCE concentration was measured in soil. Based on these observations cis-1,2-DCE is likely present at concentrations greater than 0.2

mg/kg (screening criteria) at depths in excess of 31 feet. Detections of cis-1,2-DCE are coincident with TCE detections in soil. The majority, if not all, of the cis-1,2-DCE detections were measured in saturated soil samples suggesting that natural degradation of TCE is occurring in the saturated zone, and that this is the source of the cis-1,2-DCE.

5.3.2.3 Chloroform

Chloroform was detected in 42 of the 62 analyzed samples at concentrations ranging from approximately 0.02 to 0.53 mg/kg. The average chloroform concentration detected in soil was 0.09 mg/kg. The highest chloroform concentration detected (0.53 mg/kg) was measured in the soil sample from well 41755-WL16 at a depth of approximately 11 feet bgs. Chloroform was detected in 4 samples at concentrations greater than the screening criteria of 0.34 mg/kg. Chloroform was measured in the sample from DP98-SB02 (23 feet bgs) at a concentration greater than 0.34 mg/kg. The sample from well 41755-WL17 (1.5 feet bgs) also contained chloroform at a concentration greater than 0.34 mg/kg. The frequency and concentration range of chloroform detections in soil indicates that chloroform is present at most of the sampled locations. However, the low average concentration of chloroform in soil (slightly above the detection limit) suggests that the mass of chloroform at the site is low. In addition, chloroform was detected in approximately 50% of soil trip blanks, indicating that the occurrence is likely due to laboratory contamination.

5.3.2.4 Methylene Chloride

Methylene chloride was detected in 2 of the 62 analyzed soil samples at concentrations of 0.018 and 0.027 mg/kg. Both of the concentrations are greater than the screening criteria of 0.015 mg/kg. Methylene chloride was measured at 0.027 mg/kg in the soil sample from WL12 (6 to 8 feet bgs) and at 0.018 mg/kg in the soil sample from DP98-SS01 (0.5 to 1.5 feet bgs). The low detection frequency indicates that methylene chloride impacts are very limited at the site. It is probable that the occurrence of this contaminant represents laboratory contamination.

5.3.3 SVOCs in Soil

Up to 59 soil samples were analyzed for SVOCs. SVOCs were not detected at concentrations greater than their respective screening criteria (Table 5-2).

5.3.4 Metals

An evaluation concentrations, statistical analyses and related geochemical interpretations for metals are provided in the following subsections.

5.3.4.1 Statistical Comparison of Background Concentrations

The following subsections present a sampling-and media-specific comparison of 2001 EE/CA and 2002 RI field program analytical data to background data statistics, including the preliminary ARARs and 95 percent upper tolerance limits (95 percent UTLs). Background data for metals was first reported in the 1994 OU6 RI/FS (USAF, 1996b) report and were based on the results of samples collected throughout Elmendorf AFB and incorporated data from the *Basewide Background Sampling Report* (USAF, 1993) which also included U.S. Geological Survey (USGS) dissolved and total metals concentrations in groundwater data for the greater Anchorage area.

5.3.4.2 Soil

The ranges of detected metal concentrations in soil are provided in Table 5-2 for both background and onsite surface soil samples. Table 5-4 provides the 95 percent UTLs for background metals and the preliminary ARAR soil cleanup standards.

Fifty-six soil samples and five duplicate soil samples were collected during the field portion of the 2001 EE/CA and analyzed for eight RCRA metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver). Of the samples analyzed, lead and selenium (4 samples each), mercury (2 samples), and arsenic (1 sample) were measured above the 95 percent UTL.

Table 5-4

Comparison of 2001 EE/CA Analytical Data and 1994 RI UTLs for Background Metals in Soil

Metal	Screening Criteria[a] (mg/kg)	95% UTL for Background Surface Soil (mg/kg)	95% UTL for Background Subsurface Soil (mg/kg)	2001 EE/CA Sample Results Maximum Soil Result (mg/kg)	2001 EE/CA Sample Results No Samples Exceeding Highest UTL	2001 EE/CA Sample Results Number of Samples Exceeding Background and Screening Criteria
Arsenic	**2.0**	**13.27**	**9.31**	**32.1**	**1**	**1**
Barium	1,100	196.45	95.93	140	0	0
Cadmium	5	2.68	3.07	0.65	0	0
Chromium	26	48.44	76.94	36.5	0	0
Lead	400	10.69	10.13	215.4	4	0
Mercury	1.4	0.2	0.21	0.73	2	0
Selenium	3.5	0.54	0.48	2.9	4	0
Silver	21	1.68	1.06	0.48	0	0

Notes:
No metals were found above 95% UTLs or ARARs (screening levels) in surface soil.
The maximum soil result for arsenic was collected from 10 to 11 feet below ground surface.
[a] Cleanup standard from 18 AAC 75, Table B1. Method Two, Under 40-inch zone, Migration to Groundwater (ADEC, 2003). Lead value is based on the residential scenario pathway for this metal.
mg/kg – Milligram per kilogram
UTL – Upper tolerance limit

Metals that did not exceed background UTLs in soil (e.g., barium, cadmium, chromium, and silver) are believed to represent background concentrations and are excluded from further consideration.

5.4 Free-Product Occurrences

Free product was first observed during the removal of UST AFID 755 in 1995. During the SERA Phase IV program (1996), free product was measured in wells 41755-WL01 and 41755-WL03, and hydrocarbon sheen was observed in wells 41755-WL02 and 41755-WL05. Following installation of the SERA Phase IV wells, two Petropore® passive skimmer systems were installed in each of the wells containing free product. Periodic emptying of the skimmers recovered 41 liters of free product over 18 days. The following year (1997), two larger diameter (4-inch) wells (41755-WL10 and 41755-WL11) were installed near well 41755-WL01 to increase free-product recovery rates. The 4-inch-diameter wells were equipped with Spillbuster® skimmers and actively operated for the remainder of the year; however, little free product was recovered. Since 1997, neither recovery system has been operated or maintained. A summary of the historical and 2000 free product measurements or observations is shown in Table 5-5. The estimated areal extent of the free product on groundwater is shown in Figure 5-7.

In 2000, a free product layer was measured in wells 41755-WL01, 41755-WL03, and 41755-WL11 at thicknesses of 0.5 feet, 0.33 feet, and 0.01 feet, respectively (Table 5-5). During each of these programs, well 41755-WL01 consistently contained the greatest amount of free product.

In July 2002, another active product recovery system, the Magnum Spillbuster™, was installed in well 41755-WL01 to determine the maximum amount of product that could be recovered using an active system. The system operated for approximately 3 weeks before malfunctioning. During this time, the system removed less than 1 gallon of product. After cleaning and optimizing of the system components in August 2002, the product recovery system was restarted. However, after another month of continuous operation, less than 0.5 gallon was recovered. The system was shut down in September 2002.

5.5 Groundwater Analytical Results

During all phases of investigation performed at Site DP98, 78 groundwater samples were collected and analyzed for one or more of the following:

- Petroleum hydrocarbons;
- VOCs;
- SVOCs;
- Pesticides and Aroclors; and
- Total inorganics (metals).

Groundwater samples were collected from 36 monitoring well and temporary well point locations at the site to provide a lateral, vertical, and temporal evaluation of site conditions. Locations were selected in a phased approach based on known historic and current site operations, soil gas survey results, and results of preceding investigative phases. Twelve of these locations were temporary well points installed within the margins of the wetland areas, which were sampled once and then abandoned. Groundwater samples were collected in November 1996, November 1999, September 2000, October 2001, and during the 2002 RI field program from the select locations available at the time of sampling. A summary of locations sampled by date is presented in Table 5-6. The most consistent set of wells were sampled in September 2000 and October 2001. These data sets will be used to evaluate temporal variations in site conditions.

Table 5-5

Summary of Free Product Occurrence at Site DP98

Location	Investigation and Measurement Date						
	SERA IV	**SERA VII**	**SERA VIII**	**EE/CA**		**RI/FS**	
	10/8/96	**9/16/98**	**11/10/99**	**9/15/00**	**10/2/01**	**7/23/02**	**9/19/02**
41755-WL01	0.56 ft	3.26 ft	2.0 ft	0.5 ft	Sheen	1.49 ft	0.37 ft
41755-WL02	Sheen	ND	ND	ND	ND	ND	ND
41755-WL03	0.04 ft	0.21 ft	0.01 ft	0.33 ft	0.03 ft	0.01 ft	Sheen
41755-WL05	Sheen	ND	ND	Sheen	Sheen	ND	Sheen
41755-WL11	ND	ND	Sheen	0.01 ft	NM	Sheen	Sheen
41755-423-BH02	This boring was installed in 1998	0.01 ft	NM	NM	NM	NM	NM

EE/CA – Engineering Evaluation/Cost Analysis
ft – Feet
ND – Not detected
NM – No measurement taken

Figure 5-5. Soil Analytical Data for Select VOCs

[This page intentionally left blank.]

Figure 5-6. Interpolated Extent of TCE in Soil Greater Than 0.027 mg/kg

[This page intentionally left blank.]

Figure 5-7. Estimated Limits of Free Product

[This page intentionally left blank.]

Table 5-6

Summary of Groundwater Sampling Locations by Date

Sampling Date	Locations Sampled
November 1996	41755-WL02, 41755-WL04, 41755-WL05, 41755-WL06, 41755-WL07, 41755-WL08, 41755-WL09
November 1999	41755-WL01, 41755-WL02, 41755-WL04, 41755-WL05, 41755-WL06, 41755-WL07, 41755-WL08, 41755W-L09, 41755-WL10, 41755-WL11, 41755-WL12
September 2000	41755-WL01, 41755-WL02, 41755-WL04, 41755-WL05, 41755-WL06, 41755-WL07, 41755-WL08, 41755W-L09, 41755-WL10, 41755-WL11, 41755-WL12, 41755-WL13, 41755-WL14, 41755-WL15, 41755-WL16 41755-WL17, 41755-WL18, 41755-WL19
October 2001	41755-WL01, 41755-WL02, 41755-WL04, 41755-WL05, 41755-WL06, 41755-WL07, 41755-WL08, 41755W-L09, 41755-WL10, 41755-WL12, 41755-WL13, 41755-WL14, 41755-WL15, 41755-WL16 41755-WL17, 41755-WL18, 41755-WL19
August 2002	WP-1, WP-2, WP-3, WP-4, WP-5, WP-6, WP-7, WP-8, WP-9, WP-10, WP-11, WP-12
September October 2002	41755-WL22A, 41755-WL23

41755-WLXX are groundwater monitoring wells. WP-XX are temporary wells points that were installed in the lower elevation areas, sampled, and removed

Results of groundwater sample analyses are summarized and compared to screening criteria in Table 5-7. The statistical summary of groundwater analytical results includes multiple samples from the same sampling locations. Groundwater samples collected from wells 41755-WL20 through 41755-WL23 did not contain any of the target analytes at concentrations greater than screening criteria. These wells are completed and screened within the semi-confined unit at the site. As a result the following discussion is limited to the upper unconfined aquifer at the site.

5.5.1 Petroleum Hydrocarbons in Groundwater

The analytical data show a mixture of fuel contaminants (DRO, GRO, and BTEX) in groundwater centered near the end of the building drain tile. These contaminants are migrating north-northwest with the prevailing groundwater flow. The lateral extent of each fuel contaminants observed in the combined plume is defined by wells that did not contain contaminant concentrations above screening criteria in all directions except to the northwest. The boundaries of the DRO plume can only be qualitatively defined to the northwest due to a distance of 320 feet between downgradient wells 41755-WL12 and 41755-WL17, due to the one exceedance at 41755-WL12. It is possible that DRO concentrations above screening criteria extend through this gap.

The lateral extent of fuels in groundwater varies depending upon the fuel component with DRO being the primary, most laterally extensive and highest concentration component of the identified fuel contaminants. The dimensions and trends of these plumes are shown on Figures 5-8 and 5-10. The soil gas results conducted in 1997 and 2000 correlate well with the hydrocarbon plumes, which also appears to overlie the contaminated soil areas previously discussed. For example, some of the highest DRO concentrations in groundwater samples from near the wetland correlated with some of the highest DRO concentrations in soil and TPH concentrations detected during the soil gas survey (Appendix G).

5.5.1.1 DRO

DRO is the most frequently detected petroleum hydrocarbon in groundwater. DRO was detected in 67 of the 69 analyzed samples at concentrations ranging from 0.023 to 1,300 mg/L (Table 5-7). The average DRO concentration detected in groundwater was approximately 31.5 mg/L. DRO was detected in 27 groundwater samples at concentrations greater than the screening criteria of 1.5 mg/L. The highest concentration was measured in the September 1999 groundwater sample collected from 41755-WL01. Seven of the nine highest DRO concentrations were measured in multiple groundwater samples from wells 41755-

WL01, 41755-WL03, and 41755-WL05. Table 5-8 provides a summary of DRO results by location and date. The estimated distribution of DRO contamination is provided on Figure 5-8. The interpolated extent of DRO in groundwater at concentrations greater than 1.5 mg/L is provided on Figure 5-9. Contours of fuel component concentrations are provided as Figure 5-10. A summary of groundwater hydrocarbon results by location and date is provided in Table 5-8.

Both the average and maximum measured DRO concentration in groundwater increased substantially from September 2000 to October 2001. The average measured DRO concentration in September 2000 groundwater samples was approximately 2.0 mg/L while the average measured DRO concentration in October 2001 groundwater samples was approximately 5.2 mg/L. The maximum September 2000 DRO concentration of 15.47 mg/L measured in the sample from well 41755-WL01, located immediately adjacent to the former UST. The maximum October 2001 DRO concentration of 49 mg/L was measured in the sample from well 41755-WL03, located approximately 140 feet downgradient of 41755-WL01. DRO concentrations increased from 5.79 mg/L in the September 2000 sample from well 41755-WL03 to 49 mg/L in the October 2001 sample. DRO concentrations also increased from 15.47 mg/L in the September 2000 sample from well 41755-WL01 to 24 mg/L in the October 2001 sample. Since the inferred source of DRO in the subsurface, the former USTs, have been removed or taken out of commission, this increasing concentration trend suggests that residual DRO in soil is acting as a continuing source of contamination to the groundwater. Additionally, there is a potential for emulsified DRO at the site because the reported DRO concentrations are detected at higher concentrations than the reasonable maximum solubility of DRO in fresh water, approximately 2 to 24 mg/L (Shiu et al 1990). The maximum solubility of DRO is dependent on site-specific conditions. Samples with detected DRO concentrations in excess of the maximum solubility concentration of DRO do not necessarily represent dissolved concentrations of DRO, but more likely contain emulsified DRO.

The distribution of DRO in groundwater represents the largest fuel plume at Site DP98. The plume extends from its suspected source (former UST AFID 755) south of Building 18224 north towards the slope (Figure 5-9). Groundwater data collected in 2001 and 2002 shows two areas of elevated concentrations, one beneath building 18224 (coincident with the free product plume) and one north-northwest of the western drain tile from Building 18224. The plumes are tied together with an area of lower concentrations. The relatively narrow zone of DRO contamination potentially discharges to the wetland between wells 41755-WL07 and 41755-WL09. An extension of the DRO plume within the wetland probably also extends from the base of the slope towards well 41755-WL12 at concentrations near, but not above, screening criteria. Free product has persisted in well 41755-WL01 since the well was installed in 1996 (refer to Table 5-4).

The depth to groundwater across the site ranges from approximately 5 feet bgs near the former location of UST 755 to approximately 15 feet bgs near the top of the slope north of the Facility (Figure 4-4). The thickness of the unconfined aquifer ranges from approximately 40 feet (the top of the silty clay interval) beneath the former UST location to less than 10 feet thick at the base of the slope near well 41755-WL08 and 41755-WL09. The average saturated thickness is approximately 25 feet along this trend. Given that the dimensions of the groundwater plume (Figure 5-10) to the base of the slope (where groundwater would likely discharge) are approximately 600 feet long by 150 feet wide and the average thickness (25 feet thick) and an estimated porosity range of 0.13 to 0.30 for glacial sediments (Domenico and Schwartz, 1990), the volume of groundwater potentially contaminated with DRO above screening criteria would be between 292,500 to 675,000 cubic feet (2.2 to 5.0 million gallons). Assuming a porosity of 0.3, the computer-interpolated volume of groundwater potentially contaminated with DRO above screening criteria could be up to 12 million gallons (Figure 5-9).

Table 5-7

Summary of Groundwater Analytical Results

Analyte	Units	No. Tested	No. Detected	Minimum Detected Concentration	Average Detected Concentration	Maximum Detected Concentration	Screening Value[a]	Maximum Reporting Limit	No. of Detections Greater than Screening Level
Petroleum Hydrocarbons									
Diesel range organics	mg/L	74	67	0.023	30.6	1,300	1.5	0.11	27
Gasoline range organics	mg/L	74	48	0.007	0.8	4.4	1.3	0.10	9
Residual range organics	mg/L	51	47	0.046	0.30	1.7	1.1	NA	12
Volatile Organics									
1,1,1,2-Tetrachloroethane	µg/L	71	0	NA	NA	NA	NE	23	NA
1,1,1-Trichloroethane	µg/L	71	7	0.3	1.11	3.3	200	23	0
1,1,2,2-Tetrachloroethane	µg/L	71	1	0.9	0.9	0.9	4	27.6	0
1,1,2-Trichloroethane	µg/L	71	2	0.4	0.43	0.45	5	20	0
1,1-Dichloroethane	µg/L	71	14	0.11	0.93	3.2	3,650	18.2	0
1,1-Dichloroethene	µg/L	71	13	0.52	7.33	19	7	24	9
1,1-Dichloropropene	µg/L	71	0	NA	NA	NA	NE	26	NA
1,2,3-Trichlorobenzene	µg/L	71	2	3	5.5	8	NE	8.8	NA
1,2,3-Trichloropropane	µg/L	71	0	NA	NA	NA	NE	43	NA
1,2,4-Trichlorobenzene	µg/L	71	1	2	2	2	70	40	0
1,2,4-Trimethylbenzene	µg/L	71	23	0.12	93.83	1000	NE	29	NA
1,2-Dibromo-3-chloropropane	µg/L	71	0	NA	NA	NA	NE	199	NA
1,2-Dibromoethane	µg/L	71	0	NA	NA	NA	NE	15	NA
1,2-Dichlorobenzene	µg/L	71	2	0.2	0.25	0.3	60	17	0
1,2-Dichloroethane	µg/L	71	0	NA	NA	NA	5	23	0
1,2-Dichloropropane	µg/L	71	0	NA	NA	NA	5	24.8	0
1,3,5-Trimethylbenzene	µg/L	71	20	0.16	37.19	320	NE	25	NA
1,3-Dichlorobenzene	µg/L	71	0	NA	NA	NA	600	21	0
1,3-Dichloropropane	µg/L	71	0	NA	NA	NA	NE	15.2	NA
1,4-Dichlorobenzene	µg/L	71	0	NA	NA	NA	75	17.4	0
1-Chlorohexane	µg/L	54	0	NA	NA	NA	NE	24	NA
2,2-Dichloropropane	µg/L	71	0	NA	NA	NA	NE	35	NA

Table 5-7 (Continued)

Analyte	Units	No. Tested	No. Detected	Minimum Detected Concentration	Average Detected Concentration	Maximum Detected Concentration	Screening Value[a]	Maximum Reporting Limit	No. of Detections Greater than Screening Level
2-Butanone	µg/L	22	0	NA	NA	NA	NE	20	NA
2-Chlorotoluene	µg/L	71	0	NA	NA	NA	NE	22.2	NA
2-Hexanone	µg/L	17	0	NA	NA	NA	NE	20	NA
4-Chlorotoluene	µg/L	71	0	NA	NA	NA	NE	18	NA
4-Isopropyltoluene	µg/L	71	21	0.12	10.66	48	NE	26	NA
4-Methyl-2-pentanone	µg/L	22	0	NA	NA	NA	NE	20	NA
Acetone	µg/L	22	6	2.64	4.11	8	NE	20	NA
Benzene	µg/L	78	28	0.11	16.05	160	5	21	13
Bromobenzene	µg/L	71	0	NA	NA	NA	NE	19.5	NA
Bromochloromethane	µg/L	71	0	NA	NA	NA	NE	25.2	NA
Bromodichloromethane	µg/L	71	1	0.2	0.2	0.2	80	17	0
Bromoform	µg/L	71	0	NA	NA	NA	80	56	0
Bromomethane	µg/L	71	10	0.27	0.46	1.1	NE	44	NA
Carbon disulfide	µg/L	17	3	0.2	0.27	0.3	NE	0.5	NA
Carbon tetrachloride	µg/L	71	0	NA	NA	NA	5	25	0
Chlorobenzene	µg/L	71	0	NA	NA	NA	NE	18.7	NA
Chloroethane	µg/L	71	10	0.32	0.9	2.8	NE	35	NA
Chloroform	µg/L	71	17	0.1	0.77	3.8	80	19.2	0
Chloromethane	µg/L	71	14	0.37	2.95	10	NE	28	NA
cis-1,2-Dichloroethene	µg/L	71	38	0.14	1167.91	5700	70	6.13	20
cis-1,3-Dichloropropene	µg/L	71	0	NA	NA	NA	NE	17	NA
Dibromochloromethane	µg/L	71	0	NA	NA	NA	NE	17	NA
Dibromomethane	µg/L	71	0	NA	NA	NA	NE	20	NA
Dichlorodifluoromethane	µg/L	71	0	NA	NA	NA	NE	34	NA
Ethylbenzene	µg/L	78	34	0.12	26.81	320	700	20	0
Hexachlorobutadiene	µg/L	71	2	2	2.06	2.11	NE	76	NA
Isopropylbenzene	µg/L	71	26	0.12	9.19	30	NE	14	NA

Table 5-7 (Continued)

Analyte	Units	No. Tested	No. Detected	Minimum Detected Concentration	Average Detected Concentration	Maximum Detected Concentration	Screening Value[a]	Maximum Reporting Limit	No. of Detections Greater than Screening Level
m,p-Xylene	µg/L	68	22	0.26	81.99	920	10,000	38	0
Methyl Tert-Butyl Ether	µg/L	54	0	NA	NA	NA	NE	15	NA
Methylene chloride	µg/L	71	19	0.15	24.58	170	5	20	7
Naphthalene	µg/L	68	34	0.08	130.85	1200	1,460	14.4	0
n-Butylbenzene	µg/L	71	16	0.13	11.09	39	NE	45	NA
n-Propylbenzene	µg/L	71	27	0.13	11.02	43	NE	19.4	NA
o-Xylene	µg/L	71	21	0.09	47.96	530	10,000	16	0
sec-Butylbenzene	µg/L	71	23	0.15	6.33	24	NE	26	NA
Styrene	µg/L	71	1	0.28	0.28	0.28	100	18.9	0
tert-Butylbenzene	µg/L	71	7	0.23	0.43	0.91	NE	25	NA
Tetrachloroethene	µg/L	71	17	0.14	718.69	6400	5	11	10
Toluene	µg/L	78	41	0.12	1.09	7.5	1,000	20	0
trans-1,2-Dichloroethene	µg/L	71	20	0.14	9.18	48	100	28	0
trans-1,3-Dichloropropene	µg/L	71	0	NA	NA	NA	NE	18	NA
Trichloroethene	µg/L	71	34	0.25	661.90	5000	5	12	25
Trichlorofluoromethane	µg/L	71	0	NA	NA	NA	NE	27	NA
Vinyl chloride	µg/L	71	13	0.39	4.04	15	2	43	13
Total Xylenes	µg/L	7	7	1	7	41	10,000	NA	0
Semivolatile Organics									
Acenaphthene	µg/L	25	11	0.16	4.04	14.8	2,200	0.36	0
Acenaphthylene	µg/L	25	1	0.18	0.18	0.18	NE	1.7	NA
Anthracene	µg/L	25	0	NA	NA	NA	11,000	0.1	0
Benzo(a)anthracene	µg/L	25	0	NA	NA	NA	1	0.05	0
Benzo(a)pyrene	µg/L	25	0	NA	NA	NA	0.2	0.14	0
Benzo(b)fluoranthene	µg/L	25	0	NA	NA	NA	1	0.08	0
Benzo(g,h,i)perylene	µg/L	25	1	0.04	0.04	0.04	NE	0.13	NA
Benzo(k)fluoranthene	µg/L	25	0	NA	NA	NA	10	0.17	0

Table 5-7 (Continued)

Analyte	Units	No. Tested	No. Detected	Minimum Detected Concentration	Average Detected Concentration	Maximum Detected Concentration	Screening Value[a]	Maximum Reporting Limit	No. of Detections Greater than Screening Level
Chrysene	µg/L	25	1	0.01	0.01	0.01	100	0.1	0
Dibenz(a,h)anthracene	µg/L	25	0	NA	NA	NA	NE	0.14	NA
Fluoranthene	µg/L	25	0	NA	NA	NA	NE	0.1	NA
Fluorene	µg/L	25	11	0.06	1.87	6.8	1,460	0.042	0
Indeno(1,2,3-cd)pyrene	µg/L	25	0	NA	NA	NA	NE	0.19	NA
Naphthalene	µg/L	23	11	0.26	71.47	304.7	1,460	0.47	0
Phenanthrene	µg/L	25	12	0.01	1.57	7.7	NE	0.024	NA
Pyrene	µg/L	25	0	NA	NA	NA	1,100	0.1	0
Total Inorganics									
Arsenic	µg/L	21	20	1.1	13.3	60.1	10	0.6	7
Barium	µg/L	21	21	15.4	97.7	517	2,000	NA	0
Cadmium	µg/L	21	6	0.7	1.38	2.7	5	1	0
Chromium	µg/L	21	15	4	16	97	100	3	0
Lead	µg/L	21	17	0.12	3.21	11.1	15	0.6	0
Mercury	µg/L	21	3	0.1	0.17	0.2	2	0.1	0
Selenium	µg/L	21	2	1	1	1	50	2	0
Silver	µg/L	21	11	2	3.73	5	18	10	0
Pesticides and Aroclors									
4,4-DDD	µg/L	18	0	NA	NA	NA	.36	0.012	0
4,4-DDE	µg/L	18	0	NA	NA	NA	.25	0.038	0
4,4-DDT	µg/L	18	0	NA	NA	NA	.25	0.013	0
Aldrin	µg/L	18	0	NA	NA	NA	.05	0.04	0
alpha-BHC	µg/L	18	0	NA	NA	NA	0.1	0.32	0
alpha-Chlordane	µg/L	18	0	NA	NA	NA	2.0	0.013	0
Aroclor 1016	µg/L	18	0	NA	NA	NA	0.5	0.046	0
Aroclor 1221	µg/L	18	0	NA	NA	NA	0.5	0.046	0
Aroclor 1232	µg/L	18	0	NA	NA	NA	0.5	0.046	0

Table 5-7 (Continued)

Analyte	Units	No. Tested	No. Detected	Minimum Detected Concentration	Average Detected Concentration	Maximum Detected Concentration	Screening Value[a]	Maximum Reporting Limit	No. of Detections Greater than Screening Level
Aroclor 1242	µg/L	18	0	NA	NA	NA	0.5	0.046	0
Aroclor 1248	µg/L	18	0	NA	NA	NA	0.5	0.046	0
Aroclor 1254	µg/L	18	0	NA	NA	NA	0.5	0.046	0
Aroclor 1260	µg/L	18	0	NA	NA	NA	0.5	0.046	0
beta-BHC	µg/L	18	0	NA	NA	NA	0.47	0.18	0
delta-BHC	µg/L	18	0	NA	NA	NA	NE	0.052	0
Dieldrin	µg/L	18	0	NA	NA	NA	0.05	0.14	0
Endosulfan I	µg/L	18	0	NA	NA	NA	200	0.018	0
Endosulfan II	µg/L	18	0	NA	NA	NA	200	0.015	0
Endosulfan sulfate	µg/L	18	1	0.001	0.001	0.001	NE	0.0063	NA
Endrin	µg/L	18	0	NA	NA	NA	2.0	0.038	0
Endrin aldehyde	µg/L	18	0	NA	NA	NA	NE	0.021	NA
gamma-Chlordane	µg/L	18	0	NA	NA	NA	2.0	0.14	0
Heptachlor	µg/L	18	0	NA	NA	NA	0.4	0.046	0
Heptachlor epoxide	µg/L	18	0	NA	NA	NA	0.2	0.052	0
Lindane	µg/L	18	3	0.0052	0.047	0.13	0.2	0.23	0
Methoxychlor	µg/L	18	0	NA	NA	NA	40	0.033	0
Toxaphene	µg/L	18	0	NA	NA	NA	3.0	0.53	0
Physical Parameters									
Chloride	mg/kg	8	8	17.5	22.6	38	NA	NA	NA
Nitrate	mg/kg	8	8	0.2	0.413	0.7	NA	NA	NA
Sulfate	mg/kg	8	8	2.7	6.4	13.2	NA	NA	NA
Total Solids	%	4	4	88.4	90.1	92.5	NA	NA	NA
Total Organic Carbon	mg/kg	4	4	3390	4385	6470	NA	NA	NA

[a] Source of screening level indicated in Table 5-1. Pesticides and Aroclors screening levels are from the lowest of 18AAC80, 18AAC75, and 40 CFR Part 141.

µg/L – Microgram per liter
NA – Not applicable
NE – Not established

Table 5-8

Summary of Groundwater Hydrocarbon Results by Location and Date

Sample Location	Sample Type	Sample Date	DRO (mg/L)		GRO (mg/L)		RRO (mg/L)		Benzene (µg/L)	
41755-WL01-GRND	ES	11/12/99	1,300.0		4.4		NS		160	
41755-WL01-GRND	ES	09/19/00	15.5		2.38		1.02		125	
41755-WL01-GRND	ES	10/02/01	24.0		2.8		0.45		100	
41755-WL02-GRND	ES	11/11/96	1.7	J	1.89		NS		2.3	
41755-WL02-GRND	ES	11/12/99	2.0		3		NS		4.4	
41755-WL02-GRND	ES	09/19/00	0.67	B	4.13		0.27	F	3.18	B
41755-WL02-GRND	ES	10/02/01	0.71		3.1		0.2	F	21	U
41755-WL03-GRND	ES	11/12/99	160.0		1.3		NS		7	
41755-WL03-GRND	FD	09/19/00	4.7		0.842		0.243	Y	9.57	
41755-WL03-GRND	ES	09/19/00	5.79		0.977		0.25	F	10.4	
41755-WL03-GRND	ES	10/02/01	49.0		0.53		0.21	F	5.3	U
41755-WL04-GRND	ES	11/07/96	2.7		1.07		NS		1.1	
41755-WL04-GRND	ES	11/11/99	1.6		0.4		NS		2	
41755-WL04-GRND	FD	09/20/00	0.9	J	3.43		0.153	Y	2.14	J
41755-WL04-GRND	ES	09/20/00	0.89	B	3.38		0.14	F	2.06	B
41755-WL04-GRND	ES	10/06/01	0.94		1.1		0.087	F	11	U
41755-WL05-GRND	FD	11/07/96	27.8		0.683		NS		4.3	
41755-WL05-GRND	ES	11/07/96	30.6		0.672		NS		4.1	
41755-WL05-GRND	ES	11/11/99	18.0		0.56		NS		2.6	
41755-WL05-GRND	ES	09/20/00	3.37		3.01		0.80		2.88	B
41755-WL05-GRND	ES	10/06/01	7.0	M	0.8		0.27		11	U
41755-WL06-GRND	ES	11/11/96	0.3		0.05	U	NS		0.5	U
41755-WL06-GRND	FD	11/11/99	0.09	J	0.05	U	NS		0.5	U
41755-WL06-GRND	ES	11/11/99	0.11		0.05	U	NS		0.5	U
41755-WL06-GRND	ES	09/21/00	0.14	B	0.006	U	0.16	F	0.13	U
41755-WL06-GRND	ES	10/06/01	0.16		0.026	F	0.078	F	0.11	U
41755-WL07-GRND	ES	11/07/96	2.0		0.05	U	NS		0.5	U
41755-WL07-GRND	ES	11/10/99	0.55		0.05	U	NS		0.5	U
41755-WL07-GRND	ES	09/20/00	2.07		0.025	F	0.32		0.13	U
41755-WL07-GRND	ES	10/04/01	2.3		0.021	U	0.12	F	0.11	U
41755-WL08-GRND	ES	11/25/96	0.1		0.032	J	NS		0.5	U
41755-WL08-GRND	ES	11/17/99	0.06	J	0.034	J	NS		0.5	U
41755-WL08-GRND	ES	09/25/00	0.07	F	0.041	F	0.10	F	0.14	F
41755-WL08-GRND	ES	10/05/01	0.028	F	0.041	F	NS		0.11	U
41755-WL09-GRND	ES	11/25/96	0.2		0.021	J	NS		0.5	U
41755-WL09-GRND	FD	11/17/99	NS		0.05	U	NS		0.5	U
41755-WL09-GRND	ES	11/17/99	0.09	J	NS		NS		0.5	U
41755-WL09-GRND	ES	09/20/00	0.023	U	0.012	F	0.06	F	0.13	U
41755-WL09-GRND	ES	10/03/01	0.046	F	0.021	U	0.046	F	0.11	U
41755-WL10-GRND	ES	11/12/99	0.59		0.05	U	NS		0.5	U
41755-WL10-GRND	ES	09/21/00	0.27	B	0.009	F	0.13	F	0.13	U
41755-WL10-GRND	ES	10/03/01	6.1		0.037	F	0.23	F	2.7	
41755-WL11-GRND	ES	11/12/99	10.0		0.33		NS		1.4	
41755-WL11-GRND	ES	09/21/00	5.96		0.614		0.54	F	9.84	

Table 5-8 (Continued)

Sample Location	Sample Type	Sample Date	DRO (mg/L)		GRO (mg/L)		RRO (mg/L)		Benzene (µg/L)	
41755-WL12-GRND	ES	11/11/97	0.45		0.1	U	0.67	F	1	U
41755-WL12-GRND	ES	11/10/99	0.05	J	0.05	U	NS		0.5	U
41755-WL12-GRND	ES	09/26/00	0.03	F	0.007	F	0.11	F	0.13	U
41755-WL12-GRND	ES	10/03/01	0.039	F	0.021	U	0.058	F	0.11	U
41755-WL13-GRND	ES	09/22/00	0.03	F	0.014	F	0.08	F	0.13	U
41755-WL13-GRND	ES	10/03/01	0.57	F	0.021	U	0.065	F	0.11	U
41755-WL14-GRND	ES	09/22/00	0.11	B	0.033	F	0.12	F	0.24	F
41755-WL14-GRND	ES	10/05/01	0.035	F	0.021	U	NS		0.11	U
41755-WL15-GRND	ES	09/22/00	0.023	U	0.011	F	0.05	F	0.13	U
41755-WL15-GRND	ES	10/05/01	0.023	F	0.021	U	NS		0.11	U
41755-WL16-GRND	ES	09/22/00	0.16	B	0.017	F	0.22	F	0.13	U
41755-WL16-GRND	ES	10/05/01	0.17		0.021	U	NS		0.11	U
41755-WL17-GRND	ES	09/25/00	1.58	J	0.011	F	0.27	J	0.13	U
41755-WL17-GRND	ES	10/04/01	3.4	M	0.021	F	0.28		0.11	U
41755-WL18-GRND	ES	09/26/00	0.06	F	0.015	F	0.08	F	0.13	U
41755-WL18-GRND	ES	10/02/01	0.12		0.021	U	0.14	F	0.11	U
41755-WL19-GRND	ES	09/21/00	0.19	B	0.05	B	0.22	F	0.43	B
41755-WL19-GRND	ES	10/04/01	0.088	F	0.021	U	0.094	F	0.11	U
WP-1	ES	08/08/02	4.1		0.220		0.360		2.5	
WP-2	ES	08/08/02	110		0.510		0.990	Y	24	F
WP-3	ES	08/08/02	1.6		0.280		0.370	Y	2.7	
WP-4	ES	08/08/02	11		0.180		0.850	Y	0.48	
WP-5	ES	08/08/02	320		0.310		1.7		3.1	
WP-6	ES	08/08/02	0.180		0.034	Y	0.290		0.11	F
WP-7	ES	08/08/02	0.130		0.020	U	0.250		0.11	U
WP-8	ES	08/08/02	0.260		0.034	Y	0.310		0.23	F
WP-9	ES	08/08/02	0.180		0.020		0.180		0.11	U
WP-10	ES	08/08/02	0.120		0.020	U	0.180		0.11	U
WP-11	ES	08/08/02	0.170		0.020	U	0.270		0.11	U
WP-12	ES	08/08/02	0.830		0.020	U	0.480		0.11	U
41755-WL20	ES	08/22/02	NS		0.02	U	NS		0.11	U
41755-WL20	FD	08/22/02	NS		0.02	U	NS		0.105	U
41755-WL21	ES	08/22/02	NS		0.02	U	NS		0.11	U
41755-WL22	ES	08/22/02	NS		0.02	U	NS		0.11	U

DRO – Diesel range organics
FD – Field duplicate
J – Associated value is an estimate
NS – Not sampled for specified analyte
U – Analyte not detected at the specified reporting limit
ES – Environmental sample
GRO – Gasoline range organics
mg/kg – Milligrams per kilogram
RRO – Residual range organics
µg/kg – Micrograms per kilogram
X – See case narrative
Y – The chromatographic fingerprint of the sample resembles a petroleum product eluting in approximately the correct carbon range, but the elution pattern does not match the calibration standard
B – This analyte was also detected in the associated equipment blank
F – The analyte was positively identified, but the result is below the method-reporting limit.
M – A matrix effect was present.

5.5.1.2 GRO

GRO was detected in 48 of the 72 analyzed groundwater samples at concentrations ranging from 0.007 to 4.4 mg/L (Table 5-7). The average GRO concentration reported in groundwater was approximately 0.8 mg/L. GRO was detected in 11 groundwater samples at concentrations above the screening criteria of 1.3

mg/L. The highest GRO concentrations were measured in samples from wells 41755-WL01, 41755-WL02, 41755-WL03, 41755-WL04, and 41755-WL05 (Table 5-8).

In contrast to DRO, both the average and the maximum measured GRO concentrations in groundwater decreased from September 2000 to October 2001. The average measured GRO concentration in September 2000 was approximately 0.78 mg/L, while the average measured GRO concentration in October 2001 was 0.48 mg/L. The maximum September 2000 GRO concentration of 4.13 mg/L was measured in the sample from well 41755-WL02, located approximately 160 feet downgradient of the former USTs near the end of the western drain tile for Building 18224. The maximum October 2001 GRO concentration of 3.1 mg/L was also measured in the sample from well 41755-WL02.The distribution of GRO in groundwater is generally coincident with DRO and the estimated extent of the GRO in groundwater is contoured in Figure 5-10. The source of GRO is likely the former UST; however, an unknown amount of GRO could have been contributed to the soil and groundwater via infiltration of discharge water through the drainage tile that trends along the western edge of Building 18224. It also appears that this plume has migrated to its present location approximately 100 feet north-northwest of well 41755-WL05. No GRO was measured in the well point samples located at the base of the slope. Well 41755-WL03 contained GRO at concentrations above the screening criteria (1.3 mg/L) only in 1999. The absence of GRO above regulatory criteria in well 41755-WL03 in 2000 and 2001 suggests the plume has moved north-northwest with groundwater flow, or that GRO concentrations have degraded below 1.3 mg/L. Therefore, this well is considered the eastern boundary of the GRO plume in groundwater.

Based on the hydrogeologic assumptions used for DRO in groundwater and the measured GRO plume dimensions (400 feet long by 300 feet wide) from Figure 5-10, the volume of groundwater potentially contaminated with GRO would be between 390,000 to 900,000 cubic feet, or approximately 2.9 to 6.7 million gallons.

5.5.1.3 RRO

RRO was detected in all 46 analyzed groundwater samples at concentrations ranging from 0.046 to 1.7 mg/L. The average RRO concentration detected in groundwater was approximately 0.31 mg/L (Table 5-7). The highest RRO concentration was measured in the August 2002 groundwater sample from WP-5. RRO was detected in 1 sample at a concentration greater than the screening criteria of 1.1 mg/L. RRO is distributed similarly to DRO, but at lower concentrations. The single concentration above the screening criteria was collected from temporary well point WP-5.

5.5.1.4 Benzene, Toluene, Ethylbenzene, and Xylenes

Benzene was detected in 28 of the 78 analyzed groundwater samples at concentrations ranging from 0.11 to 160 µg/L (Table 5-7). The average benzene detection in groundwater was approximately 16 µg/L. The highest benzene concentration was measured in the November 1999 sample from well 41755-WL01. Benzene was detected in 13 samples at concentrations greater than the screening criteria of 5 µg/L. Benzene results are summarized by location and sample date in Table 5-8.

Toluene was detected in 41of the 78 groundwater samples at concentrations ranging from 0.12 to 7.5 µg/L. None of the groundwater samples contained toluene at concentrations greater than the screening criteria of 1,000 µg/L. Ethylbenzene was detected in 34 of the 78-groundwater samples at concentrations ranging from 0.12 to 320 µg/L. None of the groundwater samples contained ethylbenzene at concentrations greater than the screening criteria of 700 µg/L. m,p-Xylenes were detected in 22 of the 68 analyzed samples at concentrations ranging from 0.26 to 920 µg/L and o-xylenes were detected in 21 of 71 samples at concentrations ranging from 0.09 to 530 µg/L. There were 7 groundwater samples analyzed for total xylenes that were detected at concentrations ranging from 1 to 41 µg/L. The sum of the maximum speciated xylenes and the total xylene detections were not above the screening criteria of 10,000 µg/L.

Figure 5-8. Distribution of Fuel Compounds in Groundwater

[This page intentionally left blank.]

Figure 5-9. Interpolated Extent of DRO in Groundwater Greather Than 1.5 mg/L

[This page intentionally left blank.]

Figure 5-10. Groundwater Concentration Contours for Fuel Compounds

[This page intentionally left blank.]

Figure 5-11. Distribution of Select VOCs in Groundwater

[This page intentionally left blank.]

The distributions of benzene and total BTEX concentrations in groundwater are summarized in Figure 5-10. Benzene and total BTEX in groundwater originate from the former USTs located adjacent to Building 18224. The highest concentrations for each plume are measured at well 41755-WL01. The close grouping of the benzene and BTEX plume contours suggests that the compounds were a component of the fuel contained in these former USTs. The dimensions and the estimated direction of the benzene and BTEX plumes, along with naphthalene, a component of diesel fuel, are shown in Figure 5-10. The shapes of the naphthalene and BTEX plumes are almost identical, indicating the likely lateral extent of the fuel plume downgradient of the UST.

As shown in Figure 5-10, benzene, total BTEX, and GRO form similar patterns; however, the size of the benzene plume to the north is shorter (300 feet long by 200 feet wide) based on plume measurements taken from Figure 5-10. Using the hydrogeologic assumptions used for GRO, along with the measured dimensions of the BTEX plume, the volume of groundwater potentially contaminated with BTEX would be between 195,000 to 450,000 cubic feet, or approximately 1.5 to 3.4 million gallons.

5.5.2 Chlorinated Solvents in Groundwater

Similar to the distributions observed for fuel constituents, TCE, PCE, DCE, and VC extend in groundwater from the end of the drainage tile near Building 18224 north-northwest following the prevailing groundwater flow direction towards the wells 41755-WL07, 41755-WL08, and 41755-WL09. The soil gas results from 1997 and 2001 EE/CA surveys show general agreement with the trends of the groundwater plumes based on analytical data (Appendix E). The chlorinated solvent distribution in groundwater is similar to the distribution in soil.

5.5.2.1 TCE

TCE was the most frequently detected chlorinated solvent in groundwater. TCE was detected in 34 of 71 analyzed samples at concentrations ranging from 0.25 to 5,000 µg/L. The average TCE detection was approximately 662 µg/L (Table 5-7). The maximum TCE concentration was measured in the November 1999 groundwater sample from well 47155-WL04. TCE was measured at concentrations greater than 1,000 µg/L on three separate occasions in samples from wells 41755-WL02 and 41755-WL04. TCE was detected in 25 groundwater samples at concentrations greater than the screening criteria of 5 µg/L (Table 5-7). Groundwater analytical results for select chlorinated solvents are summarized by location and sampling date in Table 5-9.

Both the average and maximum measured TCE concentrations in groundwater increased from September 2000 to October 2001. The average measured TCE concentration in September 2000 groundwater samples was approximately 343 µg/L while the average measured TCE concentration in October 2001 groundwater samples was approximately 466 µg/L. The maximum September 2000 TCE concentration of 3,815 µg/L was measured in the sample from well 41755-WL04 located approximately 250 feet downgradient of the former USTs. The maximum October 2001 TCE concentration of 4,400 µg/L was measured in the sample from well 41755-WL02.

The highest TCE concentrations (above 2,000 µg/L) were measured at wells 41755-WL04 and 41755-WL02, suggesting that these wells are nearest the source of the TCE plume. The nearest potential release point for these compounds is the drainage pipe extending from Building 18224. The northern extent of the plume has reached a line of temporary well points (WP-1 through WP-4, WP-6, WP-8, and WP-12). Two downgradient wells, 41755-WL15 and 41755-WL16, did not contain TCE above screening criteria. The leading edge or downgradient extent of TCE in groundwater is therefore located between these wells and the temporary well points. Three well point locations (WP-1 through WP-3) located near the access road to wastewater treatment pond, contained TCE above screening criteria, and this area could be an area of groundwater discharging to surface water downgradient of well 41755-WL04. The distribution of TCE in groundwater is shown on Figure 5-11. TCE and PCE concentration contours in groundwater are provided on Figure 5-12. The distribution of TCE is interpolated on Figure 5-13.

Based on the hydrogeologic assumptions used above for plumes with similar shapes and extent along with the measured TCE plume dimensions (400 feet long by 300 feet wide) on Figure 5-11, the volume of groundwater possibly containing TCE would be between 390,000 to 900,000 cubic feet, or approximately 2.9 to 6.7 million gallons.

5.5.2.2 PCE

PCE was detected in 17 of the 71 analyzed groundwater samples at concentrations ranging from 0.14 to 6,400 µg/L. The average PCE concentration in groundwater was approximately 719 µg/L (Table 5-7). PCE was detected in 10 groundwater samples at concentrations above the screening criteria of 5 µg/L. The highest PCE concentration was measured in the October 2001 sample from well 41755-WL02. Samples collected from well 41755-WL02 in November 1999, September 2000, and October 2001 were the only samples with PCE concentrations greater than 1,000 µg/L. The remaining groundwater samples collected at the site contained PCE concentrations less than or equal to 11 µg/L. The distribution of PCE in groundwater is shown on Figure 5-11. TCE and PCE concentration contours in groundwater are provided on Figure 5-12.

The maximum and average PCE detection in groundwater increased from September 2000 to October 2001. The average PCE concentration in September 2000 was approximately 158 µg/L and the October 2001 average was approximately 358 µg/L. The September 2000 maximum PCE concentration was 2,989 µg/L and the October 2001 maximum was 6,400 µg/L. Both of these maximum detections were measured in samples from well 41755-WL02. The increase in the average PCE concentration from September 2000 to October 2001 is solely due to the measured PCE concentration in well 41755-WL02. It is possible that TCE is dissolved into the oil emulsions, resulting in the higher TCE concentrations detected.

The highest concentration of PCE was located at well 41755-WL02 located near the drainage pipe suggesting that the drainage tile is the source of PCE observed in groundwater. The plume encompasses a wide area and extends past wells 41755-WL07 and 41755-WL09 at very low concentrations. The extent of this plume is defined laterally by the absence of reported VOCs in samples from downgradient wells 41755-WL12 and 41755-WL17. The estimated lateral extent of the PCE plume is shown in Figure 5-12.

Based on the hydrogeologic assumptions used above for plumes with similar shapes and extent, along with the measured PCE plume dimensions (250 feet long by 150 feet wide) from Figure 5-11, the volume of groundwater potentially contaminated with PCE would be between 121,875 to 281,250 cubic feet, or approximately 0.9 to 2.1 million gallons.

5.5.2.3 DCE

Of the three DCE isomers (cis-1,2-DCE, trans-1,2-DCE, and 1,1-DCE), cis1,2-DCE was the most frequently detected. Cis-1,2-DCE was detected in 38 of 71 analyzed samples at concentrations ranging from 0.14 to 5,700 µg/L. The average cis-1,2-DCE concentration in groundwater was approximately 1,168 µg/L. Cis-1,2-DCE was detected in 20 groundwater samples at concentrations above the screening criteria of 70 µg/L (Table 5-7). The highest concentration was measured in the November 1999 sample from well 41755-WL-05, located approximately 280 feet downgradient of the former USTs and approximately 110 feet northwest of the western Building 18224 drain tile outlet. Cis-1,2-DCE was detected at concentrations above 1,000 µg/L in groundwater samples from 41755-WL02, 41755-WL03, 41755-WL04, 41755-WL05, WP-1, and WP-2. The distribution of cis-1,2-DCE in groundwater, shown on Figure 5-14, is similar to the distribution of TCE in groundwater.

The average and maximum concentrations of cis-1,2-DCE also increased from September 2000 to October 2001. The average September 2000 concentration was approximately 527 µg/L and the average October 2001 concentration was approximately 785 µg/L. The maximum September 2000 concentration was 3,899 µg/L and the maximum October 2001 concentration was 4,700 µg/L. The maximum concentrations for both sampling dates were measured in well 41755-WL05. Cis-1,2-DCE is a known degradation product of TCE. The lateral extent of cis-1,2-DCE and TCE are similar and the maximum and average cis-1,2-DCE concentrations in groundwater are actually higher than TCE. The concentration of cis-1,2-DCE also appears to be increasing over time. These observations suggest that natural degradation of TCE to cis-1,2-DCE is occurring at the site.

1,1-DCE was detected in 13 of 71 groundwater samples at concentrations ranging from 0.52 to 19 µg/L. The average 1,1-DCE concentration was approximately 7.3 µg/L. The maximum 1,1-DCE concentration was measured in the October 2001 sample from well 41755-WL04. 1,1-DCE was detected in 9 groundwater samples at a concentration greater than the screening criteria of 7 µg/L. The distribution of 1,1-DCE in groundwater is provided on Figure 5-14.

Table 5-9

Summary of Volatile Organic Compounds in Groundwater

Sample Location	Sample Type	Sample Date	TCE µg/L	PCE µg/L	cis-1,2-DCE µg/L	Vinyl Chloride µg/L
41755-WL01-GRND	ES	11/12/99	0.8	0.5 U	3.8	0.5 U
41755-WL01-GRND	ES	09/19/00	7.29 J	0.12 U	0.94 F	0.13 U
41755-WL01-GRND	ES	10/02/01	5.9 U	9.5 F	5.8 U	11 U
41755-WL02-GRND	ES	11/12/99	2300	2800	4200	1.3
41755-WL02-GRND	ES	09/19/00	2290	2990	2490	0.61 F
41755-WL02-GRND	ES	10/02/01	4400	6400	4000	43 U
41755-WL03-GRND	ES	11/12/99	47	0.5 U	2100	0.9
41755-WL03-GRND	FD	09/19/00	12.5	0.12 U	782.3	0.89 Y
41755-WL03-GRND	ES	09/19/00	9.19	0.12 U	1054	0.95 F
41755-WL03-GRND	ES	10/02/01	120	5.5 U	2200	11 U
41755-WL04-GRND	ES	11/11/99	5000	0.5 U	2200	0.4 J
41755-WL04-GRND	FD	09/20/00	3815	1.16 X	2456	0.54 Y
41755-WL04-GRND	ES	09/20/00	3780	1.2 F	2480	0.53 F
41755-WL04-GRND	ES	10/06/01	3800	11 U	3200	22 U
41755-WL05-GRND	ES	11/11/99	5.7	0.5 U	5700	9.6
41755-WL05-GRND	ES	09/20/00	6.81	10.2	3899	12.3
41755-WL05-GRND	ES	10/06/01	12 U	11 U	4700	22 U
41755-WL06-GRND	ES	11/11/97	0.5 U	0.5 U	0.5 U	0.5 U
41755-WL06-GRND	FD	11/11/99	0.5 U	0.5 U	0.5 U	0.5 U
41755-WL06-GRND	ES	11/11/99	0.5 U	0.5 U	0.5 U	0.5 U
41755-WL06-GRND	ES	09/21/00	0.25 F	0.16 F	0.13 U	0.13 U
41755-WL06-GRND	ES	10/06/01	0.12 U	0.11 U	0.12 U	0.22 U
41755-WL07-GRND	FD	11/11/97	0.5 U	0.5 U	0.5 U	0.5 U
41755-WL07-GRND	ES	11/11/97	0.5 U	0.5 U	0.5 U	0.5 U
41755-WL07-GRND	ES	11/10/99	0.5 U	0.5 U	0.5 U	0.5 U
41755-WL07-GRND	ES	09/20/00	1.05	3.26	0.51 F	0.13 U
41755-WL07-GRND	ES	10/04/01	0.12 U	0.31 F	0.12 U	0.22 U
41755-WL08-GRND	ES	11/11/97	9.96	0.5 U	6.13 U	0.5 U
41755-WL08-GRND	ES	11/17/99	22	0.5 U	8.4	0.5 U
41755-WL08-GRND	ES	09/25/00	30.2	0.12 U	15.6 B	0.13 U
41755-WL08-GRND	ES	10/05/01	52	0.11 U	15	0.22 U
41755-WL09-GRND	ES	11/11/97	0.5 U	0.5 U	0.5 U	0.5 U
41755-WL09-GRND	FD	11/17/99	22	0.5 U	8.5	0.5 U
41755-WL09-GRND	ES	11/17/99	0.5 U	0.5 U	0.5 U	0.5 U
41755-WL09-GRND	ES	09/20/00	0.48 F	1.13 F	0.18 F	0.13 U
41755-WL09-GRND	ES	10/03/01	0.12 U	0.29 F	0.12 U	0.22 U
41755-WL10-GRND	ES	11/12/99	0.4 J	0.5 U	0.5 U	0.5 U
41755-WL10-GRND	ES	09/21/00	1.32	0.46 F	0.34 F	0.13 U
41755-WL10-GRND	ES	10/03/01	0.93 F	1.4 F	0.31 F	0.22 U
41755-WL11-GRND	ES	11/12/99	1 U	1.5 U	1 U	0.5 U
41755-WL11-GRND	ES	09/21/00	0.41 F	0.12 U	53.5 B	0.13 U
41755-WL12-GRND	ES	11/11/97	0.5 U	0.5 U	0.5 U	0.5 U
41755-WL12-GRND	ES	11/10/99	0.5 U	0.5 U	0.5 U	0.5 U
41755-WL12-GRND	ES	09/26/00	0.15 U	0.12 U	0.13 U	0.13 U

Table 5-9 (Continued)

Sample Location	Sample Type	Sample Date	TCE µg/L	PCE µg/L	cis-1,2-DCE µg/L	Vinyl Chloride µg/L
41755-WL12-GRND	ES	10/03/01	0.12 U	0.11 U	0.12 U	0.22 U
41755-WL13-GRND	ES	09/22/00	0.32 F	0.25 F	0.13 U	0.13 U
41755-WL13-GRND	ES	10/03/01	0.12 U	0.11 U	0.12 U	0.22 U
41755-WL14-GRND	ES	09/22/00	0.15 U	0.12 U	7.61 B	0.13 U
41755-WL14-GRND	ES	10/05/01	0.12 U	0.11 U	0.12 U	0.22 U
41755-WL15-GRND	ES	09/22/00	0.15 U	0.14 F	0.13 U	0.13 U
41755-WL15-GRND	ES	10/05/01	0.12 U	0.11 U	0.12 U	0.22 U
41755-WL16-GRND	ES	09/22/00	0.15 U	0.12 U	1.8 B	0.13 U
41755-WL16-GRND	ES	10/05/01	0.12 U	0.16 F	0.12 U	0.22 U
41755-WL17-GRND	ES	09/25/00	0.15 U	0.12 U	0.14 F	0.13 U
41755-WL17-GRND	ES	10/04/01	0.12 U	0.11 U	0.24 F	0.22 U
41755-WL18-GRND	ES	09/26/00	0.62 F	0.12 U	2.3 B	0.13 U
41755-WL18-GRND	ES	10/02/01	0.12 U	0.11 U	0.12 U	0.22 U
41755-WL19-GRND	ES	09/21/00	0.15 U	0.12 U	11.4 B	0.13 U
41755-WL19-GRND	ES	10/04/01	0.12 U	0.23 F	0.12 U	0.22 U
WP-1	ES	08/08/02	85	0.55 U	1900	5.7
WP-2	ES	08/08/02	290	1.1 U	1900	7.9 F
WP-3	ES	08/08/02	220	0.55 U	1500	15
WP-4	ES	08/08/02	3.5	0.11 U	46	2.4
WP-5	ES	08/08/02	3.4 F	0.55 U	780	6.4 U
WP-6	ES	08/08/02	0.57 F	0.11 U	260	0.39 F
WP-7	ES	08/08/02	0.12 U	0.11 U	56	0.22 U
WP-8	ES	08/08/02	0.55 F	0.11 U	160	2.5
WP-9	ES	08/08/02	0.12 U	0.11 U	5.8	0.22 U
WP-10	ES	08/08/02	0.12 U	0.11 U	0.12 U	0.22 U
WP-11	ES	08/08/02	0.12 U	0.11 U	0.12 U	0.22 U
WP-12	ES	08/08/02	0.32 F	0.11 U	0.12 U	0.22 U
41755-WL20	ES	08/22/02	0.12 U	0.11 U	0.12 U	0.22 U
41755-WL20	FD	08/22/02	0.12 U	0.11 U	0.12 U	0.22 U
41755-WL21	ES	08/22/02	0.12 U	0.11 U	0.12 U	0.22 U
41755-WL22	ES	08/22/02	0.12 U	0.11 U	0.12 U	0.22 U

cis-1,2-DCE – cis-1,2-dichloroethene
ES – Environmental sample
J – Associated value is an estimate
TCE – Trichloroethene
X – See case narrative
µg/L – Micrograms per liter
FD – Field duplicate
PCE - Tetrachloroethene
U – Analyte not detected at specified reporting limit
F – The analyte was positively identified, but the results is below the method reporting limit
Y – The chromatographic fingerprint of the sample resembles a petroleum product eluting in approximately the correct carbon range, but the elution pattern does not match the calibration standard

Trans-1,2-DCE was detected in 20 of the 71 samples at concentrations ranging from 0.14 to 48 µg/L. The average trans-1,2-DCE concentration in groundwater was approximately 9 µg/L. The highest trans-1,2-DCE concentration was measured in the October 2001 sample from well 41755-WL05. Trans-1,2-DCE was not detected in groundwater at concentrations greater than the screening criteria of 100 µg/L. The distribution of trans-1,2-DCE in groundwater is estimated on Figure 5-14.

The distribution of 1,1-DCE and trans-1,2-DCE in groundwater is less extensive and coincident with cis-1,2-DCE (Figure 5-14). Similar to the TCE distribution, the cis-1,2-DCE distribution also overlies the outlet of the drainage pipe extending from Building 18224. However, this structure is not considered the cis-1,2-DCE source in groundwater. Cis-1,2-DCE is not a component of solvents that was commonly used by the military. Instead, this cis-1,2-DCE is probably an indicator of chlorinated solvent biodegradation. This plume covers approximately the same area as the combined plumes for TCE and PCE, which supports the conclusion that cis-1,2-DCE is a breakdown product of TCE. Like TCE, the northern extent of the cis-1,2-DCE has reached well 41755-WL08 (Figure 5-14), and cis-1,2-DCE concentrations at this well have risen slowly over time. Only trace concentrations of cis-1,2-DCE were detected in downgradient well 41755-WL16. As a result, the lateral extent of this cis-1,2-DCE in groundwater is inferred to be located between the base of the slope and downgradient wells 41755-WL08. Also, no cis-1,2-DCE was detected in the groundwater samples from well points WP-7 through WP-12, even though well point WP11 is located less than 15 feet north of well 41755-WL08. One possible reason for the absence of cis-1,2-DCE in well point WP-11 could be that the contaminants have degraded due to the aerobic conditions of the groundwater in this area.

Based on the hydrogeologic assumptions used above for plumes with similar shapes and extent, along with the measured cis-1,2-DCE plume dimensions (400 feet long by 300 feet wide) from Figure 5-14, the volume of groundwater potentially impacted with cis-1,2-DCE would be between 390,000 to 900,000 cubic feet, or approximately 2.9 to 6.7 million gallons.

5.5.2.4 Vinyl Chloride

Vinyl chloride (VC) was detected in 13 of the 71 analyzed groundwater samples at concentrations ranging from 0.39 to 15 µg/L. The average VC detection in groundwater was approximately 4 µg/L. The highest VC concentration was measured in the August 2002 groundwater sample from well point WP-3. VC was detected in 13 groundwater samples at concentrations greater than the screening criteria of 2 µg/L (Table 5-7). The estimated distribution of VC is provided on Figure 5-14.

The VC plume covers a small area centered at well 41755-WL05 and extends north towards the base of the slope near well 41755-WL07. Further into the wetland, VC is suspected to breakdown due to the more aerobic condition of the groundwater. VC is a common breakdown product of PCE, TCE, and the three DCE isomers which includes cis-1,2-DCE.

Based on the hydrogeologic assumptions used above for plumes with similar shapes and extent, along with the measured VC plume dimensions (250 feet long by 150 feet wide) from Figure 5-14, the volume of groundwater potentially impacted with vinyl chloride is estimated to be between 121,875 to 281,250 cubic feet, or approximately 0.9 to 2.1 million gallons.

5.5.3 SVOCs in Groundwater

Twenty-five groundwater samples were analyzed for SVOCs. None of the 25 samples contained SVOCs at concentrations greater than the screening criteria.

5.5.4 Pesticides and Aroclors in Groundwater

Endosulfan sulfate was detected in one of 18 analyzed groundwater samples at a concentration of 0.001 µg/L. Lindane was detected in 3 of the 18 analyzed groundwater samples at concentrations ranging from 0.0052 to 0.13 µg/L (Table 5-7). No detected concentrations of lindane exceeded the federal MCL of 0.2 µg/L. There are no federal or ADEC regulatory criteria for endosulfan sulfate. No other pesticides were detected in groundwater samples at concentrations greater than reporting limits.

None of the 18 analyzed groundwater samples contained Aroclors at concentrations greater than the reporting limits (Table 5-7).

5.5.5 Metals in Groundwater

The maximum metals concentrations are compared to 1993 USGS summary statistic background data and are listed in Table 5-10.

A total of 19 groundwater samples and 2 field duplicate groundwater samples were collected from all existing monitoring wells at Site DP98 during the 2001 EE/CA and analyzed for eight RCRA metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver). Of the samples analyzed in 2001, cadmium (4 samples), and selenium (1 sample) exceeded the maximum background concentrations compiled by the USGS. Metals that did not exceed background levels (e.g., arsenic, chromium, lead, and silver) are believed to represent background concentrations and are excluded from further consideration.

Table 5-10

Comparison of 2001 EE/CA Analytical Data and 1993 USGS Summary Statistics for Background Metals in Groundwater

Metal	Preliminary ARARs[a] (mg/L)	Background Summary Statistics[b]				2001 EE/CA Sample Results		
		Hits[c]	Min.	Max.	Mean	Maximum Groundwater Result	No Samples Exceeding Max. Background[c]	No. of Samples Exceeding Background and Preliminary ARARs
Arsenic	0.05	28/28	0.001	0.130	0.029	0.0601	0	0
Barium	2.0	NA	NA	NA	NA	0.517	21	0
Cadmium	0.005	2/28	ND	0.001	NC	0.0027	4	0
Chromium	0.1	27/28	ND	0.350	0.043	0.097	0	0
Lead	0.015	13/28	ND	0.300	0.028	0.0111	0	0
Mercury	0.002	14/21	ND	0.001	0.000	0.0002	2	0
Selenium	0.05	0/10	ND	ND	NC	0.001	1	0
Silver	0.18	1/10	ND	0.001	NC	0.001	0	0

[a] Preliminary ARAR values taken from 18 AAC 75, Table C (ADEC, 2002) as discussed in Section 9.
[b] 1993 USGS background groundwater data summarized in the 1994 OU6 RI/FS (USAF, 1996b).
[c] Numbers of results above detection limits/entire data set compiled by the USGS.
ADEC – Alaska Department of Environmental Conservation
EE/CA – Engineering Evaluation/Cost Analysis
mg/L – Milligram per liter
NA – Not applicable
NC – Not calculated
ND – Not detected
USGS – United States Geological Survey

Barium was detected in all 21 samples collected during the 2001 EE/CA; however, this metal was not included in the 1993 USGS data set. Therefore, a comparison with the 2001 EE/CA concentrations could not be completed. Barium results did not exceed screening criteria.

Analytical results from four samples exceeded the maximum background level for cadmium; however, three of the four samples were measured at concentrations (0.0012 to 0.0014 mg/L) considered within normal variances. The remaining cadmium concentration was 0.0027, which is approximately twice the maximum background level but is not considered statistically significant. Mercury was detected in only three samples and selenium was detected in only one sample in the 2001 EE/CA field investigation, each at concentrations below screening criteria. These metals are not included for further evaluation.

5.6 Sediment Results Exceeding Regulatory Criteria

This subsection provides a comparison of the sediment analytical results to screening criteria from proposed ARARs in Table 5-1 to estimate the extent of contamination above regulatory criteria. Sediment analytical results exceeding the screening criteria are summarized in Table 5-11 and provided on Figures 5-15 through 5-17.

Analytical results from five sediment samples (DP98-SD02, DP98-SD03, DP98-SD05, DP98-SD06, and DP98-SD08) and two field duplicate sediment samples (DP98-SD02 and DP98-SD05) exceeded the screening criteria for DRO (250 mg/kg). Another sediment sample, DP98-SD10, contained DRO concentrations at the screening criteria.

Figure 5-12. Concentration Contours for PCE and TCE in Groundwater (Without Well Point Data)

[This page intentionally left blank.]

Figure 5-13. Interpolated Distribution of TCE in Groundwater Greater Than 5 µg/L

[This page intentionally left blank.]

Figure 5-14. DCE and Vinyl Chloride Concentration Contours in Groundwater

[This page intentionally left blank.]

Two VOCs (cis-1,2-DCE and TCE) were detected above the screening criteria (0.2 mg/kg and 0.027 mg/kg, respectively) in one sample each; cis-1,2- DCE (0.26 mg/kg) was detected in sediment sample DP98-SD05; and TCE was detected in sediment sample DP98-SD10 (0.037 mg/kg). Results for these two samples are only estimates because concentrations were at or (in the case of TCE result) below the method detection limits.

The extent of DRO contamination in the sediment provides an indication of potential impact to the wetland. A review of all sediment results revealed DRO and RRO in the sediment north of Building 18224. The source of these fuel compounds is probably groundwater discharging near the base of the slope. Based on the unconfined potentiometric surface shown in Figure 4-10 and groundwater screening data from well points installed in 2002, contaminated groundwater intercepts the ground surface near the sediment locations discussed above. Sediment samples DP98-SD02, DP98-SD05, and DP98-SD06 may also receive a more concentrated flow than the other sediment locations because it is located below an eroded drainage that parallels the access road.

Sediment results were also compared to the upper effects threshold values for freshwater sediment in the NOAA Screening Quick Reference Tables (NOAAm1999). Arsenic is the only analyte detected above the upper effects threshold. Sediment samples exceeded the arsenic upper effects threshold of 17 mg/kg at two locations: DP98-SD02 and DP98-SD05 with concentrations of 80.7 mg/kg and 20.9 mg/kg, respectively.

5.7 Surface Water Analytical Results

A total of 11 surface water samples were collected at Site DP98 during the SERA Phase VI (1997), 2001 EE/CA, and 2002 field investigations. With the exception of the one sample collected during the SERA Phase VI investigation, all surface water samples were collected in the wetland near the base of the slope north of the Facility. The surface water samples were collected at sediment sample locations as shown in Figure 3-1. A surface water sample was collected during the SERA Phase VI investigation in 1997 within drainage just east of the access road to the former wastewater treatment pond (see Figure 3-1).

Surface water analytical data exceeding detection limits is included in Table 5-12. Surface water samples are identified with a "SW" modifier in the sample designation, and are shown in Figure 3-1. A complete set of surface water analytical data is contained in Appendix D.

Table 5-11

Summary of Sediment Analytical Results Exceeding Screening Criteria

Analyte	Regulatory Criteria[a] (mg/kg)	Investigation	Sample Location	Depth (bgs)	Concentration (mg/kg)
Diesel range organics	250	EE/CA (2001)	DP98-SD02	0.5 - 1	2,641.5 M
				0.5 – 1 (FD)	3,021.6 M
			DP98-SD03	0.5 - 1	306.7 M
		RI/FS (2002)		0.5 - 1	5,400
				0.5 – 1 (FD)	12,000
			DP98-SD06	0.5 - 1	3,500
			DP98-SD08	0.5 - 1	1,300
			DP98-SD10	0.5 - 1	250
cis-1,2-Dichloroethene	0.2	RI/FS (2002)	DP98-SD05		0.26 J
Trichloroethene	0.027	RI/FS (2002)	DP98-SD10	0.5 - 1	0.037 J

All samples were analyzed for AK101, AK102, AK103, SW8260B, and SW8270C.

[a] Data for this column were taken from the most conservative soil cleanup standards between the ingestion, inhalation, and migration to groundwater pathways for sites with under 40 inches of annual precipitation presented in the ADEC 18 AAC 75, Method Two, Soil Cleanup Levels, Tables B.1 and B.2 (ADEC, 2003).

F – Analyte was positively identified, but the result is below the method-reporting limit.
M – A matrix effect was present.
EE/CA – Engineering Evaluation/Cost Analysis
mg/kg – Milligram per kilogram
bgs – Below ground surface
FD – Field duplicate
RI/FS – Remedial Investigation/Feasibility Study
J – Associated value is an estimate

DRO exceeded the 1.5 mg/L screening criteria in one surface water sample from location DP98-SW06 taken at the edge of the wetland near the drainage east of the dirt access road to the former wastewater treatment pond. The other locations with DRO concentrations above 1 mg/L [DP98-SW02 (1.079 mg/L) and DP98-SW05 (1.0 mg/L)] were located approximately 50 feet south of surface water location DP98-SW06. However, the result for sample DP98-SD02 was flagged with a "J," indicating that the result is considered an estimate. Another surface water location (SWS-01) located within 10 feet of DP98-SW02 contained DRO (0.98 mg/L) at concentrations just below screening criteria. DRO concentrations in surface water are shown on Figure 5-18.

None of the surface water samples contained GRO at a concentration above the screening criteria of 1.3 mg/L.

RRO levels exceeded the 1.1-mg/L screening criteria in two surface water locations (DP98-SW02 and SWS-01). The highest RRO concentration in surface water (3.262 mg/L) was detected at surface water location DP98-SW02. RRO concentrations are shown in Figure 5-18. These locations also contained DRO concentrations above screening criteria.

TCE was the only VOC detected above the screening criteria of 5 µg/L. TCE was detected at 8.9 µg/L in the surface water sample from DP98-SW10 (Figure 5-19). The remaining 9 surface water samples did not contain TCE above 1 µg/L.

A summary of surface water analytical results exceeding regulatory criteria is provided as Table 5-13.

Analytical data for the 13 surface water samples collected in 1996, 2000, and 2002 were used to calculate TAH. TAH values were calculated by combining the results for benzene, ethylbenzene, and toluene. For these 13 samples, TAH concentrations ranged from below detection limits to 0.9 µg/L. These values are below the regulatory criteria of 10 µg/L discussed in Table 5.1.4.

Analytical data for the 12 surface water samples collected in 2000 and 2002 were used to calculate TAqH. TAqH values were calculated by combining PAH results with TAH values calculated as described in the preceding paragraph. The surface water sample collected in 1999 (SWS-01) was not analyzed for PAHs; therefore, TAqH could not be calculated for this sample. TAqH values ranged from below detection limits to 0.1 µg/L to 1.78 µg/L. These results are below the screening criteria of 15 µg/L, as discussed in Table 5.1.2.4. It should be noted that the maximum TAqH result (1.78 µg/L) was measured in the field duplicate for surface water sample DP98-SW02; however, a much lower result (0.33 µg/L) was calculated for the primary surface water sample DP98-SW02 associated with this field duplicate sample. Other than this maximum result, all TAqH values were calculated below 0.36 µg/L.

Several water-quality parameters (dissolved oxygen, pH, turbidity, and TDS) were measured during the collection of the surface water samples in 2000 and 2002, and these field measurements were compared to the surface water quality parameters presented in Table 5.1.2.4. None of the measurements taken for these surface water samples exceeded the preliminary screening criteria for these parameters. For all surface water samples collected in 2000 and 2002, dissolved oxygen levels ranged from 14 to 16 mg/L; pH values ranged from 6.8 to 7.2; turbidity was less than 10 NTU; water temperature ranged from 6.6ºC to 10.2ºC; and TDS ranged from 150 to 220 mg/L. No data were available for comparison of the surface water sample collected in 1996. No sheen was noted on the surface water prior to collecting the surface water samples.

It should be noted that surface water samples collected at Site DP98 were not filtered, and in some cases contained a large amount of organic matter because they were collected from organic-rich standing water. This organic material could account for a portion of the organics measured since 1997. Furthermore, the roadside drainage above sampling location DP98-SW02 only handles visible amounts of ephemeral runoff following heavy rainfall episodes and was dry during most of the 2000 and 2002 field seasons.

The highest DRO and RRO results were measured in one 50-square-foot area at the base of the slope near the outfall of drainage that trends northwest along a road. These results were measured in samples collected from shallow ponded water coincident with sediment location with similar types of contamination. As previously discussed, the fuel impacts observed at this location are probably due to seepage of contaminated groundwater into a drainage rill near the base of the slope.

Table 5-12
Summary of Surface Water Analytical Results

	SERA VI (1997)	EE/CA (2001)					RI/FS (2002)						
Analyte/Method	**SWS-01**	**DP98-SW01**	**DP98-SW02**	**DP98-SW02 FD**	**DP98-SW03**	**DP98-SW04**	**DP98-SW05**	**DP98-SW06**	**DP98-SW07**	**DP98-SW08**	**DP98-SW08 FD**	**DP98-SW09**	**DP98-SW10**
AK101, Gasoline Range Organics (mg/L)													
Gasoline Range Organics	ND	ND	0.016 F	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
AK102, Diesel Range Organics (mg/L)													
Diesel Range Organics	0.98	0.082 F	1.078 J	0.341 J	0.118 J	0.066 F	1.00	1.70	0.20	0.55	0.58	0.072 F	0.067 F
AK103, Residual Range Organics (mg/L)													
Residual Range Organics	1.4	0.195 F	3.263 J	0.597 J	0.561 J	0.484 J	0.23	0.35	0.180 F	0.24	0.27	0.150 F	0.22
SW8260B, Volatile Organic Compounds (μg/L)													
1,1-DCA	NA	ND	0.24 F	0.22 F	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acetone	NA	ND	ND	ND	ND	ND	3.5 R	4.9 R	3.3 R	ND	ND	2.7 R	3.4 R
Bromomethane	NA	ND	ND	ND	ND	ND	0.23 F	ND	ND	ND	0.25 F	ND	0.35 F
Chloroform	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.1 F	0.12 F
Cis-1,2-DCE	NA	ND	7.3	7.1	ND	ND	4.3	ND	34	0.87 F	0.7 F	14	1.1
TCE	NA	ND	0.3 F	0.29 F	ND	ND	ND	ND	0.17 F	ND	ND	ND	8.9
Toluene	NA	ND	0.9 F	1.21	ND	ND	0.14 F	0.13 F	0.21 F	0.1 F	0.12 F	ND	0.12 F
trans-1,2 DCE	NA	ND	ND	ND	ND	ND	ND	ND	0.46 F	ND	ND	0.36 F	ND
SW8270C SIMS, Semivolatile Organic Compounds-Polynuclear Aromatic Hydrocarbons (μg/L)													
Acenaphthene	NA	ND	ND	ND	ND	ND	ND	ND	ND	0.0057 F	ND	ND	ND
Acenaphthylene	NA	ND	ND	ND	ND	0.18 F	ND	ND	ND	0.0046 F	ND	ND	ND
Anthracene	NA	ND	0.01 F	ND	ND	ND	0.0084 F	0.014 F	ND	0.011 F	0.0078 F	0.0016 F	ND
Benzo (a) anthracene	NA	ND	0.008 F	0.022 F	ND	ND	ND	ND	ND	0.0088 F	ND	0.0021 F	ND
Benzo (a) pyrene	NA	ND	ND	0.029 F	ND	ND	ND	ND	ND	0.006 F	ND	0.003 F	ND
Benzo (b) fluoranthene	NA	ND	0.01 F	0.04 F	ND	ND	ND	ND	ND	0.0079 F	ND	0.0028 F	ND
Benzo (g,h,i) perylene	NA	ND	0.015 F	0.041 F	ND	ND	ND	ND	ND	0.0076 F	ND	0.014 F	ND
Benzo (k) fluoranthene	NA	ND	ND	0.019 F	ND	ND	ND	ND	ND	0.0058 F	ND	0.002 F	ND
Chrysene	NA	ND	0.02 F	0.04 F	ND	ND	ND	ND	ND	0.0073 F	ND	0.002 F	ND
Dibenzo (a,h) anthracene	NA	ND	0.02 F	ND	ND	ND	ND	ND	ND	0.0051 F	ND	0.013 F	ND
Fluoranthene	NA	ND	0.03 F	0.11 F	ND	ND	ND	ND	ND	0.0093 F	ND	0.003 F	ND
Fluorene	NA	ND	0.02 F	ND	ND	ND	0.0058 F	ND	ND	0.008 F	ND	ND	ND
Indeno (1,2,3-c,d) pyrene	NA	ND	0.05 F	0.118 F	ND	ND	ND	ND	ND	0.007 F	ND	0.014 F	ND
Naphthalene	NA	ND	ND	ND	ND	ND	0.0034 F	0.0041 F	0.0055 F	0.0047 F	0.0048 F	0.0056 F	0.005 F

Table 5-12 (Continued)

Analyte/Method	SERA VI (1997)	EE/CA (2001)					RI/FS (2002)						
	SWS-01	DP98-SW01	DP98-SW02	DP98-SW02 FD	DP98-SW03	DP98-SW04	DP98-SW05	DP98-SW06	DP98-SW07	DP98-SW08	DP98-SW08 FD	DP98-SW09	DP98-SW10
Phenanthrene	NA	ND	0.02 F	0.07 F	0.01 F	ND	ND	0.0074 F	ND	0.0069 F	ND	ND	ND
Pyrene	NA	ND	0.02 F	0.08 F	0.01 F	ND	0.0044 F	ND	ND	0.0087 F	ND	0.0025 F	ND
SW6010B, SW6020, SW7060A, Metals (mg/L)													
Barium	NA	0.0159	0.109	0.0525	0.0353	0.0404	0.0262 B	0.0425 B	0.0541	0.0223 B	0.0217 B	0.0385 B	0.039 B
Cadmium	NA	ND	0.0015 F	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	NA	ND	0.0168	0.0037 F	ND	ND	ND	ND	0.003 B	ND	ND	ND	ND
Lead	NA	ND	0.0477	0.0219	0.0014 F	ND	0.0008 B	0.00054 B	0.00091 B	0.00027 B	0.00023 B	0.00046 B	0.00142 B
Silver	NA	ND	0.0158	0.0064 F	ND	ND	ND	ND	ND	0.0045 B	ND	0.0046 B	0.0042 B
Arsenic	NA	ND	0.0146	0.0118	0.0018 F	0.00068 F	ND	0.0088 B	0.00128 B	0.00063 B	0.0006 B	0.00057 B	0.00068 B
Selenium	NA	ND	0.0012 M	ND	ND	ND	0.0004 B	0.0007 B	0.0004 B	0.0007 B	0.0006 B	0.0007 B	0.0003 B
Mercury	NA	ND	0.00053 F	0.00022 F	ND	ND	ND	ND	ND	ND	ND	ND	ND

B – This analyte was also detected in the associated equipment blank.
EE/CA – Engineering Evaluation/Cost Analysis
F – The analyte was positively identified, but the result is below the method reporting limit.
FD – Field duplicate
J – The analyte was positively identified; the quantitation is an estimation.
M – A matrix effect was present.
mg/L – Milligram per Liter
NA – Not analyzed
ND – Analyte was not detected at or above the method detection limit.
R – Rejected
RI/FS – Remedial Investigation/Feasibility Study
SERA – State-Elmendorf Environmental Restoration Agreement

Table 5-13

Summary of Surface Water Analytical Results Exceeding Screening Criteria

Analyte	Regulatory Criteria[a]	Investigation	Sample Location	Concentration (mg/L)
Diesel Range Organics	1.5 mg/L	RI/FS (2002)		1.7
Residual Range Organics	1.1 mg/L	SERA VI (1997)	SWS-01	1.4
		EE/CA (2000)	DP98-SD02	3.263 J
Trichloroethene	5 µg/L	RI/FS (2002)	DP98-SW10	8.9

All samples were analyzed for AK101, AK102, AK103, SW8260B, SW8270C, and metals.

[a] Data for this column were taken from the groundwater cleanup standards presented in ADEC 18 AAC 75, Method Two, Groundwater Cleanup Levels, Table C (ADEC, 2002) as discussed in Table 5.1.2.2.

EE/CA – Engineering Evaluation/Cost Analysis
J – Analyte was positively identified, the quantitation is an estimation.
mg/L – Milligram per liter
RI/FS – Remedial Investigation/Feasibility Study
SERA – State-Elmendorf Environmental Restoration Agreement

[This page intentionally left blank]

Figure 5-15. Sediment Analytical Data for Fuel Compounds

[This page intentionally left blank.]

Figure 5-16. Sediment Analytical Data for VOCs

[This page intentionally left blank.]

Figure 5-17. Sediment Analytical Data for SVOCs

[This page intentionally left blank.]

Figure 5-18. Surface Water Analytical Data for Fuel Compounds

[This page intentionally left blank.]

Figure 5-19. Surface Water Analytical Data for Select VOCs

[This page intentionally left blank.]

Section 6.0
CONTAMINANT FATE AND TRANSPORT

This section discusses contaminant migration in environmental media at Site DP98. Two methods were used to evaluate the rate and transport mechanisms of chlorinated solvent contaminants and fuel contaminants. BIOCHLOR was the chosen groundwater model to estimate migration time and concentrations for solvent contaminants. To estimate the rate to which contaminants will migrate from the source area near the Facility at Site DP98, to the wetland area, max flux calculations were used. The properties of the chemicals detected beneath the site are reviewed, and the interactions of these chemicals within groundwater are summarized in Appendix G.

6.1 Potential Routes of Migration

Prior to the commencement of modeling, potential routes of migration of contaminants were identified. A physical model describing the distribution of contaminants is included in Section 5 (Figure 5-1). The contaminants present at Site DP98 are the result from a combination of operational activities at the former boiler plant and vehicle maintenance building (Building 18224), and refueling/leaking of former USTs originating around Building 18224.

Results from sampling events between 1995 and 2002 of both soil and groundwater have indicated that contaminants associated with the past activities at Site DP98 exist at levels above preliminary ARARs (see screening discussion Section 5.2). As indicated by previous sampling results, potential routes of migration for solvent and fuel compounds are being transported principally through groundwater migration.

6.2 Site-Specific Fate and Transport

TCE was selected as the target analyte for estimating transport of solvents in groundwater. An evaluation of the fate and transport of TCE and its associated degradation compounds was then performed for Site DP98. The following section provides an overview of the modeling program selected, the goals and expectations of the modeling, a discussion on the technical approach taken, the modeling results, and any uncertainties associated with the modeling program.

6.2.1 Transport Modeling – BIOCHLOR

BIOCHLOR is a screening model that simulates remediation by natural attenuation of dissolved solvents at chlorinated solvent release sites. BIOCHLOR can be used to simulate solute transport without decay and with biodegradation modeled as a sequential first-order process within one or two different zones. The software, programmed in the Microsoft Excel spreadsheet environment and based on the Domenico analytical solute transport model, has the ability to simulate one-dimensional advection, three-dimensional dispersion, linear adsorption, and biotransformation via reductive dechlorination (the dominant biotransformation process at most chlorinated solvent sites).

6.2.1.1 Modeling Goals

Fate and transport modeling for the TCE and degradation compounds observed in groundwater was performed at Site DP98. The goals of this modeling effort were as follows:

- Estimate the distance that the TCE plume in groundwater would travel downgradient of the presumed source area.
- Estimate if degradation of the TCE plume in groundwater would be achieved below applicable regulatory levels before reaching the wetlands.
- Validate assumptions made in the 2001 EE/CA regarding natural attenuation in groundwater.

6.2.1.2 Site Model for Modeling

BIOCHLOR was selected as the modeling tool to evaluate the reactive transport of both "parent" and "daughter" chlorinated solvents at Site DP98. The model accounts for dispersion, adsorption, advection, and sequential biotransformation. The reductive dechlorination of the parent solvent (PCE) to daughter product is assumed to be a first-order process. The model assumes that biotransformation starts immediately downgradient of the source and that no biotransformation of dissolved constituents in the source area occur.

As with any computer-based modeling program, BIOCHLOR has a number of known limitations. As an analytical model, BIOCHLOR assumes a simple groundwater flow condition. Because of this assumption, hydraulic gradient and conductivity values need to be calculated as a site average. The model should not be applied where pumping systems create a complicated field flow. Additionally, applying BIOCHLOR where vertical flow gradient affects contaminant transport is not recommended.

BIOCHLOR also assumes uniform hydrogeologic and environmental conditions over the entire model area. BIOCHLOR simplifies site conditions (hydrogeological and biological values) and assumes constant source for the entire model area. It should be noted that complex hydrogeological conditions are present at Site DP98 resulting in greater uncertainty in modeling results.

Finally, BIOCHLOR was designed for the simulation of sequential reductive dechlorination of chlorinated ethanes and ethenes.

6.2.1.3 Technical Approach

The BIOCHLOR software solves a set of coupled partial differential equations to describe the reactive transport of chlorinated solvent compound, such as TCE, DCE, VC, and ethane/ethane (ETH), in saturated groundwater systems. The equations describe one-dimensional advection, three-dimensional dispersion, linear sorption, and sequential, first-order biotransformation. All equations, except the first, are coupled to a parent compound equation through the reaction term as shown below:

$$R_1 \frac{\partial c_1}{\partial t} = D_x \frac{\partial^2 c_1}{\partial x^2} + D_y \frac{\partial^2 c_1}{\partial y^2} + D_z \frac{\partial^2 c_1}{\partial z^2} - v_s \frac{\partial c_1}{\partial x} - k_1 c_1 \qquad (1)$$

$$R_2 \frac{\partial c_2}{\partial t} = D_x \frac{\partial^2 c_2}{\partial x^2} + D_y \frac{\partial^2 c_2}{\partial y^2} + D_z \frac{\partial^2 c_2}{\partial z^2} - v_s \frac{\partial c_2}{\partial x} + y_1 k_1 c_1 - k_2 c_2 \qquad (2)$$

$$R_3 \frac{\partial c_3}{\partial t} = D_x \frac{\partial^2 c_3}{\partial x^2} + D_y \frac{\partial^2 c_3}{\partial y^2} + D_z \frac{\partial^2 c_3}{\partial z^2} - v_s \frac{\partial c_3}{\partial x} - y_2 k_2 c_2 - k_3 c_3 \qquad (3)$$

$$R_4 \frac{\partial c_4}{\partial t} = D_x \frac{\partial^2 c_4}{\partial x^2} + D_y \frac{\partial^2 c_4}{\partial y^2} + D_z \frac{\partial^2 c_4}{\partial z^2} - v_s \frac{\partial c_4}{\partial x} - y_3 k_3 c_3 - k_4 c_4 \qquad (4)$$

$$R_5 \frac{\partial c_5}{\partial t} = D_x \frac{\partial^2 c_5}{\partial x^2} + D_y \frac{\partial^2 c_5}{\partial y^2} + D_z \frac{\partial^2 c_5}{\partial z^2} - v_s \frac{\partial c_5}{\partial x} - y_4 k_4 c_4 - k_5 c_5 \qquad (5)$$

Where c_1, c_2, c_3, c_4, and c_5 are concentrations of TCE, DCE, VC, and ETH, respectively, (mg/L); D_x, D_y, and D_z are the hydrodynamic dispersion coefficients (ft^2/yr); v_s is the seepage velocity (ft/yr) k is the first-order degradation coefficient (1/yr); y is the yield coefficient (a dimensionless value; for example, y_1 would represent the mg of TCE produced per unit mg of PCE destroyed); and R_1, R_2, R_3, R_4, and R_5 are respective retardation factors. BIOCHLOR takes the retardation factor values of different compounds and averages them to compute an effective retardation factor, R, which is in turn used to compute the effective transport velocity and dispersion coefficients. Also, biotransformation is assumed to occur in the aqueous phase (which is a conservative assumption), and hence all the degradation reaction terms are divided by R.

6.2.1.4 Computer Model

BIOCHLOR was used to reproduce the movement of the PCE and daughter compounds at Site DP98. Table 6-1 presents the required input necessary for the BIOCHLOR program to model a given site along with the values relating to site conditions. Results from the modeling are provided in Section 6.2.1.7.

The hydraulic conductivity (K) and hydraulic gradient (I) were taken from the average mean presented within the 2001 EE/CA report. Effective porosity (n) represents a dimensionless ratio of the volume of interconnected voids to the bulk volume of aquifer matrix. For Site DP98, both the ASTM RBCA Standard for unconsolidated deposits and AFCEE field data from Site 45/57 were utilized to arrive at an effective porosity of 0.38. Using this information, a seepage velocity (Vs) was calculated at 53.6 ft/yr.

Dispersion refers to the process whereby a dissolved solvent will be spatially distributed longitudinally (along the direction of groundwater flow), transversely (perpendicular to groundwater flow), and vertically (downward) because of mechanical mixing and chemical diffusion in the aquifer. Longitudinal dispersion (Alpha *x*) was calculated using a modification of the Xu and Echstein approach as follows:

$$\text{Alpha } x = 0.82 \, x \;\; 3.28 \, x \, (\mathrm{L_{og}}(\mathrm{Lp} / 3.28))^{2.446} \qquad \text{(Xu and Echstein, 1995)}$$

where Lp= estimated plume length (ft) between WL02 and WL09

The transverse dispersion (Alpha *y*) rate was calculated by using the following equation:

$$\text{Alpha } y = 0.33 \text{ Alpha } x \qquad \text{(ASTM, 1995)}$$

Downward (vertical) dispersion (Alpha *z*) was established at 0, assuming that the vertical depth from the source (i.e., the tiled drainpipe) was approximately at the same depth as the groundwater.

Adsorption to the soil matrix can reduce the concentration of dissolved contaminants moving through the groundwater. The retardation factor is the ratio of the groundwater seepage velocity to the rate that organic chemicals migrate in the groundwater. The retardation value is calculated by the following expression:

$$R = 1 + (K_d P_b)/n$$

where $K_d = K_{oc} \, x \, f_{oc}$

P_b = bulk density

n = effective porosity

K_d = distribution coefficient

f_{oc} = fraction organic carbon on uncontaminated soil

A calculated *R* value of 1.74 was generated for Site DP98. A retardation value of 1.74 indicates that if the groundwater seepage velocity is 100 ft/yr, then the organic chemicals migrate at approximately 57 ft/yr. The degree of retardation depends on both aquifer and constituent properties.

Table 6-1

BIOCHLOR Modeling Input Parameters

Data Type	Parameter	Value	Source of Data
Advection	Seepage Velocity (Vs)	53.6 ft/yr	Calculated
	Hydraulic Conductivity (K)	3.6×10^{-4} cm/sec	2001 EE/CA
	Hydraulic Gradient (I)	0.055 ft/ft	2001 EE/CA
	Effective Porosity (n)	0.38 (-)	Average for glacial silt/sediment (Fetter, 1988)
Dispersion	Longitudinal Dispersivity (Alpha *x*)	14.22 ft	Approximate plume length for 2001 EE/CA
	Transverse Dispersivity (Alpha *y*)	4.6926 (-)	Intermediate value from Fetter 1988, ASTM 1995
	Vertical Dispersivity (Alpha *z*)	1.0×10^{-4}	ASTM 1995
Adsorption	Soil Bulk Density, rho	1.625 kg/L	Estimated
	Fraction Organic Carbon (f_{oc})	2.0×10^{-3}	2001 EE/CA
	Partition Coefficient:		
	PCE	209 (kg/L)	2001 EE/CA
	TCE	87 (kg/L)	2001 EE/CA
	DCE	49 (kg/L)	2001 EE/CA
	VC	3 (kg/L)	2001 EE/CA
	ETH	150 (kg/L)	2001 EE/CA
	Common R (used in model)	1.74	Estimated
Biotransformation	Zone 1-1st Order Decay Coef.	half-life	Based on calibration to field data using a simulation time of 5 yrs (field data collected in 1999). Started with literature values and then adjusted model to fit field data.
	PCE --> TCE	0.64 year	
	TCE --> DCE	0.48 year	
	DCE --> VC	1.74 years	
	VC --> ETH	1.36 years	
General	Estimated Time	5 years	Based on extent of existing field data (1997-2002).
	Model Area Width	300 feet	Distance from WL02 to wetland as estimated in the 2001 EE/CA.
	Model Area Length	305 feet	
Source Data	Source Thickness	25 feet	Based on geologic logs and monitoring data
	Source Width	200 feet	Based on field data – EE/CA.
	Source Concentration (mg/L)	PCE = 7.0 mg/L TCE = 4.8 mg/L DCE = 5.0 mg/L VC = .000355 mg/L ETH = 0 mg/L	Based on calibration to field data and back-calculations of degradation timeframe. Started with analytical values and then adjusted model to fit field data.

cm/sec -Centimeters per second
DCE - Dichloroethene
ETH - Ethane/ethene
ft/ft - Feet per foot
ft/yr - Feet per year
kg/L - Kilogram per liter
mg/L - Milligram per liter
PCE - Tetrachloroethene
TCE - Trichloroethene
VC - Vinyl chloride

In choosing a single planar option, the maximum source area concentration is normally entered in the dialog box. Using a single planar source yields accurate centerline concentrations profiles, but concentrations off the centerline tend to be overestimated. However, given the limited amount of available data, a single planar selection was selected.

6.2.1.5 Sensitivity Analysis

Sensitivity analyses are recommended when literature values are used and if there is uncertainty in an input parameter. To illustrate the response of the BIOCHLOR model to changes in the input parameters, a sensitivity analysis was conducted for the first order decay coefficients and also for the common retardation factor.

In the first sensitivity analysis example, the case study (baseline) problem was run with the same input parameters, except that the first order decay coefficients was multiplied by two. Similarly, another simulation was conducted whereby the rate coefficient was 0.1 times those used in the baseline example; in this instance, the simulated concentration of PCE and its daughter products increased substantially when the rate coefficient is decreased by a factor of 10. The centerline concentrations of TCE, DCE, and VC downgradient from the source are presented in Table 6-2 for each simulation. Doubling the rate coefficient decreases the chlorinated solvent concentrations at the downgradient location.

In contrast, changes in the retardation factor have nominal effects on the dissolved chlorinated solvents concentrations, as shown in Table 6-3. In this sample case, when the retardation factor is decreased from the baseline value of 1.74 to 1.0, chlorinated solvent concentrations increased significantly. However, with an increase in the retardation factor, the chlorinated solvent concentrations downgradient decrease by a small amount. These small variations in the concentrations are due to the changes in the retardation factor, which may be attributed to the plume not being at steady state.

The results of the sensitivity analysis show that the BIOCHLOR model is sensitive to changes in the first-order decay rate and in the retardation factor.

6.2.1.6 Model Calibration

Model calibration is an iterative procedure that involves varying model parameters within the general range of reasonable values until the plume concentrations estimated by the model approximate the measured field concentrations. TCE was selected for model calibration because it has the highest concentration in groundwater and historical data are available.

The calibrated transport model assumes that TCE enters the groundwater in the year 1999 and the source concentration begins first-order decay. The rationale of selecting 1999 as the beginning year of the source concentration is based on the limited field analysis for Site DP98. Using this assumption overestimates the mobility of PCE and its daughter products in the groundwater. The source contaminants may have entered the aquifer decades earlier when operations began at DP98 in the 1950s. The documented TCE concentration contours in groundwater show the estimated extent of the plume north of the Facility.

6.2.1.7 Modeling Results

The groundwater fate and transport model was used to evaluate the movement of the TCE and daughter compounds in the unconfined aquifer. The goal of this analysis was to estimate the extent of plume migration downgradient, whether natural attenuation of TCE is occurring, and if degradation can achieve concentrations below applicable regulatory levels before reaching the wetlands. Output produced by the BIOCHLOR model is provided in Appendix G.

Because a considerable amount of uncertainty is associated with estimating future concentration levels, the groundwater fate and transport model is based on assumptions that result in conservative estimates. Future concentrations of contaminants have been estimated in groundwater based on the assumption of no groundwater cleanup.

Some of the assumptions used for the model may not directly apply to the site. The model assumes a simple groundwater flow regime, whereas in reality, it is more complex. The model assumes a decaying source and does not account for a continuing source from the NAPL (emulsion) that is present. The accuracy of model results should be considered in light of the assumptions.

Table 6-2

Sensitivity Analysis Results – Rate Coefficients

Constituent	Concentration (mg/L)		
	2 Times Baseline	Baseline	0.1 Times Baseline
Tetrachloroethene	0.00	0.002	0.030
Trichloroethene	0.00	0.004	0.025
Dichloroethene	0.013	0.031	0.033
Vinyl chloride	0.010	0.013	0.002

mg/L - Milligram per liter
Baseline: $_{\text{PCE->TCE}} = 1.091\ \text{yr}^{-1}$, $_{\text{TCE -> DCE}} = 1.459\ \text{yr}^{-1}$, $_{\text{DCE -> VC}} = 0.398\ \text{yr}^{-1}$, $_{\text{VC-> ETH}} = 0.510\ \text{yr}^{-1}$

Table 6-3

Sensitivity Analysis Results – Retardation Factor

Constituent	Concentration (mg/L)		
	R=1	R=1.74 (Baseline)	R=3.48
Tetrachloroethene	0.665	0.002	0.000
Trichloroethene	0.610	0.004	0.000
Dichloroethene	0.900	0.031	0.000
Vinyl chloride	0.079	0.013	0.000

mg/L - Milligram per liter
R – Retardation factor

The model results indicate that a TCE groundwater concentration of 0.005 mg/L will reach the wetlands in approximately 5 years (after 1999), assuming biodegradation. If the actual degradation rates were higher than input into the model, the downgradient extent of the plume would be less than modeled. This could also explain why the actual PCE plume is significantly less than the TCE plume. Additionally, TCE could have been transported overland with the DRO emulsion, resulting in a larger plume relative to the PCE plume. TCE and DRO are present at the base of the slope and edge of the wetland, which confirms the results of the groundwater model.

The cis-1,2-DCE retardation factor is lower than the TCE retardation factor, and as a result, cis-1,2-DCE migrates through the groundwater faster than TCE.

The lateral extent of the shallow groundwater zone beyond Site DP98 and the extent of contamination beyond the site are unknown. Because groundwater emerges at ground surface less than 300 feet downgradient of the assumed source area, complete degradation of TCE and daughter compounds is not occurring. Volume calculations and percent change were not calculated because the groundwater emerges at ground surface (i.e., the model is being run within too small of an area to address complete degradation; however, the size cannot be increased because groundwater emerges at the wetlands).

In summary, the model results show that the plume is migrating downgradient at the site, and natural degradation is occurring. The model predicts that complete breakdown is not possible based on the limited area of migration that is upgradient of groundwater flow into the wetland. However, the model overstates the mobility of PCE and its daughter products. There is ample evidence of naturally occurring degradation as indicated by the presence of cis-1,2-DCE and VC.

6.2.1.8 Uncertainty Analysis

When a complex chemical and physical system is simplified and modeled, there is uncertainty in the results. Although uncertainty is present in this analysis, the intent was to estimate conservative and reasonable results. The uncertainties resulting from the simplifying assumptions used in the analysis are discussed in the following paragraphs.

The complex geology in the study area is one of the largest sources of uncertainty at this site. This uncertainty affects the estimated groundwater velocities, flow direction, and plume concentration.

Since the hydraulic conductivities and hydraulic gradient are consistent with laboratory results and field observations at Site DP98, the estimated regional groundwater velocities and travel time of the plume are judged to be reasonable. However, the extrapolation of these conditions beyond the area where the groundwater flow region and water quality data have been collected is uncertain.

A reliable estimate of source strength over the last 50 years (1950s to 2000) requires data at several locations and at several points in time. Because these data are unavailable, source strength was based on PCE concentrations in the groundwater. It is not possible to know with what degree of precision the model source strength reflects actual contamination loadings.

6.3 Max Flux Calculations

Due to the uncertainties of the BIOCHLOR model and to answer the question of how long it will take for contaminants at the source (the Facility) to reach the wetland, a simple max flux calculation was performed. This calculation includes several assumptions regarding volume of contaminants in soils and groundwater and the current disposition of the source areas within the Facility. A brief summary of the calculations is presented below, and calculations and equations are presented in Appendix G.

6.3.1 Contaminant Velocity and Flux

Flux of DRO and TCE mass from the Facility, which contains the primary source areas and is higher in elevation, to the wetland located to the north at a lower ground elevation was estimated to assess the time required for site restoration via natural processes. To start, the contaminant velocity was estimated by calculating the Darcy velocity for groundwater and applying retardation factors for DRO and TCE. The soil-to-groundwater partitioning coefficient for P-xylenes was used as a conservative surrogate for DRO. The distances that TCE and DRO have migrated are approximately 350 and 650 feet, respectively.

The retarded velocity and average DRO and TCE concentrations were used to calculate the flux of dissolved DRO and TCE in groundwater through a 600-foot-wide by 10-foot-thick cross-section representing the boundary between the elevated and lower wetland portions of the site. The velocity calculations were made using the minimum, average, and maximum hydraulic conductivities estimated for the unconfined aquifer at the site via slug testing (USAF, 2001).

The flux was calculated using the maximum estimated hydraulic conductivity resulting in a conservatively high groundwater velocity and a conservatively low, or minimum, estimated restoration time. These calculations are provided in Appendix G.

6.3.2 Results

Unlike the mass flux calculations that estimate a time for a dissolved contaminant mass to migrate through a section of the aquifer, the BIOCHLOR model results estimate concentrations downgradient of the source over time. The calculations suggest that no less than 137 years, at a minimum, would be required before all of the dissolved DRO in groundwater migrated from the Facility area to the wetland area. It is estimated to take approximately 29 years, at a minimum, for all of the dissolved TCE to migrate from the upper elevated area to the wetland area. It should be noted that these estimates do not take into consideration continued contribution of TCE and DRO contamination from soils above the groundwater saturation zone or TCE dissolved in DRO emulsion, which contain high levels of these contaminants.

6.4 Groundwater Cleanup Timeframes

Groundwater cleanup timeframes, the predicted time it may take for chemicals in groundwater to attenuate naturally to concentrations at or below screening criteria, were approximated using BIOCHLOR for TCE and BIOSCREEN for DRO. Several assumptions were made in order to predict cleanup timeframes. Assumptions are as follows:

- Cleanup timeframes assume that no active treatment of contaminants in groundwater or soil will take place, but are based on monitored natural attenuation.
- Predicted TCE cleanup timeframe assumes that soil will not contribute further TCE to groundwater and TCE in groundwater will continually decay.
- Predicted DRO cleanup timeframes assume that soil will contribute a degrading amount of DRO to groundwater and DRO in groundwater will continually decay.
- Maximum TCE and DRO concentrations detected at Site DP98 were used to develop cleanup timeframes.
- Cleanup timeframes are based on first order rate constants. Depending on the value of the first order rate constant used for biodegradation, the time required to meet screening criteria ranges from 0.15 to364 years.
- Published first order rate constants for TCE ranged from 0.06 yr^{-1} to 146.0 yr^{-1}. A value of 0.62 yr^{-1} was used to calculate TCE cleanup timeframes for Site DP98.
- The first order rate constant for DRO (0.3 yr^{-1}) was calculated from an average of rate data for xylenes, naphthalene, and phenanthrene.

Based on these assumptions, the TCE groundwater cleanup timeframe was calculated at 55 years upgradient of the wetland and 35 years in the wetland. The DRO groundwater cleanup timeframe was calculated at 50 years upgradient of the wetland and 75 years in the wetland.

Section 7.0
HUMAN HEALTH RISK ASSESSMENT

This RI/FS has identified chlorinated solvents and petroleum compounds above preliminary ARARs at Site DP98 from past spills, leaks, and work practices associated with vehicle maintenance and the underground storage tanks (USTs). The human health risk assessment evaluates whether potential health risks are present if people encounter these solvent- and petroleum-contaminated materials in their environment. Appendix H contains the complete risk assessment report. The following is a summary of the risk assessment process and its findings.

A risk assessment evaluates the likelihood of adverse effects occurring in human populations potentially exposed to contaminants released in the environment. Risk assessments are not intended to predict the actual risk for an individual. Rather, they provide upper bound and central tendency (CT) estimates of risk with an adequate margin of safety, according to EPA, USAF, and ADEC guidelines, for the protection of human receptors that may potentially come into contact with contaminants at the site.

According to EPA and ADEC guidance, human health risk assessments (HHRAs) are composed of four basic steps:

1. The sampling data is initially screened to select the applicable data set for humans and, within that data set, to select contaminants that could be a potential health concern.
2. Contaminant sources, pathways, receptors, exposure duration and frequency, and routes of exposure are evaluated to quantitatively assess the amount of exposure to the contaminants of potential concern (COPCs).
3. A toxicity assessment is performed, which summarizes the carcinogenic and noncarcinogenic effects associated with the COPCs and provides toxicity values that are used to calculate the dose-response relationship.
4. Risk characterization is performed that integrates the quantitative and qualitative results of the data evaluation, exposure, and toxicity assessment sections.

7.1 Data Evaluation and Selection of COPCs

In the first step in this risk assessment, sampling data from soil, semi-confined aquifer groundwater, upper aquifer groundwater, surface water, and sediment were reviewed to select the appropriate data set for human health COPCs within the data set. The data were found to be of acceptable quality and selected for evaluation in the risk assessment.

Typically, not all contaminants present at a site pose health risks or contribute significantly to overall site risks. EPA guidelines (1989) recommend focusing on a group of "compounds of potential concern" based on inherent toxicity, site concentration, and behavior of the contaminants in the environment. To identify these COPCs, risk-based screening values are compared to site concentrations of contaminants. If site concentrations of a contaminant exceed their respective screening concentrations, then the contaminants are generally retained as COPCs for further evaluation in the risk assessment. In this assessment, EPA Region 9 residential preliminary remediation goals (PRGs) were generally used as risk-based screening values. Note, metals were not included in the screening process for the selection of COPCs, because as discussed in Section 5.0, metals concentrations in soil and groundwater were generally found to be within the range of background concentrations. Therefore, the presence of metals in soil or groundwater is not likely to be related to historic activities at the Facility. Refer to Appendix H for a more detailed discussion of the screening process. Table 7-1 summarizes the results of the screening assessment for each medium.

7.2 Exposure Assessment

The exposure assessment evaluates sources, pathways, receptors, exposure duration and frequency, and routes of exposure to assess total human exposure to the substances of concern, or COPCs at the site. The goal of this second step is to calculate the dose, or chemical intake per body weight per day for each COPC, receptor, and exposure pathway combination. In order to calculate dose, first a conceptual site model (CSM) must be developed that identifies exposure pathways and populations; secondly, exposure assumptions must be selected; and lastly, the assumptions must be used in combination with estimates of media concentrations at the exposure point in order to quantify each chemical dose.

Table 7-1

Summary of Contaminants of Potential Concern for Each Medium

Chemical	Semi-confined Aquifer Groundwater[a]	Upper Aquifer Groundwater	Surface/ Subsurface Soil	Wetlands Surface Material[b]	Wetlands Surface Water
DRO	NS	X	X	X	NS
GRO	NS	X	NS	NS	NS
1,2,4-Trimethylbenzene	NS	X	NS	NS	NS
1,3,5-Trimethylbenzene	NS	X	NS	NS	NS
Benzene	NS	X	NS	NS	NS
Benzo(a)pyrene	NS	NS	NS	NS	X
Chloroform	NS	X	NS	X	NS
Chloromethane	NS	X	NS	NS	NS
Cis-1,2-Dichloroethene	NS	X	NS	NS	X
Dibenzo(a,h)anthracene	NS	NS	NS	NS	X
Ethylbenzene	NS	X	NS	NS	NS
Indeno(1,2,3-cd)pyrene	NS	NS	NS	NS	X
Lindane	NS	X	NS	NS	NS
Methylene chloride	NS	X	NS	NS	NS
Naphthalene	NS	X	NS	NS	NS
Tetrachloroethene	NS	X	NS	NS	NS
Trans-1,2-Dichloroethene	NS	X	NS	NS	NS
Trichloroethene	NS	X	X	X	X
Vinyl chloride	NS	X	NS	NS	NS
Xylenes (o-xylene and m,p-xylene)	NS	X	NS	NS	NS

[a] No chemicals were selected as COPCs in the semi-confined aquifer.
[b] Wetlands surface materials include surface soil and sediment in the wetland area.
COPC - Contaminant of potential concern
DRO - Diesel range organics
GRO - Gasoline range organics
NS - Chemical not selected as a COPC in this media.
X – Chemical selected as a COPC in this media.

7.2.1 Conceptual Site Model (CSM)

A CSM describes the sources of contaminants at a site, their release and transfer through environmental media (e.g., soil and air), and the points and means by which human populations might contact the contaminants. The goal of the CSM is to provide an understanding of where the site-related contaminants are present and where they may be present in the future, in order that the populations that could encounter the contaminants can be identified. The populations and applicable exposure pathways can then be selected for quantitative evaluation of health risks. Exposure pathways may be complete but insignificant. Only complete and significant pathways of exposure will be quantitatively evaluated; however, insignificant pathways will be discussed qualitatively. Figure 7-1 illustrates the CSM under current and future land use conditions; Figure 7-2 graphically presents the CSM under current conditions; and Figure 7-3 graphically depicts future land use conditions.

A key requirement when developing a CSM is a determination of land use. Land use at the site currently consists of military and civilian workers engaged in running the secure listening post that is at the Facility. While this use is likely to continue, it is possible that under a future scenario the site could be developed for residential housing. Drinking water is currently obtained from Fort Richardson; however, groundwater at the site was evaluated as a potential untreated drinking water source under the current military land use and also under a hypothetical future residential scenario. Based on the CSM, complete and significant exposure pathways were selected for quantitative evaluation for three populations under the current land use: (1) civilian workers within the Facility, (2) military workers within the Facility, (3) construction workers involved in active subsurface disturbance. Three populations were selected for quantification under future land use conditions: (1) residents, (2) neighborhood children (ages 6 to 12 years) as recreational users or trespassers, and (3) construction workers were also selected for quantification under the future land use scenario. Note, construction worker exposure assumptions are not expected to differ under current or future conditions. Therefore, the evaluation of construction worker exposures under current conditions are also representative of exposures under future conditions.

It should be noted that a previous evaluation of Facility worker exposures to surface soil did not find risks above target health goals. Thus, this pathway was not re-evaluated in this risk assessment. The following pathways were evaluated for current exposure scenarios:

- Military personnel and civilian workers occupying Building 18224 exposed to volatile contaminants in indoor air moving from groundwater through the subsurface into the building (this building was over the most contaminated area of the groundwater plume; therefore, this building was selected for quantitative evaluation because risks would be highest in this area);
- Military personnel and civilian workers at the Facility using impacted groundwater as a drinking water source (groundwater in the unconfined aquifer is extremely unlikely to serve as a source of drinking water);
- Construction worker exposure to contaminants in surface and subsurface soils through incidental ingestion, inhalation of dusts, and dermal absorption from soil; and
- Construction worker exposure to contaminants in groundwater through inhalation of volatiles and dermal absorption of contaminants through the skin.

The following pathways were evaluated for future exposure scenarios:

- Future residents of the Site DP98 area exposed to contaminants in groundwater through incidental ingestion, dermal contact, and inhalation of groundwater vapors during use of groundwater by residents for domestic activities, including drinking, bathing, and cleaning. Note, the groundwater vapor intrusion pathway was not evaluated for the residential scenario. It is assumed that 50 percent of the concentrations of volatile chemicals in groundwater will volatilize into the home during domestic uses. Therefore, concentrations of volatile chemicals in indoor air from vapor intrusions are likely insignificant in comparison to indoor air concentrations from domestic use;

- Future residents of the site area exposed to contaminants in surface soil through incidental ingestion, dermal contact and inhalation of fugitive dusts and soil vapors;
- Neighborhood child exposures to wetland sediment through incidental ingestion, vapor inhalation, and dermal contact with sediment during recreational/trespass activities; and
- Neighborhood child exposures to wetland surface water through inhalation of vapors and dermal contact with surface water during recreational/trespass activities.
- Construction worker exposure to contaminants in surface and subsurface soils through incidental ingestion, inhalation of dusts, and dermal absorption from soil; and
- Construction worker exposure to contaminants in groundwater through inhalation of volatiles and dermal absorption of contaminants through the skin. Note, while identified as being quantitatively evaluated under future conditions, the exposure assumptions for construction workers are not expected to differ under current or future conditions. Thus, the results of the risk characterization for construction worker exposures under current conditions will be the same as those under future conditions.

7.2.2 Exposure Assumptions

The exposure assumptions define the magnitude, frequency, and duration of potentially exposed populations for each of the exposure pathways selected for quantitative evaluation. The information required to quantify exposure includes the daily intake or contact rates of environmental media (e.g., the amount of air inhaled in 8 hours), duration of exposure, and other population characteristics affecting exposure. These exposure factors are combined with the exposure point concentrations in Section 7.2.3 to calculate a chemical dose. In general, EPA (1991a and 1993) default factors were used in the evaluation of the onsite worker and future residents; and EPA's Soil Screening Guidance (EPA, 2001a) defaults were used in the evaluation of the construction worker exposure. General population survey information and site-specific weather conditions were used as the basis for the neighborhood child recreational scenario. A detailed description of the default and site-specific exposure factors used in the calculations, along with the rationale for their use in this risk assessment, is provided in Appendix H. Exposure factors were selected assuming reasonable maximum exposure (RME) conditions and central tendancy (CT) conditions as defined by EPA (EPA, 1991a, 1993). RME exposure factors are intended to estimate the upper percentile of an exposed population while CT factors represent more average, or typical population exposures.

7.2.3 Exposure Point Concentrations (EPC)

To calculate a cancer risk or a noncancer hazard, an estimate must be made of the contaminant concentration to which an individual may be exposed. According to EPA (EPA, 1992b, 1992), the concentration term at the exposure point should be an estimate of the average concentration to which an individual would be exposed over a significant part of a lifetime. Because of the uncertainty associated with estimating the true average concentration at a site, EPA recommends the use of the 95 percent upper confidence limit (UCL) of the arithmetic mean as the appropriate estimate of the average site concentration for the RME and CT scenarios (EPA, 1991a, 1992, 1993). At the 95 percent UCL, the probability of underestimating the true mean is less than 5 percent. The 95 percent UCL can address the uncertainties surrounding a distribution average due to limited sampling data. A detailed discussion of

the data used to calculate exposure point concentrations (EPCs) for each media is provided in Appendix H; and a complete listing of data used to calculate EPCs is presented in Attachment B of Appendix H. Table 7-2 summarizes the RME and CT EPCs used in this risk assessment. Figures 7-4 and 7-5 depict the sample locations within each exposure area that were used in the calculations.

7.3 Toxicity Assessment

The toxicity assessment evaluates the relationship between the dose of a chemical and the occurrence of toxic effects. Toxicity criteria for chemicals, which are based on this relationship, consider both carcinogenic and noncarcinogenic effects. Table 7-3 presents toxicity criteria used in this assessment. Attachment C of Appendix H contains discussions of the specific criteria and associated health effects for each COPC.

7.4 Risk Characterization

In the final step of this risk assessment, exposure information is combined with contaminant-specific toxicity information to estimate risks and hazards. Risk characterization is the summarizing step of a risk assessment (EPA, 1995; ADEC, 2000a). In the risk characterization, the toxicity values (references doses [RfDs] and slope factors [SFs]) are applied in conjunction with the concentrations of COPCs and dose or intake assumptions to estimate cancer risks and health hazards other than cancer.

Noncancer health hazards and cancer risks were calculated for RME and CT exposure conditions. RME hazard/risk estimates are based on the maximum exposure that is reasonably expected to occur at a site. Intake parameter values were selected so that the combination of all parameters resulted in an estimate of the RME for a particular exposure pathway. By design, the estimated RME is higher than that expected to be experienced by most of the exposed population. Hazards and risks are compared to ADEC and EPA target health goals. The target health goal for noncancer compounds is a hazard quotient (HQ) equal to or less than 1. The HQ is the ratio of the contaminant intake to contaminant specific RfDs. The target cumulative cancer risk level for ADEC is 1×10^{-5}, while EPA defines a potentially acceptable target risk range of 10^{-6} to 10^{-4}. In general, EPA considers sites with risks greater than 10^{-4} usually warrant some type of remedial action while risks less than this level may not require active remediation. However, whether or not a site warrants remediation is a risk management decision.

USEPA and ADEC risk assessment guidelines (USEPA, 1989; ADEC, 2000a) consider the additive effects associated with simultaneous exposure to several contaminants by specifying that all HQs initially be summed across exposure pathways and contaminants to estimate the total hazard index. This summation conservatively assumes that the toxic effects of all contaminants would be additive, or in other words, that all contaminants cause the same toxic effect and act by the same mechanism. Total RME and CT risks and hazard indices for each exposure scenario are summarized on Table 7-4. Note that cancer risks for the 0 to 6 year old age group are included in the child/adult evaluation and not evaluated separately. Appendix H provides the details of the risk characterization results. Contaminants with risks and/or hazards above ADEC's and EPA's target health goals were identified as contaminants of concern (COC). Table 7-5 summarizes the contaminants that were identified as COCs in groundwater for each exposure scenario. No contaminants were identified as COCs in any other media.

7.4.1 Current Land Use Risk Characterization Results

Summaries of RME and CT cumulative human health hazard and risk estimates and COCs identified for current land use scenarios are presented below.

7.4.1.1 Civilian Building Worker Scenario

Cumulative RME cancer risk for the civilian building worker scenario of 3×10^{-3} exceeded target health goals (Table 7-4). Risks from groundwater as a drinking water source alone resulted in a cancer risk of 3×10^{-3}, which is in excess of EPA's and ADEC's target health goals.

The noncancer hazard index for the civilian building worker scenario of 84 also exceeded target health goals (Table 7-4). Hazards from groundwater as a drinking water source alone resulted in a cumulative noncancer hazard index of 83 in excess of EPA's and ADEC's target health goals

Risks and hazards for the civilian building worker scenario were both overwhelmingly driven by the use of untreated groundwater as a drinking water source and TCE was the largest single contributor to site risks (true for all groundwater pathways). Five contaminants have individual risks or HQs that exceed ADEC's target health goals, and were identified as COCs in groundwater for civilian building workers: DRO, cis-1,2-DCE, TCE, tetrachloroethene, and vinyl chloride (Table 7-5). Therefore, the use of the unconfined aquifer as a drinking water source for civilian personnel would present some health concerns due primarily to TCE, but also the other 4 COCs. We note that TCE's toxicity criteria are provisional, not final, values and are currently undergoing external peer review by EPAs Integrated Risk Information System (IRIS). If the old toxicity criteria were used, risks and hazards from TCE could be less for this scenario and all others where TCE was selected as a COPC. However, four other chemicals besides TCE are also present at concentrations in groundwater that exceed some target health goals.

For civilian building workers, the indoor air risk of 4 x 10^{-4} is driven almost entirely by TCE concentrations, suggesting that under current land use conditions, some health concerns may exist for civilian personnel inhaling TCE vapors in indoor air. No COPCs were found at levels where the HQ exceeded 1.

7.4.1.2 Military Building Worker Scenario

The cumulative RME cancer risk for the military building worker scenario of 5 x 10^{-4} exceeded target health goals and is similar to that described above for civilian workers (Table 7-4). Risk for the drinking water scenario contributes 88 percent to total RME cancer risks. The RME tap water cancer risk of 4 x 10^{-4} exceeds both EPA's and ADEC's target health goals.

The noncancer hazard index for the military building worker scenario of 84 also exceeded target health goals and is similar to that described above for civilian workers (Table 7-4). Hazards for the drinking water scenario contribute 99 percent to the total hazard index. The hazard index of 83 exceeds both EPA's and ADEC's target health goals.

As with the civilian building worker, risks and hazards were overwhelmingly driven by the use of groundwater as a potable drinking water source. Four contaminants have individual risks or HQs that exceed ADEC's target health goals of 1 x 10^{-5} and 1, respectively, and were identified as COCs in groundwater for military building workers: DRO, cis-1,2-DCE, TCE, and tetrachloroethene (Table 7-5). In addition, the cumulative CT hazard index of 57 and cancer risk of 1 x 10^{-4} for this pathway also exceeded ADEC's target health goals. Therefore, the use of the unconfined aquifer as a drinking water source for military personnel would present health concerns due almost entirely to TCE.

Cumulative RME cancer risk from inhalation of volatile contaminants emanating from groundwater to indoor air is within EPA's target risk range of 10^{-6} to 10^{-4}, but the RME cancer risk for the military building worker of 6 x 10^{-5} exceed ADEC's target health goal of 1 x 10^{-5}. Cancer risks for this pathway were almost entirely driven by TCE, suggesting that under current land use conditions, health concerns may exist for military personnel inhaling TCE vapors in indoor air. No contaminants were detected at levels where the HQ exceeded 1.

7.4.1.3 Construction Worker Scenario

Cumulative cancer risk from the construction worker exposure to DRO and TCE in soil of 1 x 10^{-6} is below ADEC's and EPA's target health goals. The total RME cancer risk of 3 x 10^{-5} for construction worker exposures to groundwater exceeds EPA's risk level of 10^{-6} and ADEC's cumulative risk level of 1 x 10^{-5} (Table 7-4).

The noncancer hazard index for the construction worker exposure to DRO and TCE in soil of 0.07 is also below ADEC's and EPA's target health goals. The cumulative hazard index of 9 slightly exceeds the target health goal of 1 (Table 7-4).

Because both the cumulative cancer risk and the noncancer hazard index for the construction worker scenario are below ADEC's and EPA's target health goals, contaminants in soil are not a health concern for the construction worker. For groundwater, both the cumulative cancer risk and noncancer hazard index exceed EPA's and ADEC's target health goals; however, only one contaminant, TCE, evaluated in groundwater individually exceeded the target health goals. Therefore, TCE was identified as a COC in groundwater for the construction worker scenario (Table 7-5).

7.4.2 Future Land Use

As under current military and civilian land use conditions, TCE in groundwater is also the major contributor to site risks and hazards, under the future land use scenario. The RME cumulative hazard indices for the residential child and child/adult exposures to contaminants in soil and groundwater of 875 and 476, respectively, and the RME cumulative cancer risk from exposures to soil and groundwater of 6×10^{-2} is driven by the tap water pathway. RME risks and hazard indices for residential exposures to contaminants in soil were below ADEC's target health goals. Residential cancer risk from soil was 9×10^{-6}; and child and child/adult hazard indices were 0.2 and 0.05, respectively. Therefore, contaminants in soil were not a health concern for residents and no contaminants were identified as COCs in soil. Both the total groundwater RME cancer risks and hazard indices greatly exceeded EPA's and ADEC's target health goals. The total RME cancer risk from groundwater was 6×10^{-2}. Total RME child and child/adult noncancer hazard indices were 875 and 476, respectively. Eleven contaminants were identified as COCs because of individual cancer risks and/or individual hazard indices above ADEC's target health goals of 1×10^{-5} and 1, respectively: GRO (only the aromatic portion), DRO, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene, cis-1,2-dichloroethene, ethylbenzene, naphthalene, tetrachloroethene, trichloroethene and vinyl chloride. While these 11 contaminants all had cancer risks and/or hazards greater than ADEC's target health goals, total risks and hazards are driven by TCE. Ninety-seven percent of the total cancer risks are due to TCE, 80 percent of which are due to inhalation exposures. Likewise, TCE is the greatest contributor to noncancer hazards contributing 50 percent to total RME hazards.

The RME cumulative cancer risk and noncancer hazard index for recreational exposures to contaminants in wetland sediment and surface water of 8×10^{-7} and 0.02 are below both EPA's and ADEC's target health goals. Therefore, no contaminants in either wetland sediment or surface water were found to be a significant health concern for the neighborhood recreational scenario, and no contaminants were identified as COCs in either medium.

7.4.3 Risk Characterization Summary

Table 7-5 summarizes the contaminants that were identified as COCs in groundwater for each exposure scenario. In conclusion, under current land use conditions, use of the unconfined aquifer as a drinking water source would result in risks and hazards that exceed target health goals, with exceedances primarily due to elevated concentrations of TCE, DRO, cis-1,2-DCE, and tetrachloroethene. Drinking water for the site is currently obtained from Fort Richardson. Indoor air exposures resulting from vapors emanating from groundwater under current conditions, for both civilian and military Building 18224 occupants could present some potential health concerns due primarily to elevated concentrations of TCE. Construction worker exposures to contaminants in groundwater could present some health concerns, due primarily to dermal contact with TCE in groundwater. Construction worker exposures to contaminants in soil are unlikely to present health concerns.

Table 7-2

Summary of Exposure Point Concentrations[a]

Contaminant of Potential Concern	Building Worker[b] (Vapor Intrusion Pathway)		Building Worker[a] (Tap Water Ingestion)		Construction Worker (Direct Contact)		Hypothetical Future Resident (Direct Contact)			Hypothetical Future Neighborhood Child (Direct Contact)	
			Groundwater		Groundwater	Soil	Groundwater		Surface Soil	Surface Water	Surface Materials
	Groundwater RME and CT (µg/L)	Indoor Air[c] RME and CT ($\mu g/m^3$)	RME (µg/L)	CT (µg/L)	RME and CT (µg/L)	RME and CT (mg/kg)	RME (µg/L)	CT (µg/L)	RME and CT (mg/kg)	RME and CT (µg/L)	RME and CT (mg/kg)
GRO (C6-C8 aliphatics)	1038.7	2215	1038.7	736.7	736.7	[g]	1038.7	736.7	[g]	[g]	[g]
GRO (C6-C8 aromatics)	1038.7	28	1038.7	736.7	736.7	[g]	1038.7	736.7	[g]	[g]	[g]
DRO (C9-C24 aliphatics)	117467.4	[d]	117467.4	84619.7	84619.7	1006.8	117467.4	84619.7	725.2	[g]	1924.7
DRO (C9-C24 aromatics)	43487.6	[d]	43487.6	29859.4	29859.4	355.9	43487.6	29859.4	242.1	[g]	695.9
1,2,4-Trimethylbenzene	184.2	[e]	184.2	121.9	121.9	[g]	184.2	121.9	[g]	[g]	[g]
1,3,5-Trimethylbenzene	63.5	[e]	63.5	40.5	40.5	[g]	63.5	40.5	[g]	[g]	[g]
Benzene	34.7	0.29	34.7	23.05	23.05	[g]	34.7	23.05	[g]	[g]	[g]
Benzo(a)pyrene	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	0.029[f]	[g]
Chloroform	2.34	0.02	2.34	1.77	1.77	[g]	2.34	1.77	[g]	[g]	0.49[f]
Chloromethane	4.56	[e]	4.56	3.14	3.14	[g]	4.56	3.14	[g]	[g]	[g]
cis-1,2-Dichloroethene	2567	14.6	2567	1829.9	1829.9	[g]	2567	1829.9	[g]	34[f]	[g]
Dibenzo(a,h)anthracene	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	0.02[f]	[g]
Indeno(1,2,3-cd)pyrene	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	[g]	0.12[f]	[g]
Lindane	0.13[f]	[d]	0.13[f]	0.05	0.05	[g]	0.13[f]	0.05	[g]	[g]	[g]
Methylene chloride	40.7	0.16	40.7	27.3	27.3	[g]	40.7	27.3	[g]	[g]	[g]
Naphthalene	335	0.12	335	227.7	227.7	[g]	335.0	227.7	[g]	[g]	[g]
Tetrachloroethene	1178.5	24.3	1178.5	854.3	854.3	[g]	1178.5	854.3	[g]	[g]	[g]
trans-1,2-Dichloroethene	15.3	0.21	15.3	10.44	10.44	[g]	15.3	10.44	[g]	[g]	[g]
Trichloroethene	1748.2	23.8	1748.2	1167.8	1167.8	0.688	1748.2	1167.8	0.45	8.9[f]	0.13[f]
Vinyl chloride	6.2	0.38	6.2	4.33	4.33	[g]	6.2	4.33	[g]	[g]	[g]
Xylene	108.3	0.85	108.3	72.6	72.6	[g]	108.3	72.6	[g]	[g]	[g]
Ethylbenzene	59	0.50	59	40.5	40.5	[g]	59	40.5	[g]	[g]	[g]

[a] All RME and CT exposure point concentrations (EPCs) are 95 percent upper confidence limits (UCL95) of the data set, unless otherwise marked

[b] Building worker EPCs apply to both military and civilian personnel.

[c] The building worker groundwater EPCs were used in the Johnson-Ettinger Model for Subsurface Vapor Intrusion to estimate indoor air concentrations.

[d] This chemical is not volatile; therefore the indoor air pathway is incomplete for this chemical.

[e] Indoor air concentrations could not be estimated for these chemicals because the chemical properties needed for the Johnson and Ettinger model are not available.

[f] This data set contained fewer than 10 samples. Therefore, a UCL95 could not be calculated and the maximum detected concentration was used as the EPC.

[g] This chemical was not selected as a COPC in this media.

CT - Central tendency
DRO - Diesel range organics
GRO - Gasoline range organics
RRO - Residual range organics
RME - Reasonable maximum exposure
$\mu g/m^3$ - Microgram of chemical per cubic meter of air
µg/L - Microgram of chemical per liter of water

Table 7-3

Toxicity Criteria for Concentrations of Potential Concern at Site DP98

Chemical	Cancer: Slope Factor (mg/kg-day)$^{-1}$	Noncancer: Reference Dose (mg/kg-day)	Toxicity Endpoint	Uncertainty Factor/Level of Confidence[a]	Reference
Benzo(a)pyrene	7.3 (oral/inhalation) EPA Group B2 carcinogen[b]	None	Tumors in mice	None	EPA 2002a
Indeno(1,2,3-cd)pyrene	0.73 (oral/inhalation) EPA Group B2 carcinogen[b]	None	Tumors in mice	None	EPA 2002b
cis-1,2-Dichloroethene	None EPA Group D carcinogen[b]	0.01 (oral/inhalation)	Rat hemoglobin production	3,000	USEPA 1997
trans-1,2-Dichloroethene	None EPA Group D carcinogen[b]	0.02 (oral/inhalation)	Increased serum alkaline phosphates in mice	1,000	EPA 2002a
1,2,4-Trimethylbenzene	None EPA Group D carcinogen[b]	0.05 (oral) 0.0017 (inhalation)	Not available[c]	None	EPA 2002b
1,3,5-Trimethylbenzene	None EPA Group D carcinogen[b]	0.05 (oral) 0.0017 (inhalation)	Not available[c]	None	EPA 2002b
Benzene	0.0055 (oral) 0.029 (inhalation) EPA Group A carcinogen[b]	0.003 (oral) 0.0017 (inhalation)	Leukemia (cancer)	None	EPA 2002a (SF); EPA 2002b (RfDs)
Ethylbenzene	0.00385 (inhalation) EPA Group B2 carcinogen[b]	0.1 (oral) 0.29 (inhalation)	Kidney tumors (SF) Liver & kidney toxicity (RfD-oral) Developmental toxicity (RfD-inhalation)	1000/low (oral) 300/low (inhalation)	EPA 1999 (SF) EPA 2002b (RfDs)
Dibenzo(a,h)anthracene	7.3 (oral/inhalation) EPA Group B2 carcinogen[b]	None	Carcinomas in mice.	None	EPA 2002b
Chloroform	0.0061 (oral) 0.081 (inhalation) EPA Group B2 carcinogen[b]	0.01 (oral) 0.00086 (inhalation)	Beagle dog cyst formation in liver	1,000	EPA 2002a
Chloromethane	0.013 (oral) 0.0063 (inhalation) EPA Group D carcinogen[b]	0.086 (inhalation)	Not available[c] (SF) CNS, liver and kidney toxicity (RfD-inhalation)	None	EPA 2002b
DRO aliphatics	None	0.1 (oral) 0.29 (inhalation)	Hepatic and hematological changes	None	ADEC 2000b

Table 7-3 (Continued)

Chemical	Cancer: Slope Factor (mg/kg-day)$^{-1}$	Noncancer: Reference Dose (mg/kg-day)	Toxicity Endpoint	Uncertainty Factor/Level of Confidence[a]	Reference
DRO aromatics	None	0.04 (oral) 0.06 (inhalation)	Decreased body weight	None	ADEC 2000b
GRO aliphatic	None	5.0 (oral) 5.3 (inhalation)	Neurotoxicity	None	ADEC 2000b
GRO aromatics	None	0.2 (oral) 0.11 (inhalation)	Hepatotoxicity and nephrotoxicity	None	ADEC 2000b
Lindane	1.3 (oral/inhalation)	0.0003 (oral/inhalation)	Liver and kidney toxicity	1,000	EPA 2002a
Methylene chloride	0.0075 (oral) 0.0016 (inhalation)	0.06 (oral) 0.86 (inhalation)	Liver toxicity	100/medium (oral)	EPA 2002a
Naphthalene	None EPA Group D carcinogen[b]	0.02 (oral) 0.00086 (inhalation)	Decreased body weight (oral) Nasal effects (inhalation)	3,000/low (oral) 3,000/medium (inhalation)	EPA 2002a
Tetrachloroethene	0.052 (oral) 0.01 (inhalation)	0.01 (oral) 0.17 (inhalation)	Liver toxicity in mice	1,000/Medium confidence	EPA 1998
Trichloroethene	0.4 (oral) 0.4 (inhalation) EPA Group B1 carcinogen[b]	0.0003 (oral) 0.01 (Inhalation)	CNS, liver & endocrine (RfD) Kidney (SF)	None	EPA 2001b
Vinyl chloride (Adult)	0.75 (oral) 0.016 (inhalation) EPA Group A carcinogen[b]	0.003 (oral) 0.029 (inhalation)	Liver toxicity in rats (RfD) Liver cancer in rats (SF)	30/Medium confidence	EPA 2002a
Xylenes	None EPA Group D carcinogen[b]	0.7 (oral) 0.29 (inhalation)	Hyperactivity, decreased body weight, and increased mortality	100/medium	EPA 2002c

[a] Applies only to reference doses.

[b] EPA's Weight-of-Evidence Classification System:

Group A - Human carcinogen (sufficient evidence in humans)
Group B1 - Probable human carcinogen (limited human data available)
Group B2 - Probable human carcinogen (sufficient evidence in animals, inadequate or no evidence in humans)
Group C - Possible human carcinogen (limited evidence in animals)
Group D - Not classifiable as to human carcinogenicity

[c] Toxic effects of these chemicals are unknown.

mg/kg-day - Milligram per kilogram per day
RfD - Reference dose
SF - Slope factor

Table 7-4

Summary of RME and CT Cumulative Human Health Hazard/Risk Estimates for Each Exposure Scenario

Land Use Scenario	Exposure Scenario	Exposure Population	Exposure Medium	Total Hazard/Risk	
				Hazard Index	Cancer Risk
Reasonable Maximum Exposure					
Current	Civilian Building Worker	Adult	Tap Water	**83**	**3E-03**
			Indoor Air (GW)	0.5	**4E-04**
			Total	**84**	**3E-03**
	Military Building Worker	Adult	Tap Water	**83**	**4E-04**
			Indoor Air (GW)	0.5	**6E-05**
			Total	**84**	**5E-04**
	Construction Worker	Adult	Surface/Subsurface Soil	0.07	1E-06
			Groundwater	**9**	**3E-05**
			Total	**9**	**3E-05**
Future	Resident	Child (age 0-6 years)	Tap Water	**875**	NE
			Surface Soil	0.2	NE
			Total	**875**	NE
		Child/Adult (age 0-70 years)	Tap Water	**476**	**6E-02**
			Surface Soil	0.05	9E-06
			Total	**476**	**6E-02**
	Neighborhood Recreational Child	Elementary Aged Child (age 6-12 years)	Wetland Surface Materials	0.01	6E-08
			Wetland Surface Water	0.007	8E-07
			Total	0.02	8E-07
Central Tendency					
Current	Civilian Building Worker	Adult	Tap Water	**50**	**4E-04**
			Indoor Air (GW)	0.4	**7E-05**
			Total	**50**	**5E-04**
	Military Building Worker	Adult	Tap Water	**57**	**1E-04**
			Indoor Air (GW)	0.5	**3E-05**
			Total	**57**	**2E-04**
	Construction Worker	Adult	Surface/Subsurface Soil	0.03	6E-07
			Groundwater	**6**	2E-05
			Total	**6**	2E-05
Future	Resident	Child (age 0-6 years)	Tap Water	**346**	NE
			Surface Soil	0.07	NE
			Total	**346**	NE
		Child/Adult (age 0-70 years)	Tap Water	**168**	**6E-03**
			Surface Soil	0.03	2E-06
			Total	**168**	**6E-03**
	Neighborhood Recreational Child	Elementary Aged Child (age 6-12 years)	Wetland Surface Materials	0.006	9E-09
			Wetland Surface Water	0.003	2E-07
			Total	0.009	2E-07

Risks and hazards that exceed target health goals are bolded.
CT - Central tendency
NE - Not evaluated. Cancer risks are not evaluated separately for the 0 to 6 year old age group, but are included in the child/adult evaluation.
RME - Reasonable maximum exposure
GW – Groundwater

Under future land use conditions, use of the unconfined aquifer as a drinking water source also would result in risks and hazards in excess of target health goals, due to elevated contaminant concentrations, particularly of TCE, tetrachloroethene, naphthalene, and cis-1,2-dichloroethene and vinyl chloride. Residential exposures to site surface soils are not likely to present health concerns. Neighborhood recreational exposures to contaminants in wetland surface water and sediment are not likely to present health concerns.

We note that the chemical contributing the majority of the risks and hazards in groundwater, TCE, has toxicity criteria that are proposed, not final, values. TCE's criteria are currently undergoing external peer review. If the previous, less stringent toxicity criteria were applied, risks and hazards from TCE could be less wherever TCE was evaluated. However, concentrations of other chemicals in groundwater would still exceed ADEC and some EPA target health goals for all drinking water scenarios. Where estimated risks and hazards were closer to target health goals, (i.e., the indoor air and construction worker scenarios), use of the older TCE toxicity criteria could result in estimated risks and hazards for the applicable exposure pathways consistent with or within EPA or ADEC target health goals.

Table 7-5

Summary of Contaminants Identified as Contaminants of Concern (COCs) in Groundwater for Each Exposure Scenario

	Current Conditions			Future Conditions
Chemical	**Building Worker Indoor Air**	**Building Worker Tap Water**	**Construction Worker**	**Residential Tap Water**
GRO				x
DRO		x		x
1,2,4-Trimethylbenzene				x
1,3,5-Trimethylbenzene				x
Benzene				x
Cis-1,2-Dichloroethene		x		x
Ethylbenzene				x
Naphthalene				x
Tetrachloroethene		x		x
Trichloroethene	x	x	x	x
Vinyl chloride		x		x

7.5 Summary of Uncertainties in Risk Assessment

An evaluation of the uncertainties in risk assessment is required by state and federal regulations. Every aspect of a risk assessment contains multiple sources of uncertainty. Simplifying assumptions are often made so that health risks can be estimated quantitatively. Because the exact amount of uncertainty cannot be quantified, the risk assessment is intended to overestimate rather than underestimate probable risk. The results of this assessment are therefore likely to be protective of health despite the inherent uncertainties in the process.

The major areas of uncertainties in this assessment that could potentially affect the results of the risk characterization are summarized below. These areas of uncertainty should be considered when making risk management decisions.

- **Toxicity values for petroleum compounds.** DRO was identified as a COC for the drinking water pathway and is the highest contributor to total drinking water hazards. There are currently no toxicity criteria that represent exposures to the whole mixtures of the petroleum groups. Rather, the toxic effects from exposure to petroleum compounds are quantified based on the toxicity of surrogate compounds that best represent the composition of the fuel fraction. Therefore, there is a large degree of uncertainty surrounding hazard estimates.

- **Toxicity values for TCE.** TCE was identified as a COC in both soil and groundwater and is responsible for the majority of cancer risks at the site. The toxicity criteria used to quantify exposures to TCE in this assessment are reported in EPA's *Trichloroethylene Health Risk Assessment: Synthesis and Characterization* (USEPA 2001c), which has been presented as an external review draft, and its findings are subject to change. These proposed toxicity criteria are significantly more health protective for cancer risks and for ingestion hazards than previous values. Although, even if TCE risks/hazards are overestimated because the toxicity criteria are overly protective, target health goals would still be exceeded for all drinking water scenarios if traditional older values for TCE were used in the risk assessment. However, indoor air risks/hazards under current building use conditions could be acceptable if the older values were used.
- **Subchronic toxicity criteria for construction worker exposures.** While the 1-year construction worker exposure duration evaluated in this assessment meets EPA's definition of subchronic exposures, chronic toxicity criteria were conservatively used to quantify construction worker hazards. Chronic criteria are designed to be protective over a lifetime of exposure. Thus, construction worker hazards are likely overestimated. Subchronic RfDs are not available for most compounds and, unlike chronic RfDs, have not gone through a peer review process to evaluate their applicability. The few available subchronic RfDs are either higher than or equal to chronic RfDs; thus, if subchronic RfDs were used, risks calculated for the construction scenario would be the same or even lower than the calculated values presented in this assessment.

Figure 7-4.

Figure 7-5.

[This page intentionally left blank.]

Section 8.0
ECOLOGICAL RISK ASSESSMENT

This section presents an abridged discussion of the findings of the ecological risk assessment (EcoRA) of Site DP98. The risk assessment described in this section is limited to the evaluation of risks associated with petroleum components and chlorinated solvents. By previous agreement with USEPA, risks from metals have not been evaluated in this EcoRA. An expanded discussion of the methodologies used and findings of this EcoRA is found in Appendix I of this RI report. The discussion in Appendix I provides elaboration about the habitats and species present at the site, presents detailed derivations of the toxicity reference values (TRVs) and risk-based screening concentrations (RBSCs) used, and provides additional aspects of the uncertainties associated with the identified risks.

The risk assessment procedures used follow current ADEC (ADEC, 2000), EPA (EPA, 1998, 1997a, 1997b), USAF (AFCEE, 1997), and Tri-Service (Wentsel et al., 1996) ecological risk assessment guidance. The general format of the EcoRA follows the ADEC (ADEC, 2000) format, which is consistent with EPA and DoD risk assessment guidance.

Under ADEC (ADEC, 2000) risk assessment guidance, the first stage of an ecological risk assessment at a site is to determine whether a detailed ecological risk assessment of that site is required. Before a decision can be made on the need for a detailed ecological risk assessment of a given site, a determination is made regarding the following:

- The presence of sensitive environments, critical habitats, or sensitive species at a site; and
- The presence of complete exposure pathways that result in the exposure of ecological receptors to site contaminants.

If it is determined that no sensitive environments, critical habitats, or sensitive species are present at a given site, and complete exposure pathways cannot be identified, ADEC (2000) guidance permits termination of the ecological risk assessment process for that site. If sensitive environments are present, and/or if complete exposure pathways are identified, the detailed ecological risk assessment process must continue with an ecological effects evaluation of onsite contaminants. Before this decision can be made, ADEC requires the development of an ecological CSM to define exposure pathways, if any, of ecological receptors to site contaminants.

The CSM illustrating the food web at the site (Figure 8-1) and a more detailed CSM (Figure 8-2), descriptions of the ecological setting, ecological receptors, and fate and transport of contaminants in soil, groundwater, surface water, and sediment at Site DP98, are presented in the problem formulation section of the ecological risk assessment.

8.1 Problem Formulation

This section describes the ecological setting of Site DP98, ecological receptors at the site, and the environmental fate and transport of site contaminants. These discussions culminate with the development of an ecological CSM (Figure 8-1), and completion of ADEC (ADEC, 2000) ecological checklists (Appendix I) that document the environmental setting of Site DP98. The problem formulation stage of the risk assessment concludes with ADEC Ecological Scientific/Management Decision Point #1 (SMDP #1): the decision as to whether or not a significant ecological threat may be posed to receptors by site contaminants. The outcome of the problem formulation stage of the ecological risk assessment is to either (1) proceed with the ecological effects evaluation portion of the risk assessment, or (2) to terminate the ecological risk assessment, depending on whether or not a potential ecological threat is identified.

Figure 8-1. Ecological Conceptual Site Model

Figure 8-2. Detailed Ecological Conceptual Site Model

[This page intentionally left blank.]

8.1.1 Ecological Setting of Site DP98

Site DP98 is located at a high-security communications facility situated in the northwestern portion of Elmendorf AFB, which is bordered on the south by the city of Anchorage, on the east by the U.S Army's Fort Richardson, and on the north and west by the Knik Arm of Cook Inlet. Figure 1-1 shows a general location map of Site DP98 as it relates to Elmendorf AFB, and Section 1.2 provides a description of Site DP98 and the Facility, including current and historical site uses.

The ecological setting of Site DP98 can be divided in the following four main areas:

- **The wooded area located north of the fence line** — covers approximately 15 percent of the site. This undeveloped woodland provides habitat to terrestrial species such as plants, soil invertebrates, amphibians, birds, and mammals.
- **The wetland located at the base of the slope north of the wooded area** — covers approximately 37 percent of the site. It provides habitat to aquatic invertebrates, macrophytes, amphibians, birds and mammals.
- **The ½-acre kettle pond located north of the wetland and three drainage rills extending from the slope north of the facility** — provides habitat to aquatic invertebrates, macrophytes, amphibians, birds, and mammals.
- **The developed portion of the site** — contains buildings, roads, parking areas, and some landscaped areas, providing little or no significant ecological habitat.

Two primary sources of contamination have been identified at Site DP98: (1) a drainage tile network associated with a former garage (Building 18224) and (2) two former USTs that formerly supplied generators in the vehicle maintenance garage. The drainage tile network can be linked to the majority of chlorinated solvents and a minor portion of the fuel compounds detected on the soil and groundwater. The main source of petroleum fuel contamination in the soil, surface water, and ground water is attributed to leakage from the former 3,000-gallon and 25,000-gallon diesel USTs. A secondary source for petroleum contamination is a former grease oil pit that overflowed into the drain tile network.

The environmental setting of Site DP98 has been summarized using the ADEC (ADEC, 2000) ecological checklists. The ecological checklists for the site are contained in Appendix I of this document.

Groundwater flow beneath the developed portion of the site is to the north-northwest towards the Knik Arm of the Cook Inlet. Onsite groundwater and runoff flow from the Facility down the slope towards the wetland, and the wetland discharges towards the northeast to the kettle pond. These flows are the primary means of contaminant transport from the source areas to portions of the site where ecological receptors may be exposed to contaminants.

8.1.2 Conclusion of the Preliminary (Screening-Level) Problem Formulation

Site DP98 has not been identified as containing federal or state sensitive environments. Nevertheless, the presence of National Wetlands Inventory (NWI) designated wetlands onsite may be construed by some as indication of the presence of a sensitive environment.

Several complete exposure pathways have been identified for the site. As shown in the CSM for Site DP98 (Figure 8-1), complete exposure pathways have been identified for terrestrial ecological receptors exposed to contaminants in surface soil and aquatic receptors exposed to site contaminants in surface water and sediments. All of these scenarios warrant a quantitative risk assessment.

Based on our assessment of the ecological characteristics of the site and potential exposure scenarios, we conclude that a potential ecological threat exists to ecological receptors from petroleum release products and chlorinated solvents contamination at Site DP98. This conclusion from ADEC

SMDP #1 was used to justify proceeding with an ecological effects evaluation of Site DP98. An ecological effects evaluation that quantitatively describes the potential ecological risk associated with exposure to site contaminants is presented in the following sections.

8.1.3 Target Ecological Receptors

Ecological risk assessments do not normally evaluate risks to all species present at a site. The large number of species present at most sites makes this impractical. Instead, one or more target ecological receptors are selected as representative species, and risks to the target receptors are evaluated.

With the exception of plants, which represent the primary producers at the site, all target ecological receptors are intended to be representative of a functional feeding group of animals present at the site. Each target receptor is exposed to site contaminants through a different combination of exposure pathways, primarily differences in diet. The terrestrial ecological receptors chosen for this assessment include terrestrial plants, terrestrial invertebrates, the dark eyed-junco (*Junco hyemalis* Linnaeus, an avian herbivore), the American robin (*Turdus migratorius*, an terrestrial avian invertivore), the common snipe (*Gallinago gallinago*, an invertivore which feeds primarily on aquatic macroinvertebrates), the meadow vole (*Microtus pennsylvanicus*, a mammalian herbivore), the masked shrew (*Sorex cinereus*, a mammalian invertivore), the least weasel (*Mustela nivalis*, a mammalian carnivore), and the wood frog (*Rana sylvatica*, the adult life stage of which is a terrestrial insectivore). Ecological relationships among these target receptors are illustrated in Figure 8-1. With the exception of the meadow vole, a replacement for the tundra vole (*Microtus oeconomus*) apparently not found on site, all target receptors have been identified by ADEC as appropriate default ecological receptors in the southcentral ecoregion of Alaska.

For surface water, all fresh water aquatic invertebrates resident in the water column, phytoplankton, and macrophytes have been selected as target ecological receptors for exposure to surface water contaminants. The tadpole life stage of the wood frog is also a target ecological receptor.

For sediment, rooted macrophytes and benthic invertebrates have been selected as the target ecological receptors exposed to contaminants in sediment.

8.1.4 Assessment Endpoints and Measures of Ecological Effects

Assessment endpoints are explicit expressions of environmental values to be protected (EPA, 1998). A measure of ecological effect is defined as a measurable ecological characteristic that is related to the valued characteristics selected as assessment endpoints (Suter et al., 2000). Ecological effect measures in this ecological risk assessment are measurable environmental concentrations of contaminants of potential ecological concern (COPECs) that can be related to the environmental values, which are to be protected. As discussed in more detail in Section 8.4, ecological effect measures describe the effects elicited by a COPEC, links the effects to the assessment endpoints, and evaluates how they change with changes in COPEC concentrations in the environment. The assessment endpoints, measures of ecological effect, and the linkage between the measures of effect and the assessment endpoints are presented in Table 8-1.

Table 8-1

Assessment Endpoints and Measures of Effect for the Ecological Risk Assessment of Site DP98

Assessment Endpoint	Measure of Effect	Linkage Between Measure of Effect and Assessment Endpoint
Survival, reproduction, and growth of terrestrial plants and soil macroinvertebrates	Comparison of measured COPEC concentrations in surface soil-to-soil RBSCs derived from toxicity studies of contaminants in soil with plants and soil invertebrates.	Benchmarks represent no observed adverse effect levels (NOAELs) for COPECs in soil to terrestrial plants and soil invertebrates.
Survival, reproduction, and growth of terrestrial avian herbivores	Comparison of measured COPEC concentrations in surface soil to soil RBSCs derived from ingested dose (dietary) benchmarks for wildlife.	Benchmarks represent NOAELs for COPECs in the diet of wildlife, where the combined concentration in surface soil and that bioaccumulated in forage plant species has no effect on wildlife receptors.
Survival, reproduction, and growth of terrestrial avian invertivores	Comparison of measured COPEC concentrations in surface soil to soil RBSCs derived from ingested dose (dietary) benchmarks for wildlife.	Benchmarks represent NOAELs for COPECs in the diet of wildlife, where the combined concentration in surface soil and that bioaccumulated in prey species has no effect on wildlife receptors.
Survival, reproduction, and growth of freshwater semi-aquatic avian invertivores	Comparison of measured COPEC concentrations in surface soil to soil RBSCs derived from ingested dose (dietary) benchmarks for wildlife.	Benchmarks represent NOAELs for COPECs in the diet of wildlife, where the combined concentration in surface soil and that bioaccumulated in prey species has no effect on wildlife receptors.
Survival, reproduction, and growth of mammalian herbivores	Comparison of measured COPEC concentrations in surface soil to soil RBSCs derived from ingested dose (dietary) benchmarks for wildlife.	Benchmarks represent NOAELs for COPECs in the diet of wildlife, where the combined concentration in surface soil and that bioaccumulated in forage plant species has no effect on wildlife receptors.
Survival, reproduction, and growth of terrestrial amphibian and mammalian invertivores	Comparison of measured COPEC concentrations in surface soil to soil RBSCs derived from ingested dose (dietary) benchmarks for wildlife.	Benchmarks represent NOAELs for COPECs in the diet of wildlife, where the combined concentration in surface soil and that bioaccumulated in prey species has no effect on wildlife receptors.

Table 8-1 (Continued)

Assessment Endpoint	Measure of Effect	Linkage Between Measure of Effect and Assessment Endpoint
Survival, reproduction, and growth of terrestrial mammalian carnivores	Comparison of measured COPEC concentrations in surface soil to soil RBSCs derived from ingested dose (dietary) benchmarks for wildlife.	Benchmarks represent NOAELs for COPECs in the diet of wildlife, where the combined concentration in surface soil and that bioaccumulated in prey species has no effect on wildlife receptors.
Survival, reproduction, and growth of phytoplankton, aquatic macrophytes, zooplankton and amphibians	Comparison of measured COPEC concentrations in surface water to protective water quality guidelines.	Water quality guidelines represent COPEC concentrations in surface water which adversely affect 5% or fewer of aquatic genera under chronic exposure conditions, or result in less than a 20% reduction in abundance of individual receptor populations.
Survival, reproduction, and growth of benthic macroinvertebrates	Comparison of measured COPEC concentrations in sediment-to-sediment quality guidelines protective of benthic biota.	Sediment quality guidelines represent COPEC concentrations in surficial sediments, which have no or minimal adverse effects on benthic species under chronic exposure conditions.

COPEC - Contaminants of potential ecological concern
RBSC - Risk-based screening concentrations

8.2 Data Evaluation

All available site-specific analytical data for soil, surface water, and sediment samples collected at Site DP98 were compiled and evaluated. The data set was reduced by the following strategy, which reduced the available data set for Site DP98 considerably:

- Groundwater samples were excluded because no exposure of ecological receptors to onsite groundwater was established during problem formulation. Groundwater that surfaces through sediment and enters surface water is considered sediment pore water, and is evaluated as part of the sediment.

- Samples were excluded where the reported contaminant concentration was below the lower limit of detection for a specified analytical method.

- Soil samples begun greater than 2 feet bgs were excluded because they are below the biologically active zone in soil, which precludes exposure of ecological receptors.

- Sediment samples begun greater than 10 cm below the water-sediment interface were excluded because they are below the biologically active zone in sediment, which precludes exposure of ecological receptors.

- Any samples collected and analyzed prior to 1 January 1997 were excluded as unrepresentative of current site conditions.

  Summary statistics were prepared for the remaining data set, including the following:

- Maximum detected concentration (MDC) for each contaminant in each medium;

- Minimum detected concentration for each contaminant in each medium;
- Number of detects for each contaminant in each medium;
- Mean detected concentration for each contaminant in each medium; and
- 95 percent upper confidence limit on the mean (95 percent UCL) for each contaminant in each medium.

These data are summarized in Appendix I of this report. Each of the MDCs were used in our preliminary risk screen to identify COPECs; 95 percent UCLs were used in our baseline risk characterization if a sufficient number of samples were available to permit the calculation of a 95 percent UCL and if the 95 percent UCL was smaller than the MDC.

This strategy reduced the available data set for the Site DP98 down to 12 soil samples, 10 freshwater sediment samples, and 11 fresh surface water samples. These data are summarized in Appendix I of this report.

8.3 Selection of Contaminants of Potential Ecological Concern

This section presents the results of a screening level ecological risk assessment of surface soils, fresh surface water, and freshwater sediment at or in the vicinity of Site DP98. The purpose of this section is to identify, using a hazard quotient approach, the combinations of complete exposure pathways to ecological receptors and site contaminant concentrations that potentially pose unacceptable ecological risks to receptors. Contaminants identified as having a potential to pose unacceptable ecological risks to one or more receptors are termed COPECs. Contaminants with a potential to pose risks were defined as chemicals with a hazard quotient greater than or equal to 1.0. Potential ecological risks from identified COPECs are evaluated in more detail in the baseline ecological risk characterization in Section 8.6.

Contaminants that are not identified as having a potential to pose unacceptable ecological risks to target receptors in this screening level ecological risk assessment will not be identified as COPECs. Contaminants not believed to have the potential to pose significant ecological risks will not be evaluated further during the baseline ecological risk characterization.

To maximize the likelihood that all detected contaminants with a potential to pose unacceptable ecological risks are retained for more detailed evaluation, the maximum detected concentration for each analyte was divided by a conservative risk-based screening concentration (RBSC) to derive the hazard quotient. The sources and derivations of the RBSCs are described in detail in Appendix I. A summary of the RBSC sources is as follows:

Soil – URS 1996c or Appendix I of this RI report

Surface water – USEPA 1999, USEPA 1991, MDEQ 2001 and URS 1996c

Sediment – URS 1996c

The results of the screening level ecological risk assessment to identify COPECs are presented in Table 8-2 for soil, Table 8-3 for fresh surface water, and Table 8-4 for freshwater sediment. A portion of URS (1996c) has been updated with recent information to derive the soil, surface water and sediment RBSCs for gasoline range organics (GRO), diesel range organics (DRO) and residual range organics (RRO). This portion of URS (1996c) has been incorporated into the toxicity assessment portion of Appendix I, specifically Sections I5.2.1 and I5.2.2 due to the length and detail of the RBSC derivations and their supporting tables.

No soil contaminants (Table 8-2), one surface water contaminant (DRO, Table 8-3) and four sediment contaminants (2-methylnaphthalene, fluorene, DRO and RRO, Table 8-4) were identified as COPECs. The five identified COPECs are passed forward for quantitative evaluation in the baseline risk assessment. One additional surface water contaminant (RRO) does not have an RBSC available, and is also considered a COPEC. Risks from contaminants without RBSCs cannot be quantitatively evaluated.

8.4 Analysis

The analysis phase of the ecological risk assessment process evaluates the two primary components of risk (exposure and effects) and their relationships to each other and ecological characteristics of a site. The products of the analysis phase are measures of exposure, which in this EcoRA are measured contaminant concentrations used to quantify the exposure of ecological receptors to site contaminants, and measures of effect, which describe dose-response relationships, examine causality, and discuss the relationship between measures of effect and assessment endpoints.

8.4.1 Measures of Exposure (Exposure Assessment)

To account for the spatial and temporal variation of contaminant concentrations at Site DP98, exposure point concentrations (EPCs) are defined for each COPEC. Exposure point concentrations in this ecological risk assessment are defined as the 95 percent UCL of the arithmetic mean COPEC concentration for contaminants, where a 95 percent UCL could be calculated (i.e., more than one detected value). Because the 95 percent UCL cannot be calculated for analytes with only one detected value, EPCs are defined as the maximum detected concentrations for those analytes. For contaminants whose calculated 95 percent UCL is greater than the arithmetic mean concentration, the maximum detected concentration was used as the EPC so as not to overstate any potential site risks.

Summary statistics and exposure point concentrations for the COPECs in all environmental media at Site DP98 are presented in Table 8-5. The values in the 95 percent UCL column of Table 8-5 are used as EPCs in the baseline ecological risk assessment.

The concentrations of nearly all COPECs in all environmental media (soil, surface water, and sediment) are highest in a small area at the base of the slope northwest of Building 18220, north and east of the Loop Road. Soil and surface water COPEC concentrations decline rapidly to the northeast of this small area of elevated contamination. Sediment concentrations appear to also decline to the northeast of the area of elevated contamination but at a slower rate than do soil and surface water values. The only exception to this pattern appears to be RRO, which is found at the highest concentrations in the wetlands due north of the site, and to the northeast of the locations with the highest concentrations of other COPECs.

8.4.2 Measures of Ecological Effect (Toxicity Assessment)

During the risk characterization portion of this ecological risk assessment, EPCs for COPECs are compared to the measures of adverse ecological effect described and developed in this section. Measures of ecological effect define concentrations of COPECs in environmental media that can result in adverse effects to ecological receptors. These concentrations are termed RBSCs in this risk assessment. RBSCs represent contaminant concentrations in environmental media that may pose unacceptable ecological risks to receptors if they are exposed to site contaminants at concentrations greater than or equal to the RBSC.

Soil screening RBSCs for PAHs, BTEX compounds, VOCs, DRO and RRO were developed using methods presented in URS (1996a, 1996b, 1996c), updated with more recent toxicological information.

Table 8-2

Results of the Screening Level Ecological Risk Assessment to Identify COPECs in Soil at Site DP98

Analyte	Detection Frequency	Minimum Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)	Detection Limits (mg/kg)	Background Concentration (mg/kg)	Risk-based Screening Concentration (mg/kg)	Hazard Quotient
cis-1,2-Dichloroethene	1/12	0.257	0.257	0.011	NA	306	0.00084
Benzo(a)pyrene	1/12	0.066	0.066	0.027	NA	6908	0.000010
Benzo(b)fluoranthene	1/12	0.434	0.434	0.068	NA	6908	0.000063
Chloroform	10/12	0.0276	0.49	0.012	NA	117	0.0042
Chrysene	1/12	0.598	0.598	0.05	NA	5272	0.00011
Fluoranthene	1/12	1.75	1.75	0.041	NA	2886	0.00061
Methylene chloride	1/12	0.018	0.018	0.018	NA	17.6	0.0010
Phenanthrene	1/12	1.15	1.15	0.061	NA	1816	0.00063
Pyrene	1/12	1.25	1.25	0.087	NA	2830	0.00044
Trichloroethene	3/12	0.021	0.127	0.012	NA	9.4	0.014
TPH – Diesel range organics	12/12	2.38	213.39	NA	NA	20,146	0.011
TPH – Gasoline range organics	4/12	0.24	2.1	0.13	NA	1840	0.0011
TPH – Residual range organics	12/12	0.36	1.5	NA	0.54	>1,000,000	<1.5E-06

hazard quotient - Maximum detected concentration/risk-based screening concentration
mg/kg - Milligram contaminant per kilogram of soil sampled
NA -Not available
NC - Not calculated (No risk-based screening concentration is available, so the contaminant is carried forward into the baseline risk characterization.)
ND - Not detected
TPH - Total petroleum hydrocarbon
Contaminants listed in bold typeface are the identified COPECs

Table 8-3

Results of the Screening-Level Ecological Risk Assessment to Identify COPECs in Fresh Surface Water at Site DP98

Analyte	Detection Frequency	Minimum Detected Concentration (µg/L)	Maximum Detected Concentration (µg/L)	Detection Limits (µg/L)	Background Concentration (µg/L)	Risk-based Screening Concentration (µg/L)	Hazard Quotient
1,1-Dichloroethane	1/10	0.24	0.24	0.091	NA	47	0.0051
cis-1,2-Dichloroethene	6/10	0.87	34	0.12	NA	590	0.058
trans-1,2-Dichloroethene	2/10	0.36	0.46	0.11	NA	590	0.00078
Acenaphthene	1/10	0.0046	0.0046	0.002	NA	6	0.00077
Acenaphthylene	2/10	0.0057	0.18	0.0018	NA	60	0.0030
Anthracene	5/10	0.0016	0.014	0.0011	NA	0.034	0.41
Benzo(a)anthracene	3/10	0.0021	0.022	0.0021	NA	2.2	0.010
Benzo(a)pyrene	3/10	0.003	0.029	0.0016	NA	0.96	0.030
Benzo(b)fluoranthene	3/10	0.0028	0.04	0.002	NA	0.68	0.059
Benzo(g,h,i)perylene	3/10	0.0076	0.041	0.0037	NA	0.44	0.093
Benzo(k)fluoranthene	3/10	0.002	0.019	0.0014	NA	0.64	0.30
Bromomethane	3/10	0.23	0.35	0.16	NA	11	0.032
Chloroform	2/10	0.1	0.12	0.096	NA	1240	0.00010
Chrysene	3/10	0.002	0.04	0.0013	NA	2.0	0.020
Dibenz(a,h)anthracene	3/10	0.0051	0.02	0.0017	NA	0.28	0.071
Fluoranthene	3/10	0.003	0.11	0.0024	NA	7.1	0.015
Fluorene	3/10	0.0058	0.02	0.0026	NA	12	0.0017
Indeno(1,2,3-cd)pyrene	3/10	0.007	0.118	0.0021	NA	0.28	0.42
Naphthalene	6/10	0.0034	0.0056	0.0034	NA	1.0	0.0056
Phenanthrene	4/10	0.0069	0.07	0.0032	NA	19.1	0.0037
Pyrene	5/10	0.0025	0.08	0.0023	NA	10.1	0.0079
Toluene	6/10	0.12	1.21	0.098	NA	3500	0.00035
Trichloroethene	3/10	0.17	8.9	0.12	NA	47	0.19
TPH – Diesel range organics (DRO)	**11/11**	**66**	**1,700**	**NA**	**NA**	**0.014**	**>120,000[a]**
TPH – Gasoline range organics (GRO)	1/11	16	16	14	NA	114	0.14
TPH – Residual range organics (RRO)	**11/11**	**150**	**3,263**	**NA**	**NA**	**NA**	**NC**

[a] DRO hazard quotient based on surface water concentrations which exceed maximum water concentration for which RBSC is applicable (i.e. the maximum water solubility of DRO is estimated to be approximately equal to the RBSC. The RBSC was designed to evaluate only risks from dissolved DRO, not from DRO concentrations which exceed its water solubility).

µg/L - Microgram per liter
hazard quotient - Maximum detected concentration/risk-based screening concentration
NA - Not available
NC - Not calculated (No risk-based screening concentration is available, so the contaminant is carried forward into the baseline risk characterization.)
TPH - Total petroleum hydrocarbon
Contaminants listed in bold typeface are the identified COPECs

Table 8-4

Results of the Screening-Level Ecological Risk Assessment to Identify COPECs in Freshwater Sediment at Site DP98

Analyte	Detection Frequency	Minimum Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)	Detection Limits (mg/kg)	Background Concentration (mg/kg)	Risk-based Screening Concentration (mg/kg)	Hazard Quotient
2-Methylnaphthalene	**1 /4**	**0.26**	**0.26**	**NA**	**NA**	**0.0202**	**13**
Acenaphthene	3/10	0.00088	0.041	0.00026	NA	0.15	0.27
Anthracene	3/10	0.00074	0.0075	0.00024	NA	0.085	0.088
Benzo(a)anthracene	3/10	0.00039	0.0049	0.00016	NA	1.1	0.0045
Benzo(a)pyrene	3/10	0.00052	0.0038	0.00017	NA	0.4	0.0095
Benzo(b)fluoranthene	5/10	0.00051	0.0033	0.00017	NA	2.3	0.0014
Benzo(g,h,i)perylene	5/10	0.00044	0.002	0.00013	NA	0.31	0.0065
Benzo(k)fluoranthene	4/10	0.00054	0.0028	0.00019	NA	2.3	0.0012
Chloroform	4/4	0.045	0.571	NA	NA	1.1	0.52
Chrysene	5/10	0.00065	0.0058	0.00019	NA	0.4	0.015
Dibenz(a,h)anthracene	2/10	0.00044	0.00048	0.00022	NA	0.06	0.0080
Fluoranthene	4/10	0.00055	0.0085	0.00021	NA	0.6	0.014
Fluorene	**3/10**	**0.0012**	**0.15**	**NA**	**NA**	**0.035**	**4.3**
Indeno(1,2,3-cd)pyrene	5/10	0.00036	0.0018	0.00019	NA	0.34	0.0053
Naphthalene	7/10	0.00052	0.21	0.00052	NA	0.99	0.21
Phenanthrene	6/10	0.00031	0.038	0.00031	NA	0.225	0.17
Pyrene	5/10	0.00056	0.016	0.00014	NA	0.35	0.046
TPH – Diesel range organics (DRO)	**10/10**	**7.6**	**12,000**	**NA**	**NA**	**90.6**	**132**
TPH – Gasoline range organics (GRO)	1/10	0.54	0.54	1	NA	12.2	0.044
TPH – Residual range organics (RRO)	**10/10**	**41**	**5,130.4**	**NA**	**NA**	**1,172**	**4.4**

mg/kg - Milligram contaminant per kilogram of soil sampled
hazard quotient - Maximum detected concentration/risk-based screening concentration
NA - Not available
TPH - Total petroleum hydrocarbon
Contaminants listed in bold typeface are the identified COPECs

Where possible, surface water RBSCs were taken from the ADEC freshwater aquatic life criteria listed on ADEC's Internet site. The most recent update of the site was listed as February 3, 2003. The updated criteria were adopted into Alaska's water quality standards on March 24, 2003. The ADEC aquatic life criteria are the only ecological ARARs available for surface water, sediment, or soil for the contaminants evaluated in this risk assessment. Most PAH surface water RBSCs were taken from draft water quality criteria prepared by USEPA (1999) as part of their draft sediment quality guidelines for PAH mixtures. The remaining PAH surface water RBSCs were taken from URS (1996c). Surface water RBSCs for VOCs were taken from the Oak Ridge National Laboratory compendium of toxicological benchmarks for aquatic biota (Suter and Tsao, 1996). Surface water RBSCs for DRO and RRO were derived using methods in URS (1996c). This derivation is presented in complete detail in Appendix I.

Sediment RBSCs for BTEX contaminants and PAH compounds were derived following procedures presented in guidance for evaluating sites at Naval Air Facility (NAF) Adak (URS, 1995). The guidelines used on Adak were derived from EPA ambient water quality criteria, Washington sediment management standards, and EPA (1993) equilibrium partitioning approaches to deriving sediment quality criteria. DRO and RRO sediment RBSCs were derived as per URS (1996c).

8.5 Risk Characterization

This section quantifies ecological risks to target ecological receptors from the COPECs identified in Section 8.3. This section combines the results of the measures of exposure (exposure assessment) and measures of ecological effects (toxicity assessment) to provide an estimate of ecological risks from contaminants in surface soil and freshwater sediment at Site DP98.

Hazard quotients less than one are indicative of environmental concentrations of COPECs that do not pose unacceptable levels of risk to ecological receptors. Hazard quotients greater than one are interpreted as indicating an unacceptable risk to ecological receptors, with the magnitude of the risk increasing as the hazard quotient increases. However, the magnitude of a hazard quotient that exceeds one cannot be directly related to the extent of an adverse effect on a given species for a given contaminant.

All risk calculation tables are presented in Appendix I.

8.5.1 Terrestrial Wildlife Risks From Contaminated Soil

The maximum detected concentration of all analyzed soil chemicals were below their respective RBSCs (Table 8-2). The conclusion of the screening level EcoRA presented in Section 8.3 concluded that no wildlife receptors were exposed to unacceptable levels of risk via the exposure to soil pathway.

8.5.2 Aquatic Biota Risks From Contaminated Surface Water

The following COPEC has a hazard quotient above 1.0 and was identified as a COC in this baseline ecological risk assessment:

- TPH – Diesel Range Organics (exceeds maximum water solubility by >60,000 times).

The only other surface water COC is TPH – residual range organics, for which a surface water RBSC is not available. As described in the uncertainty analysis, ecological risks from DRO and RRO are uncertain for two reasons: 1) A lack of analytical detail which precludes assurance that the detected concentrations are of petrogenic origin, or are naturally occurring organics from vegetation that are quantified as DRO and RRO, and 2) Presence of DRO and RRO in water at concentrations that exceed their maximum water solubility, a situation which the DRO in surface water RBSC is not designed to evaluate.

Table 8-5

Summary Statistics and Exposure Point Concentrations (EPC = 95%UCL) for COPECs at Site DP98 to Which Ecological Receptors Are Exposed

Analyte	Media	Units	Detection Frequency	Minimum Detected Concentration	Maximum Detected Concentration	Detection Limits	Background Concentration	95% UCL Concentration[a]
TPH – diesel-range organics (DRO)	Surface Water	µg/L	11/11	66	1,700	NA	NA	850
TPH – residual-range organics (RRO)	Surface Water	µg/L	11/11	150	3,263	NA	NA	1,170
2-Methylnaphthalene	Sediment	mg/kg	1 /4	0.26	0.26	NA	NA	0.26[a]
Fluorene	Sediment	mg/kg	3/10	0.0012	0.15	NA	NA	0.15[a]
TPH –DRO	Sediment	mg/kg	10/10	7.6	12,000	NA	NA	4,220
TPH – RRO	Sediment	mg/kg	10/10	41	5,130.4	NA	NA	2,530

mg/kg - Milligram per kilogram
ND - Not detected
µg/L - Microgram per liter
95% UCL -The 95% upper confidence limit of the arithmetic mean contaminant concentration
NA - Not available
a - Not calculated; the 95%UCL cannot be calculated for analytes with only one detected value, therefore the maximum detected value is reported in this column.

8.5.3 Benthic Biota Risks from Contaminated Freshwater Sediment

The EPC for DROs results in a hazard quotient of 47, the highest hazard quotient of any of the four identified sediment COCs. The only other sediment contaminant with a hazard quotient greater than 10 was the one detected concentration of 2-methylnaphthalene, with a hazard quotient of 13. The remaining two COCs all had hazard quotients less than 5.0.

The following sediment contaminants (with their associated hazard quotients) are the COCs identified in this baseline ecological risk assessment:

- TPH – Diesel Range Organics (HQ = 47);
- TPH – Residual Range Organics (HQ = 2.2);
- 2-Methylnaphthalene (HQ = 13); and
- Fluorene (HQ = 4.3).

8.6 Uncertainties Associated with the Ecological Risk Assessment

Limitations associated with any risk assessment have a number of components, including degree of success in meeting objectives, the range of conditions over which conclusions can be applied, and the certainty with which conclusions can be drawn. The conclusions of a risk assessment are useful only when they have been placed in perspective relative to the uncertainties associated with the evaluation.

Uncertainty in risk estimation has both qualitative and quantitative components. Where possible, quantitative uncertainty analyses provide objective measures of the relative confidence in conclusions and applications. Both qualitative and, in some cases, quantitative evaluations of uncertainty are presented in this section.

For practical purposes, uncertainty has two primary components: uncertainty and variability. True uncertainty is indicative of an area where risk assessors have a lack or absence of knowledge of an environmental parameter. Lack of knowledge of the ingested dose of a mixture of DRO that reduces survival of any species of bird is an uncertainty encountered in this risk assessment. Variability refers to observed differences attributable to heterogeneity or diversity in a population or exposure parameter. Differences in COPEC concentrations at different locations within a site are an example of variability. Statistical theory indicates that true variability of a parameter is fixed but that the estimate of variability can be improved by additional measurements or study.

From a risk management perspective, we believe the most important uncertainty in this EcoRA is the significance of the DRO and RRO risks in sediment. Analytical methods employed during the analysis of samples do not permit a determination of the source(s) of the detected DRO and RRO. The concentration gradient of RRO in particular does not appear to be related to leaks of diesel fuel from Site DP98, but may be consistent with patterns of biogenically produced organic matter which is quantified as DRO and RRO. If the source of the detected DRO and RRO in the wetlands is naturally produced organic matter from terrestrial vegetation, no remediation of the site due to petroleum contamination is warranted.

Some of the identified COPECs (e.g. 2-methylnaphthalene in sediment) are infrequently detected, not widely distributed at the site, have unknown bioavailability to receptors, have an unknown relationship with contaminant source materials at Site DP-98, and are of limited potential risk to mobile ecological receptors. Risks from infrequently detected chemicals are often overstated for animals with large home ranges.

[This page intentionally left blank.]

Section 9.0
IDENTIFICATION OF PRELIMINARY APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

This section presents a detailed identification of potential ARARs. All ARARs discussed in this section, and in this entire RI/FS, are preliminary ARARs. The development of ARARs is an iterative procedure during the remediation process at Site DP98 involving the USAF and the regulatory agencies. A final selection of ARARs will be made in the Record of Decision for this site.

An EE/CA was started at Site DP98 during the summer of 2000. Due to the level and extent of soil and groundwater contamination discovered at Site DP98, an agreement reached between the regulatory agencies and the USAF to address cleanup at this site was to transition into an RI/FS. Site DP98 was added 28 August 2002 to the Elmendorf Federal Facility Agreement. This RI/FS follows Environmental Restoration Program (ERP) and CERCLA guidance. As part of the RI/FS process, the preliminary ARARs identified during the 2001 EE/CA have been re-evaluated. The following paragraphs define the preliminary ARARs for Site DP98 based on definitions provided in 40 Code of Federal Regulations (CFR) 300.5.

- **Applicable requirements** are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental, or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.
- **Relevant and appropriate requirements** are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a site, address problems or situations sufficiently similar to those found at the CERCLA site that their use is well suited. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.

In addition, criteria, advisories, or guidance documents that do not meet the definition of ARARs, but may assist in determining what actions are necessary to be protective or otherwise useful in developing an appropriate action, are described as information "to be considered" (TBC). TBC criteria are to be used on an "as appropriate" basis and are intended to complement the use of ARARs, not to compete with ARARs. For example, many regulatory agencies issue guidance documents and advisories to assist in compliance with environmental laws and regulations. These guidelines are commonly used to determine cleanup requirements at contaminated sites where specific, enforceable laws or regulations are absent. Ecological and human health risk assessments are also commonly employed to help determine appropriate remedial actions.

The EPA classifies ARARs into three groups: chemical specific, action specific, and location specific. These groups are defined below:

- **Chemical specific** – Requirements that set concentration limits for an element or chemical compound in various environmental media such as ambient water, drinking water, ambient air, soil, or solid waste. These limits may include health or RBC limits or ranges in various environmental media for a specific hazardous substance or contaminant.

- **Location specific –** Requirements that apply based on the location of the site (e.g., in a coastal zone) or siting restrictions (e.g., industrial versus residential properties, native versus disturbed land).
- **Action specific –** Performance, design, or technical requirements applicable to remedial actions that may include the generation, transport, treatment, or disposal of regulated hazardous wastes or contaminated environmental media.

The preliminary chemical-specific, location-specific, and action-specific ARARs and TBCs considered in the RI/FS conducted for Site DP98 are explained in the following subsections.

9.1 Preliminary Chemical-Specific ARARs

Chemical-specific ARARs are typically health-based or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values. These values, in turn, establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the environment (soil, sediment, groundwater, surface water, or air) as a result of the remedial action. Tables containing chemical-specific preliminary ARARs and TBC criteria in Section 9 are limited to the analytical method classes that underwent evaluation at Site DP98 (petroleum hydrocarbons, VOCs, SVOCs, and metals in all media and pesticides and aroclors in groundwater only).

9.1.1 Soil

The following preliminary ARAR for soil at Site DP98 is listed below. A brief discussion of the preliminary applicability of the ARAR is also included.

State of Alaska Oil and Hazardous Substances Pollution Control Regulations, 18 AAC 75, Sections 340 and 341, dated 30 January, 2003: As applicable to Site DP98, this regulation provides guidance for discharge, reporting, cleanup, and disposal of hazardous substances. Due to the presence of petroleum hydrocarbons and additional chemicals such as chlorinated solvents at the site, Method Two of the regulation was selected as guidance for the establishment of preliminary cleanup levels for soils and sediment. As a result of site characteristics, including annual precipitation of less than 40 inches and an absence of continuous permafrost at Site DP98, the selected cleanup level category as described in the regulations is “Under 40-inch Precipitation Zone.” The regulations call for the most conservative pathway, “Migration to Groundwater,” to be used in establishing soil cleanup levels. Table 9-1 contains the selected Method Two regulatory criteria for 18 AAC 75. These are considered to be potentially applicable for the site.

9.1.2 Sediment

In the absence of numerical freshwater sediment criteria, freshwater sediment from the wetland and onsite drainage will be screened against the preliminary soil ARARs selected for Site DP98 (18 AAC 75.341 Method Two) until alternative regulatory criteria can be identified. The use of 18 AAC 75.341 Method Two (Table 2), migration to groundwater, is a preliminary ARAR for contaminated sediment.

9.1.3 Surface Water and Groundwater

ARARs for surface water and groundwater quality are addressed below.

- *State of Alaska Water Quality Standards*, 18 AAC 70, dated May 27, 1999: This regulation is potentially applicable to Site DP98 due to the presence of intermittent surface water ponding in low areas and the existence of a year-round pond downgradient of Site DP98. Surface water at Site DP98 is seasonal, access to the site is currently restricted, and no industrial or recreational activities occur in the area. Under current site use, the applicable water quality criteria are for ecological receptors under Class 1(C) (Fresh Water Use for the Growth and Propagation of Fish, Shellfish, and Other Aquatic Life and Wildlife). For a potential future residential scenario for

Site DP98, human exposure to surface water or groundwater at the site would also be anticipated. Table 9-2 summarizes these criteria for toxic substances and petroleum hydrocarbons as stated in 18 AAC 70 for the future residential scenario. Water Class 1 (A)(i) (Fresh Water Use for Drinking, Culinary, and Food Processing) within 18 AAC 70.020 cites the Alaska Drinking Water Standards (18 AAC 80) as the primary reference for human health. When drinking water standards do not exist, the EPA Quality Criteria for Water will be used.

- *State of Alaska Oil and Hazardous Substances Pollution Control Regulations,* 18 AAC 75, Section 345, dated January 30, 2003: This regulation is potentially applicable to Site DP98 under regulatory criteria 18 AAC 75.345, Table C. Under this provision, releases of contaminants to either surface water or groundwater must meet the requirements of this regulation. Unless demonstrated through an approved human health and ecological risk assessment performed under the requirements outlined in 18 AAC 75.340, groundwater that may potentially be used as a drinking water source or that is connected to surface water must meet the criteria contained in Table C of 18 AAC 75.345. For Site DP98, 18 AAC 75 is considered to be potentially applicable for both surface and groundwater. Table 9-3 provides ADEC groundwater regulatory criteria for contaminants addressed in Table C.

- *State of Alaska Drinking Water Regulations,* 18 AAC 80, Section 300(b), dated September 21, 2002: This regulation applies to public drinking water and sets the maximum contaminant levels (MCLs) allowable for water (surface water or groundwater) that is currently or potentially a drinking water source for humans. Though currently neither the surface water nor the groundwater at Site DP98 is used as a drinking water source, nor are they likely to become a drinking water source in the future, this regulation may be considered a potentially relevant and appropriate requirement. Table 9-4 presents federal MCLs and Alaska state drinking water regulatory criteria. Because 18 AAC 70 makes reference to 18 AAC 80.300(b) Drinking Water Regulations, 18 AAC 80.300(b) is included in Table 9-4 as compared to EPA's 40 CFR Part 141 primary MCLs.

- *National Recommended Ambient Water Quality Criteria*, 40 CFR Part 131, (April 1999): Developed under the Clean Water Act Section 304(a) to provide guidance to the states in adopting water quality standards, the regulation is potentially relevant and appropriate to Site DP98 because it establishes water quality criteria based on toxic effects on human health and the environment (aquatic life). This regulation would only be used for the establishment of ARARs based on the outcome of the ecological risk assessment.

- *Safe Drinking Water Act, National Primary Drinking Water Regulations*, 40 CFR Part 141, dated July 2002: This regulation is potentially relevant and appropriate to Site DP98 because it establishes standards for current and potential drinking water supplies by setting MCLs. For groundwater, 18 AAC 70 makes reference to two key ARARs pertaining to water quality regulatory criteria, including the National Primary Drinking Water Regulations (40 CFR 141). For comparison, Table 9-4 lists federal primary MCLs and maximum contaminant level goals (MCLGs) (40 CFR Part 141). By final rule effective 22 February 2002, EPA has lowered the MCL for arsenic from 0.05 to 0.01 mg/L (66 FR 7061). While community water systems have until 2006 January to comply with the new MCL for arsenic, the new MCL is potentially relevant and appropriate for ensuring that drinking water is protective of human health.

9.2 Preliminary Location-Specific ARARs

Location-specific ARARs are those requirements that relate to the geographic position or physical condition of the site. These requirements may limit the type of remedial action that can be implemented or may impose additional constraints on some remedial alternatives. Examples of locations include wetlands, flood plains, historic areas, native burial areas, and wildlife refuges. The preliminary location-specific ARARs and TBC criteria for Site DP98 are presented in Table 9-5.

9.3 Preliminary Action-Specific ARARs

Action-specific ARARs are technology-based or activity-based requirements that may be triggered by the particular remedial action chosen for Site DP98. 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 implemented. Table 9-6 presents preliminary action-specific ARARs for remediation activities being evaluated at Site DP98.

Table 9-1

ADEC 18 AAC 75.341 Method Two Soil Regulatory Criteria for Sites with Under 40 Inches[a] of Annual Precipitation

Analyte	ADEC Cleanup Level[b] (mg/kg)	Exposure Pathway[c]
Petroleum Hydrocarbons		
GRO	300	Migration to groundwater[d]
DRO	250	Migration to groundwater[d]
RRO	10,000	Ingestion[e]
Volatile Organic Compounds		
Benzene[f]	0.02	Migration to groundwater[d]
Bromodichloromethane	0.35	
Carbon tetrachloride	0.03	
Chlorobenzene	0.6	
Chloroform	0.34	
1,2-Dichlorobenzene	7	
1,4-Dichlorobenzene	0.8	
1,1-Dichloroethane	12	
1,2-Dichloroethane	0.015	
1,1-Dichloroethene	0.03	
cis-1,2-Dichloroethene	0.2	
trans-1,2-Dichloroethene	0.4	
1,2-Dichloropropane	0.017	
1,3-Dichloropropene	0.02	
Ethylbenzene[f]	5.5	
Hexachloro-1,3-butadiene	8	
Methylene chloride	0.015	
Styrene	1.3	

Table 9-1 (Continued)

1,1,2,2-Tetrachloroethane	0.017	
Tetrachloroethene	0.03	
Toluene[f]	5.4	
1,2,4-Trichlorobenzene	2	
1,1,1-Trichloroethane	1.0	
1,1,2-Trichloroethane	0.017	
Trichloroethylene	0.027	
Vinyl chloride (Chloroethene)	0.009	
Xylenes (total)[f]	78	
Polycyclic Aromatic Hydrocarbons		
Acenaphthene[f]	210	Migration to groundwater[d]
Anthracene[f]	4,300	
Benzo(a)anthracene[f]	6	
Benzo(b)fluoranthene[f]	11	Ingestion[e]
Benzo(k)fluoranthene[f]	110	
Benzo(a)pyrene[f]	1	
Chrysene[f]	620	Migration to groundwater[d]
Dibenzo(a,h)anthracene[f]	1	Ingestion[e]
Fluorene[f]	270	Migration to groundwater[d]
Indeno(1,2,3-c,d)pyrene [f]	11	Ingestion[e]
Naphthalene[f]	43	Migration to groundwater[d]
Pyrene[f]	1,500	
Metals		
Arsenic	2	Migration to groundwater[d]
Barium	1,100	
Cadmium	5	
Chromium (Total)	26	
Lead	400[g]	Ingestion[e]
Mercury	1.4	Migration to groundwater[d]
Selenium	3.5	
Silver	21	

[a] "Under 40-inch zone" means a site that receives mean annual precipitation of less than 40 inches each year.

[b] Data and selected footnotes for this table are taken from the ADEC 18 AAC 75.341 Method Two, Soil Cleanup Levels, Table B1 and B2 (ADEC, 2003).

[c] The most conservative soil cleanup standards between the ingestion, inhalation, and migration to groundwater pathways were used.

[d] "Migration to groundwater" means a potential exposure to hazardous substances in soil through direct ingestion of groundwater contaminated with concentrations of hazardous substances at levels listed in Table C at 18 AAC 75.345(b)(1) as a result of movement of hazardous substances through soil to the groundwater.

[e] "Ingestion" means a potential pathway of exposure to hazardous substances in soil through direct consumption of the soil.

[f] If using Method Two or Method Three, the applicable petroleum hydrocarbon cleanup levels must be met in addition to the applicable chemical-specific cleanup levels for benzene, toluene, ethylbenzene, and total xylenes; the chemical-specific cleanup levels for the polynuclear aromatic hydrocarbons acenaphthene, anthracene, benzo (a) anthracene, benzo (b) fluoranthene, benzo (k) fluoranthene, benzo (a) pyrene, chrysene, dibenzo (a, h) anthracene, fluorene, indeno (1,2,3-c, d) pyrene, naphthalene, and pyrene must also be met unless the department determines that those cleanup levels need not be met to protect human health, safety, and welfare, and the environment. (Eff. 1/22/99, Register 149).

[g] The cleanup level for lead must be determined on a site-specific basis, based on land use; for residential land use, that level is 400 mg/kg, and for commercial or industrial land use, that level is 1,000 mg/kg.

AAC – Alaska Administrative Code
ADEC – Alaska Department of Environmental Conservation
DRO – Diesel range organics
GRO – Gasoline range organics
mg/kg – Milligrams per kilogram
RRO – Residual range organics

Table 9-2

Potentially Applicable Water Quality Criteria (18 AAC 70) for Surface Water at Site DP98 Under Future Residential Scenario

1. Fresh Water Uses	Toxic and Other Deleterious Organic and Inorganic Substances	Petroleum Hydrocarbons, Oils, and Grease
(A) Water Supply (i) drinking, culinary, and food processing	Substances shall not exceed Alaska Drinking Water Standards (18 AAC 80) or, where those standards do not exist, EPA Quality Criteria for Water (See Note 1).	May not cause a visible sheen upon the surface of the water. May not exceed concentrations that individually or in combination impart odor or taste as determined by organoleptic tests.
(A) Water Supply (ii) agriculture, including irrigation and stock watering	Same as (1) (A) (i) where contact with a product destined for subsequent human consumption is present. Same as (1) (C) or FWPCA/WQC as applicable to substances for stock waters: concentrations for irrigation waters shall not exceed FWPCA/WQC or WQC 1972 (see Notes 2 and 3).	May not cause a visible sheen upon the surface of the water.
(A) Water Supply (iii) aquaculture	Individual substances may not exceed criteria in EPA Quality Criteria for Water (see Note 1) or, if those criteria do not exist, may not exceed the primary MCLs of the Alaska Drinking Water Standards (18 AAC 80). If those criteria are absent, or if the department finds that the criteria are not appropriate for sensitive resident Alaskan species, the department will, in its discretion, establish in regulation chronic and acute criteria to protect sensitive and biologically important life stages of resident Alaskan species, using methods approved by the department. There may be no concentrations of toxic substances in water or in shoreline or bottom sediments that, singly or in combination, cause, or reasonably can be expected to cause, toxic effects on aquatic life, except as authorized by this chapter. Substances may not be present in concentrations that individually or in combination impart undesirable odor or taste to fish or other aquatic organisms, as determined by either bioassay or organoleptic tests (see Note 1).	TAqH in the water column may not exceed 15 µg/L (see Note 4). TAH in the water column may not exceed 10 µg/L (see Note 4). There may be no concentrations of petroleum hydrocarbons, animal fats, or vegetable oils in shoreline or bottom sediments that cause deleterious effects to aquatic life. Surface waters and adjoining shorelines must be virtually free from floating oil, film, sheen, or discoloration.
(A) Water Supply (iv) industrial	Substances that pose hazards to worker contact may not be present.	Shall not make the water unfit or unsafe for the use.
(B) Water Recreation (i) contact recreation	Same as (1) (A) (i)	May not cause a film, sheen, or discoloration on the surface or floor of the water body or adjoining shorelines. Surface waters shall be virtually free from floating oils.
(B) Water Recreation (ii) secondary recreation	Substances that pose hazards to incidental human contact may not be present.	Same as (1) (B) (i).

Table 9-2 (Continued)

1. Fresh Water Uses	Toxic and Other Deleterious Organic and Inorganic Substances	Petroleum Hydrocarbons, Oils, and Grease
(C) Growth and Propagation of Fish, Shellfish, other Aquatic Life and Wildlife	Individual substances may not exceed criteria in EPA Quality Criteria for Water (see Note 1) or, if those criteria do not exist, may not exceed the primary MCLs of the Alaska Drinking Water Standards (18 AAC 80). If those criteria are absent, or if the department finds that the criteria are not appropriate for sensitive resident Alaskan species, the department will, in its discretion, establish in regulation chronic and acute criteria to protect sensitive and biologically important life stages of resident Alaskan species, using methods approved by the department. There may be no concentrations of toxic substances in water or in shoreline or bottom sediments that, singly or in combination, cause, or reasonably can be expected to cause, toxic effects on aquatic life, except as authorized by this chapter. Substances may not be present in concentrations that individually or in combination impart undesirable odor or taste to fish or other aquatic organisms, as determined by either bioassay or organoleptic tests (see Note 1).	TaqH in the water column may not exceed 15 µg/L (see Note 4). TAH in the water column may not exceed 10 µg/L (see Note 4). There may be no concentrations of petroleum hydrocarbons, animal fats, or vegetable oils in shoreline or bottom sediments that cause deleterious effects to aquatic life. Surface waters and adjoining shorelines must be virtually free from floating oil, film, sheen, or discoloration.

Notes:

1. The term "EPA Quality Criteria for Water" includes Quality Criteria for Water, July 1976, U.S. Environmental Protection Agency, Washington, D.C. 20460, U.S. Government Printing Office: 1977 0-222-904; The Ambient Water Quality Criteria for the 64 toxic pollutants listed in the Federal Register, Vol. 45, No. 231, pg. 79318, November 1980; the Ambient Water Quality Criteria Document for 2, 3, 7, 8-tetrachlorodibenzopdioxin (TCDD) listed in the Federal Register, Vol. 49, No. 32, pg. 5831, February 1984; and the final ambient water quality criteria documents listed in the Federal Register, Vol. 50, No. 145, pg. 30784, July 1985. These documents may be seen at the EPA Juneau office or may be purchased through the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161.
2. *The Report of the Committee on Water Quality Criteria,* Federal Water Pollution Control Administration, Washington, D.C., April 1, 1968, available from the Superintendent of Documents, United States Government Printing Office, Washington, D.C. This document is on file in the Lieutenant Governor's office and may be seen at the department offices in Anchorage, Fairbanks, and Juneau.
3. *Water Quality Criteria 1972*, Environmental Studies Board of the National Academy of Sciences and the National Academy of Engineering, Washington, D.C., 1972, EPA-R3-73-033, March 1973, is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20204 (Stock No. 5501-00520.) This document is on file in the Lieutenant Governor's office and may be seen at the department offices in Anchorage, Fairbanks, and Juneau.
4. Samples to determine concentrations of TAH and TaqH must be collected in marine and fresh waters below the surface and away from any observable sheen. Concentrations of TAqH must be determined and summed using a combination of (A) EPA Method 602 (plus xylenes) to quantify monoaromatic hydrocarbons and to measure TAH; and (B) EPA Method 610 to quantify polynuclear aromatic hydrocarbons. Use of an alternative method requires department approval. The EPA methods referred to in this note may be found in 40 CFR 136, Appendix A, as amended as of February 14, 1996, adopted by reference. They may be reviewed at the EPA or are available from the Office of Monitoring Systems and Quality Assurance, Office of Research and Development, EPA, Washington D.C., 20460.

AAC – Alaska Administrative Code
EPA – U.S. Environmental Protection Agency
FWPCA/WQC – Federal Water Pollution Control Administration, Water Quality Criteria
MCL – Maximum contaminant level
µg/L – Micrograms per liter
TAH – Total aromatic hydrocarbons
TaqH – Total aqueous hydrocarbons

Table 9-3

ADEC Groundwater Cleanup Levels (18 AAC 75.345 Table C)

Analyte	ADEC Cleanup Level[a] (mg/L)
Fuel Related Compounds	
GRO	1.3
DRO	1.5
RRO	1.1
Volatile Organic Compounds	
Benzene	0.005
Bromodichloromethane	0.1
Carbon tetrachloride	0.005
Chlorobenzene	0.1
Chloroform	0.1
1,2-Dichlorobenzene	0.6
1,4-Dichlorobenzene	0.075
1,1-Dichloroethane	3.65
1,2-Dichloroethane	0.005
1,1-Dichloroethylene	0.007
cis-1,2-Dichloroethylene	0.07
trans-1,2-Dichloroethylene	0.1
1,2-Dichloropropane	0.005
1,3-Dichloropropene	0.005
Ethylbenzene	0.7
Hexachloro-1,3-butadiene	0.01
Methylene chloride	0.005
Styrene	0.1
1,1,2,2-Tetrachloroethane	0.004
Tetrachloroethylene	0.005
Toluene	1.0
1,2,4-Trichlorobenzene	0.07
1,1,1-Trichloroethane	0.2
1,1,2-Trichloroethane	0.005
Trichloroethylene	0.005
Vinyl chloride (Chloroethene)	0.002
Xylenes (total)	10.0
Polycyclic Aromatic Hydrocarbons	
Acenaphthene	2.2
Anthracene	11.0
Benzo(a)anthracene	0.001
Benzo(b)fluoranthene	0.001
Benzo(k)fluoranthene	0.01
Benzo(a)pyrene	0.0002
Chrysene	0.1
Dibenzo(a,h)anthracene	0.0001
Fluorene	1.46
Indeno(1,2,3-c,d)pyrene	0.001

Table 9-3 (Continued)

Analyte	ADEC Cleanup Level[a] (mg/L)
Naphthalene	1.46
Pyrene	1.1
Pesticides and Arochlors	
4,4-DDD	0.0036
4,4-DDE	0.0025
4,4-DDT	0.0025
Aldrin	0.00005
alpha-BHC	0.0001
alpha-Chlordane	0.002
beta-BHC	0.00047
Dieldrin	0.00005
Endosulfan I	0.2
Endosulfan II	0.2
Endrin	0.002
gamma-Chlordane	0.002
Heptachlor	0.0004
Heptachlor epoxide	0.0002
Lindane	0.0002
Methoxychlor	0.04
Polychlorinated biphenyls (PCBs)	0.0005
Toxaphene	0.003
Inorganics	
Arsenic	0.05
Barium	2
Cadmium	0.005
Chromium (Total)	0.1
Lead	0.015
Mercury	0.002
Selenium	0.05
Silver	0.18

[a] Data for this table are taken from the ADEC Groundwater Cleanup Levels, Table C (ADEC, 2003).

ADEC – Alaska Department of Environmental Conservation
DRO – Diesel range organics
GRO – Gasoline range organics
mg/L – Milligrams per liter
RRO – Residual range organics

Table 9-4

Federal MCLs and Alaska State Drinking Water Regulatory Criteria[a]

Contaminants	National Primary MCLs [b] (mg/L)	National MCLGs [b] (mg/L)	Alaska Primary MCLs [c] (mg/L)	State Secondary MCLs [c] (mg/L)
Organic Constituents				
Benzene	0.005	0	0.005	--
Benzo(a)pyrene	0.0002	0	0.0002	--
Bromodichloromethane	0.08 [d, e]	0	--	--
Bromoform	0.08 [e]	0	--	--
Carbon tetrachloride	0.005	0	0.005	--
Chlordane	0.002	0	0.002	--
Chlorodibromomethane	0.08 [e]	0	--	--
Chloroform	0.08 [e]	0	--	--
Dibromochloropropane	0.0002	0	0.0002	--
1,2-Dichlorobenzene	0.6	0.6	0.6	--
1,3-Dichlorobenzene	0.6	0.6	--	--
1,4-Dichlorobenzene	0.075	0.075	0.075	--
1,2-Dichloroethane	0.005	0	0.005	--
1,1-Dichloroethene	0.007	0.007	0.007	--
cis-1,2-Dichloroethene	0.07	0.07	0.07	--
trans-1,2-Dichloroethene	0.1	0.1	0.1	--
1,2-Dichloropropane	0.005	0	0.005	--
Dichloromethane (methylene chloride)	0.005	0	0.005	--
Di(2-ethylhexyl)adipate	0.4	0.4	0.4	--
Di(2-ethylhexyl)phthalate	0.006	0	0.006	--
Endrin	0.002	0.002	0.002	--
Ethylbenzene	0.7	0.7	0.7	--
Heptachlor	0.0004	0	0.0004	--
Heptachlor epoxide	0.0002	0	0.0002	--
Hexachlorobenzene	0.001	0	0.001	--
Hexachlorobutadiene	-- [d]	-- [d]	--	--
Hexachlorocyclopentadiene	0.05	0.05	0.05	--
Lindane	0.0002	0.0002	0.0002	--
Methoxychlor	0.04	0.04	0.04	--
Monochlorobenzene	0.1	0.1	0.1	--
Pentachlorophenol	0.001	0	0.001	--
Polychlorinated biphenyls (PCBs)	0.0005	0	0.0005	--
Styrene	0.1	0.1	0.1	--
Tetrachloroethene	0.005	0	0.005	--
Toxaphene	0.003	0	0.003	--
Toluene	1	1	1	--
1,2,4-Trichlorobenzene	0.07	0.07	0.07	--
1,1,1-Trichloroethane	0.2	0.2	0.2	--
1,1,2-Trichloroethane	0.005	0.003	0.005	--

Table 9-4 (Continued)

Contaminants	National Primary MCLs [b] (mg/L)	National MCLGs [b] (mg/L)	Alaska Primary MCLs [c] (mg/L)	State Secondary MCLs [c] (mg/L)
Trichloroethene	0.005	0	0.005	--
Vinyl chloride	0.002	0	0.002	--
Xylenes (total)	10	10	10	--
Inorganic Constituents				
Antimony	0.006	0.006	0.006	--
Arsenic	0.01	0	0.05	--
Barium	2	2	2	--
Beryllium	0.004	0.004	0.004	--
Cadmium	0.005	0.005	0.005	--
Chloride	--	--	--	250
Chromium (total)	0.1	0.1	0.1	--
Copper	TT [f]	1.3	TT [g]	1.0
Cyanide	0.2	0.2	0.2	--
Fluoride	4.0	4.0	4.0	2.0
Iron	--	--	--	0.3
Lead	TT [f]	0	TT [g]	--
Manganese	--	--	--	0.05
Mercury	0.002	0.002	0.002	--
Nickel	--	--	0.1	--
Nitrate (as nitrogen)	10	10	10	--
Nitrite (as nitrogen)	1	1	1	--
Total nitrate and nitrite (as nitrogen)	10	10	10	--
pH	--	--	--	6.5 to 8.5
Selenium	0.05	0.05	0.05	--
Silver	--	--	--	0.1
Sodium	--	--	--	250
Sulfate	--	--	--	250
Total dissolved solids	--	--	--	500
Thallium	0.002	0.0005	0.002	--
Zinc	--	--	--	5

[a] Limited to analytical classes (petroleum hydrocarbons, VOCs, SVOCs, and inorganics) that were analyzed for groundwater during the 2001 EE/CA field investigation.

[b] From EPA Drinking Water Regulations and Health Advisories, Summer 2002.

[c] From 18 AAC 80.300.

[d] Under review.

[e] 1998 Final Rule for Disinfectants and Disinfection Byproducts: The total for trihalomethanes is 0.08 mg/L.

[f] Copper action level is 1.3 mg/L; lead action level 0.015 mg/L.

[g] Copper and lead primary MCLs are action levels 1.3 mg/L and 0.015 mg/L from 18 AAC 80.510. These action levels trigger requirements for a monitoring program and treatment techologies.

-- MCL or MCLG not specified.
AAC – Alaska Administrative Code
EPA – U. S. Environmental Protection Agency
MCLG – Maximum contaminant level goal
SVOC – Semi-volatile organic compound
VOC – Volatile organic compound
EE/CA – Engineering evaluation/cost analysis
MCL – Maximum contaminant level
mg/L – Milligrams per liter
TT – Treatment technology

Table 9-5

Potential Location-Specific ARARs and TBC Criteria for Site DP98

Standard, Requirement, Criterion, or Limitation	Criterion	Description	Potentially Applicable/ Relevant and Appropriate	Documentation
Solid Waste Disposal Act – 42 USC Section 6902-6987				
Location Standards for Hazardous Wastes Management Units	40 CFR 264.18	Prohibits or restricts siting of hazardous waste management units in certain sensitive areas (e.g., 100-year flood plain).	No/No	Hazardous waste management units are neither present nor proposed for Site DP98. Site DP98 is located outside a 100-year flood plain.
National Historic Preservation Act (NHPA) – 16 USC 470				
Accounting for Historic Places and Cultural Resources	36 CFR 800; 40 CFR 6.301(b); Executive Order 11593 National Register of Historic Places (36 CFR 60)	Federal agencies must identify possible effects of proposed remedial activities on historic properties (cultural resources). Historic sites or structures are those included on or eligible for the National Register of Historic Places, generally older than 50 years.	Yes/--	Site DP98 is not contained within list of Register of Historic Places. However, since DP98 was constructed in the early 1950s it may be eligible for listing on the National Register of Historic Places, which are generally older than 50 years.
Archeological and Historical Preservation Act – 16 USC 469 et seq.				
Preservation of Historical and Archeological Data	40 CFR 6.301(c)	Establishes procedures to provide for preservation of historical and archeological data that might be destroyed through alteration of terrain as the result of a federal construction project or a federally licensed activity or program.	Yes/--	Presence or absence of historical or archeological data on the site must be verified. If historical or archeological artifacts are present in remediation areas, the remedial actions must be designed to minimize adverse effects on the artifacts. If artifacts are encountered, work will stop immediately and the State Historic Preservation Office (SHPO) and local native tribes will be consulted.
Historic Sites, Building, and Antiquities Act – 16 USC 461-467				
Accounting for Natural Landmarks	40 CFR 6.301 (a) National Historic Landmarks Program (36 CFR Part 65)	If historic properties or landmarks eligible for, or included in, the National Register of Historic Places exist within remediation areas, remediation activities must be designed to minimize the effect on such properties or landmarks.	No/No	Site DP98 is not contained within the list of National Historic Landmarks.

Table 9-5 (Continued)

Standard, Requirement, Criterion, or Limitation	Criterion	Description	Potentially Applicable/ Relevant and Appropriate	Documentation
Archeological Resources Protection Act (ARPA) – 16 USC 470aa et. seq				
Protection of Archeological Resources	43 CFR 7	ARPA and implementing regulations prohibit the unauthorized disturbance of archeological resources on public and Indian lands.	Yes/--	ARPA and implementing regulations are potentially applicable for the conduct of any selected remedial actions that may result in ground disturbance. Presence or absence of archeological resources on the site is not known. If artifacts are encountered, work will stop immediately and the SHPO and local native tribes will be consulted.
Native American Graves Protection and Repatriation Act (NAGPRA) – 25 USC 3001 et seq.				
Protects Native American burial sites and funerary objects.	43 CFR 10	If Native American graves are discovered within remediation areas, project activities must cease and consultation must take place between the Department of Interior and the affected tribe.	Yes/--	This program is applicable to ground- disturbing activities such as soil grading and removal. Potentially applicable. Presence of Native American burial sites not identified. If burial sites or artifacts are encountered, work will stop immediately and the SHPO and local native tribes will be consulted.
American Indian Religious Freedom Act – 42 USC 1996 et seq.				
Native Sites	The statute has no implementing regulations; following the NAGPRA process should meet with the intent of the law.	Protects religious, ceremonial, and burial sites and the free practice of religions by Native American groups	Yes/--	Potentially applicable. This statute would apply to soil excavation in areas of the site. If sacred sites are discovered in the course of soil disturbances, work will be stopped and the local tribes will be contacted.

Table 9-5 (Continued)

Standard, Requirement, Criterion, or Limitation	Criterion	Description	Potentially Applicable/ Relevant and Appropriate	Documentation
Alaska Coastal Zone Management Act (CZMA) – AS 46.40				
Alaska Coastal Zone Management Program	6 AAC 80.130 (c)(3).	Requires that wetlands be managed to ensure adequate water flow, nutrients, and oxygen levels and to avoid adverse effects on natural drainage patterns, the destruction of important habitat, and the discharge of toxic substances.	No/No	Site DP98 and the wetland are near but not on Knik Arm and would not "directly affect" the coastal zone. However, any federal remedial action preformed at Site DP98 will comply with the applicable or relevant and appropriate provisions of the CZMA.
Fish and Wildlife Conservation Act – 16 USC 2901 et seq.				
Conservation of nongame fish and wildlife and their habitats	50 CFR 83	Provides the consideration of impacts on wetlands, protected habitats, and fisheries.	Yes/--	Because Site DP98 is situated in proximity to a wetland and because contaminants may be present within the wetland, this regulation is considered applicable.

AAC – Alaska Administrative Code
ARPA – Archeological Resources Protection Act
CFR – Code of Federal Regulations
CZMA – Coastal Zone Management Act
NAGPRA – Native American Graves Protection and Repatriation Act
USC – United States Code

Table 9-6

Potential Action-Specific ARARs and TBC Criteria for Site DP98

Standard, Requirement, Criterion, or Limitation	Criterion	Description	Potentially Applicable/ Relevant and Appropriate	Documentation
Solid Waste Disposal Act – 42 USC 6901-6987				
Criteria for Municipal Solid Waste Landfills (RCRA Subtitle D)	40 CFR 258	Nonhazardous solid waste criteria for municipal solid waste landfills.	No/Yes	Potentially relevant and appropriate if containment is selected as part of the remedial action.
Clean Water Act – 33 USC Section 1251-1376				
National Pollutant Discharge Elimination Requirements	40 CFR 122-125	Specifies requirements for point source discharge of stormwater from construction sites to surface water and provide for Best Management Practices such as erosion control for removal and management of sediments to prevent run-on and run-off.	No/Yes	Substantive requirements are potentially relevant and appropriate for discharges to Knik Arm.
	40 CFR 136	Establishes guidelines for test procedures for analysis of pollutants.	No/Yes	Guidelines are not applicable for demonstrating compliance with permits, but are potentially relevant and appropriate for monitoring activities.
National Pretreatment Standards	40 CFR 403	Provides limits for discharge to sanitary sewer systems, protecting municipal systems from accepting wastewater that would cause it to exceed its NPDES permit discharge limits.	Yes/--	Substantive requirements are potentially applicable for treatment and disposal of wastewater to sanitary sewer system.
Clean Air Act – 42 USC Section 7401				
National Primary Secondary Ambient Air Quality Standards	40 CFR 50	Establishes standards for ambient air quality to protect public health and welfare. Remedial actions must not result in exceedance of ambient air quality standards.	Yes/--	Emissions from the remediation process will be subject to the ambient air quality standards unless state standards are more stringent.

Table 9-6 (Continued)

Standard, Requirement, Criterion, or Limitation	Criterion	Description	Potentially Applicable/ Relevant and Appropriate	Documentation
Resource Conservation and Recovery Act (RCRA) – 42 USC Section 6901 et. seq.,				
RCRA Subtitle C: Hazardous Waste Management (Identification, Treatment, Storage, and Land Disposal)	40 CFR 261, 264, and 268	RCRA Subtitle C addresses the identification, treatment, storage, and land disposal of hazardous wastes. To the extent hazardous waste, as defined by RCRA, is removed from soil and/or extracted from the groundwater and to the extent air emissions result from treatment operations, the selected remedies will comply with the requirements of 40 CFR 264.	No/Yes	Potentially relevant and appropriate for remedial actions resulting in the generation of hazardous waste. Spent carbon from the carbon adsorption units and filter that may be used in conjunction with the selected remedies will be stored and disposed of or recycled at a RCRA approved facility in accordance with EPA policy for offsite disposal of CERCLA waste (40 CFR 300.440).
Clean Water Act – 33 USC Section 1344				
Clean Water Act, Section 404 – Dredge or Fill Requirements	33 CFR Parts 320-330; 40 CFR Part 230.	These requirements are applicable to work in or near navigable waters. They establish requirements that limit the discharge of dredged or fill material into navigable waters and associated wetlands. EPA guidelines for discharge of dredged or fill materials in 40 CFR Part 230 specify consideration of alternatives that have less adverse impacts and prohibit discharges that would result in exceedance of surface water quality standards, exceedance of toxic effluent standards, and jeopardy of threatened or endangered species. Special consideration required for "special aquatic sites" defined to include wetlands.	No/Yes	Under 33 CFR Part 330, the substantive requirements for a nationwide permit (i.e., placement of heavy equipment on mats) may be needed to be met for intrusive activities within the wetland at Site DP98.
Hazardous Materials Transportation Act – 49 USC 1801-1813				
Hazardous Materials Transportation Requirements	49 CFR 107, 171-177	Establishes requirements for transportation of hazardous materials.	Yes/--	Potentially applicable to remedial actions involving transport of hazardous materials off site.

Table 9-6 (Continued)

Standard, Requirement, Criterion, or Limitation	Criterion	Description	Potentially Applicable/ Relevant and Appropriate	Documentation
Safe Drinking Water Act – 42 USC 300				
Underground Injection Control Program	40 CFR 144-147	Provides for protection of underground sources of drinking water.	No/Yes	Substantive requirements are potentially relevant and appropriate to alternatives proposing reinjection of treated groundwater.
State of Alaska				
Alaska Solid Waste Management Regulations	18 AAC 60	Closure (18 AAC 60.395) and post closure requirements (18 AAC 60.397) for landfills.	No/Yes	This potential action-specific ARAR addresses only remedial actions involving containment. If containment was selected as part of the remedial action, then requirements for containment listed within 18 AAC 60 (e.g., liner thicknesses and material compatibility with petroleum hydrocarbons) would be considered relevant and appropriate. (For remedial actions not involving containment, the potential action-specific ARAR would not apply).
Alaska Air Quality Control Regulations	18 AAC 50.300 through 50.380	These sections include, by reference, other chapters and sections of 18 AAC 50 that specify chemical emissions, feed rates, and other operating parameters.	Yes/--	The substantive construction and operational requirements are potentially applicable for remedial actions involving air emissions of contaminants.
Alaska Water Quality Standards	18 AAC 70.20	Specifies separation distances from drinking water (18 AAC 72.015) and requirements for design reviews (18 AAC 72.225), stabilization ponds (lagoons) (18 AAC 72.260), and collection and pumping systems (18 AAC 72.275). They also govern temporary discharge of wastewater and sediments following dredging, gravity separation, and dewatering.	Yes/--	The substantive construction and operational requirements are potentially applicable for remedial actions involving pumping, treatment, and disposal of groundwater.

Table 9-6 (Continued)

Standard, Requirement, Criterion, or Limitation	Criterion	Description	Potentially Applicable/ Relevant and Appropriate	Documentation
State of Alaska (Continued)				
Alaska UST Regulations	18 AAC 78	Applies to investigation requirements for releases or overflow from USTs that historically held petroleum hydrocarbons. 18 AAC 78 refers to 18 AAC 75 to establish contaminant cleanup level requirements at UST release sites.	Yes/--	Potentially applicable. Previous investigations at Site DP98 have determined that a petroleum hydrocarbon contaminant plume thought to originate from a former UST located at Site DP98 exists.
Recycling of Recovered Oil	18 AAC 78.240	Requires that recovered free product be disposed of in compliance with applicable disposal regulations. Any flammable substances must be handled in a manner that avoids fires or explosions.	Yes/--	Potentially applicable when free product recovery is selected.
Free Product Recovery	18 AAC 75.325	Provides site cleanup rules for the recovery of free product. Free-product recovery efforts are required as long as practicably recoverable volumes are present. Petroleum will be removed to the maximum extent practicable as defined by 18 AAC 75.990(93).	Yes/--	Potentially applicable if free product recovery is selected.
Natural Attenuation	18 AAC 75.340	Specifies when natural attenuation has been successful for soil and/or groundwater.	Yes/--	Potentially applicable if natural attenuation is selected.
Cleanup Operations Requirements	18 AAC 75.360	Provides requirements for management of daily operations, waste management, and disposal plans.	Yes/--	Potentially applicable to the operation of free-product recovery systems.
Soil Storage and Disposal	18 AAC 75.370	Provides requirements for location, liner permeability for temporary stockpiling of petroleum-contaminated soils, and blending with other soils prior to treatment and disposal.	Yes/--	Potentially applicable.

Table 9-6 (Continued)

Standard, Requirement, Criterion, or Limitation	Criterion	Description	Potentially Applicable/ Relevant and Appropriate	Documentation
State of Alaska (Continued)				
Institutional Controls	18 AAC 75.375	Defines situations where institutional controls are required, describes institutional controls, and specifies criteria that institutional controls must meet.	Yes/--	Potentially applicable if remedy is likely to require some form of institutional controls to reduce or eliminate contact with contaminated media.
Other Criteria and Guidances				
Monitored natural attenuation	EPA OSWER Directive 9200.4.17P	Guides the use of monitored natural attenuation at a site, including performance monitoring and evaluation. States that use of monitored natural attenuation is appropriate in conjunction with other remediation measures (e.g., source control or groundwater extraction) or as a follow-up to active remediation measures that have already been implemented.	No/No	Potential TBC if monitored natural attenuation is part of the remedy.
Recommended Practices for Monitoring Well Design, Installation, and Decommissioning	ADEC, April 1992	Specifies construction standards for recovery and monitoring well installation. A well start card is required and the well construction log must be submitted to ADEC.	No/No	Potential TBC during remedial actions involving the construction of recovery or monitoring wells.
Management of Investigative-Derived Waste (IDW)	EPA Publication 9345.3-03FS, April 1992	This guidance applies to wastes generated during investigations performed at CERCLA sites and includes discussion on disposal options for IDW.	No/No	Potential TBC for activities at Site DP98 because wastes in the form of soil cuttings were generated during the EE/CA field investigation.

AAC – Alaska Administrative Code
ADEC – Alaska Department of Environmental Conservation
ARAR – Applicable or relevant and appropriate requirement
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
CFR – Code of Federal Regulations
EE/CA – Engineering Evaluation/Cost Analysis
EPA – U.S. Environmental Protection Agency
IDW – Investigation derived waste
NPDES – National Pollutant Discharge Elimination System
OSWER – Office of Solid Waste and Emergency Response
RCRA – Resource Conservation and Recovery Act
TBC – To be considered
USC – United States Code
UST – Underground Storage Tank

[This page intentionally left blank.]

Section 10.0
DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

Remedial action objectives (RAOs) consist of media-specific goals to protect human health and the environment. Identification of RAOs is necessary because they establish what is to be achieved by the selected remedial alternative identified in the FS. The RAOs identify the acceptable exposure levels that are protective of human health and the environment for each COC. These levels are identified in Section 9 of this RI as potential ARARs and are media specific.

10.1 Contaminants of Potential Concern (COPCs)

Data collected from several investigations conducted between 1995 and 2002 were compared to screening criteria to determine the nature and extent of contamination at Site DP98. The screening criteria used are considered potential ARARs and are presented in Section 9.0. Based on this evaluation, fuel and solvents are present at concentrations above preliminary ARARs in both water and soil. Contaminants that exceed these preliminary ARARs are considered COPCs, and are included in the development of RAOs. The results of this comparison are summarized below.

10.1.1 Soil

Fuel hydrocarbons (DRO, GRO, and benzene) and solvents (PCE, TCE, cis-1,2-DCE, and 1,1-DCE) were detected in soil at concentrations above preliminary ARARs. The contaminant DRO was the most common fuel contaminant detected at Site DP98. The contaminant DRO was measured above the soil screening criteria (250 mg/kg) in a total of 24 soil samples at concentrations from 369 to 42,000 mg/kg. The contaminants GRO and benzene were also measured above the preliminary ARARs in soil samples collected adjacent to the former UST.

TCE was the most common chlorinated contaminant detected at Site DP98. TCE was measured above preliminary ARARs (0.027 mg/kg) in a total of 16 soil samples and 5 duplicate soil samples at concentrations from 0.06 to 59.63 mg/kg. The highest concentration of TCE was measured in soil boring DP98-SB01, located at the terminus of the drain tile extending from the southern portion of Building 18224 (Figure 1-2). The contaminant cis-1,2-DCE, a primary breakdown product of TCE, was also measured above preliminary ARARs (0.2 mg/kg) in 10 soil samples and 5 duplicate soil samples between 0.257 to 2.084 mg/kg. The contaminants PCE and 1,1-DCE were measured above criteria in only one soil boring.

10.1.2 Sediment

DRO is the most common petroleum hydrocarbon contaminant. For solvents, TCE and cis-1,2-DCE were detected above preliminary ARARs. The contaminant DRO was detected in five sediment samples at concentrations ranging from 306.7 to 12,000 mg/kg. The highest DRO concentrations were measured in a sediment sample DP98-SD05, located near the access road to the water treatment pond. The contaminants TCE and cis-1,2-DCE were detected at 0.037 mg/kg in sediment sample DP98-SD10 and 0.26 mg/kg in sediment sample DP98-SD05, respectively.

10.1.3 Surface Water

For surface water, the same screening criteria or preliminary ARARs used for groundwater were used for surface water to determine nature and extent. However, no chemical specific preliminary ARARs are available for surface water except from ADEC 18 AAC 70 Surface Water Quality Standards. These are TAH and TAqH. No COPCs were identified from comparison to screening criteria.

10.1.4 Groundwater

With the addition of VC, the same fuel hydrocarbons (DRO, GRO, and benzene) and solvents (PCE, TCE, cis-1,2-DCE, and 1,1-DCE) that were detected in soil were also detected in groundwater above the preliminary ARARs. The contaminant DRO was the most common petroleum hydrocarbon detected in groundwater at Site DP98 above preliminary ARARs (1.5 mg/L). DRO was detected above the screening criteria in 21 groundwater samples at concentrations between 1.579 to 1,300 mg/L. The highest concentration of DRO was measured in a well that has historically contained free-phase fuel product.

The contaminant GRO was measured above the preliminary ARARs (1.3 mg/L) in 10 groundwater samples at concentrations ranging from 1.89 to 4.4 mg/L. The GRO plume covers a relatively small area and is collocated within the much larger DRO plume.

Benzene was measured above groundwater screening criteria (5 μg/L) in six groundwater samples at concentrations ranging from 7 to 160 μg/L. The highest concentrations of benzene were measured in wells located within 50 feet of Building 18224, adjacent to the former leaking UST.

Detected in 16 groundwater samples, TCE was the most common solvent detected in groundwater above preliminary ARARs at concentrations ranging from 5.7 to 5,000 μg/L. The highest concentration of TCE (5,000 μg/L) was measured in a well located outside the Facility approximately 110 feet north (downgradient) of the terminus of the drain tile (the likely source of solvents in soil and groundwater at Site DP98). One well located just within the wetland area north of the Facility (41755-WL08) has shown increasing TCE concentrations since 1996.

The contaminant cis-1,2-DCE was measured above the screening criteria (70 μg/L) in 12 groundwater samples at concentrations ranging from 782.3 to 5,800 μg/L. All of these groundwater samples were collected from four wells within 200 feet of Building 18224.

The contaminants PCE and 1,1-DCE (5 groundwater samples each) were also measured above the groundwater screening criteria of 5 μg/L and 7 μg/L, respectively. The PCE concentrations range from 9.5 to 6,400 μg/L. Concentrations of 1,1-DCE above the groundwater screening criteria have been measured in only two wells north of the DP98 Facility at concentrations ranging from 9.1 to 12.11 μg/L.

The contaminant VC was measured above the groundwater screening criteria (2 μg/L) in three groundwater samples at concentrations ranging from 9.6 to 16 μg/L.

10.2 Development of Contaminants of Concern

In the nature and extent evaluation (Section 5), contaminants detected at Site DP98 from investigations conducted between 1995 and 2002 were compared to screening criteria. The screening criteria used were based on chemical specific preliminary ARARs, which are discussed in Section 9 of this report, and are referred to as such. Contaminants that exceeded the screening criteria were identified as COPCs. COPCs identified during the nature and extent evaluation are considered COCs. Although these contaminants may not pose a risk to human health or ecological receptors as determined during the risk assessments, they still exceed preliminary ARARs and are, therefore, included in Table 10-1.

The human health and ecological risk assessments for Site DP98 also screened COPCs according to completed exposure pathways and potential receptors and from this process developed COCs. COCs were defined for the site as contaminants that exceed concentrations that pose a cancer risk to human health greater than 10^{-5}, or a non-cancer risk to human health with an HQ greater than 1 for both current (civilian, building, and construction workers) and future (residential, recreational, and construction worker) land use. COCs identified in the ecological risk assessment were identified as contaminants with concentrations high enough to represent an HQ greater than 1.

From a risk management perspective, the uncertainty in the EcoRA regarding the levels of DRO and RRO in sediment should be considered when identifying COCs for Site DP98. Analytical methods employed during the analysis of samples do not permit a determination of the source(s) of the detected DRO and RRO. The concentration gradient of RRO in particular does not appear to be related to leaks of diesel fuel from Site DP98, but may be consistent with patterns of biogenically produced organic matter which is quantified as DRO and RRO. If the source of the detected DRO and RRO in the wetlands is naturally produced organic matter from terrestrial vegetation, no remediation of the site due to petroleum contamination is warranted. For this reason, DRO and RRO were not included in Table 10-1 and RAOs were not developed for these contaminants in sediment.

The COPECs 2-methylnaphthalene is infrequently detected in sediment, not widely distributed at the site, has unknown bioavailability to receptors, has an unknown relationship with contaminant source materials at Site DP-98, and is of limited potential risk to mobile ecological receptors. Risks from infrequently detected chemicals like 2-methylnaphthalene are often overestimated for animals with large home ranges. For these reasons, 2-methylnaphthalene is not considered to pose an unacceptable risk to the environment due to occurrence in sediments, and is not included in Table 10-1 nor assigned a RAO.

ADEC 18 AAC 75 Method Two (ADEC, 2002) is used to establish cleanup levels that must be met for soils and sediment following the completion of the remedial action. As previously stated, these concentrations are established by the ADEC based on human health risk calculations.

For groundwater cleanup, ADEC 18 AAC 75 Table C for contaminant concentrations are considered to be criteria on which to base cleanup. For contaminants that are not listed under 18 AAC 75 and are found to potentially pose a risk to human health or the environment, federal MCLs will be used. Also, if contaminants are listed under both federal MCLs and ADEC 18 AAC 75, the more stringent of the values will be used.

For surface water, ADEC 18 AAC 70 Surface Water Quality Standards are used.

Section 9 of this RI contains a complete evaluation of potential ARARs and TBCs for Site DP98.

10.3 Development of Remedial Action Objectives (RAOs)

The development of RAOs for Site DP98 includes identifying the following three components to be evaluated as part of the process to determine the final list of RAOs:

- COCs;
- Receptors and exposure routes that could be affected by COCs; and
- Remedial goals to address COCs for each exposure pathway that is protective of human health and the environment.

The RAOs are identified by environmental media; that is, separate RAOs may be selected for soils, sediment, surface water, and groundwater. Note that in the FS, the effectiveness of remedial technologies is evaluated in terms of their ability to treat water (evaluating surface water and groundwater media together) and solids (evaluating sediment and soil together).

10.3.1 Receptors and Exposure Routes

Receptors and exposure routes are considered in the development of RAOs as the level of protectiveness that may be achieved through either the remedial alternatives evaluated in the FS by reducing the contaminants to levels below preliminary ARARs, or by reducing or eliminating the exposure routes to receptors. A specific example for Site DP98 would be to eliminate the risk to human health through use of institutional controls that block the use of the groundwater beneath the site as a drinking water source. Potential exposure routes and receptors for human health are evaluated in Section 7 of this RI and are graphically shown in the CSM (Figure 7-1). Potential ecological receptors and exposure routes are evaluated in Section 8 and shown in Figure 8-1.

10.3.2 Remedial Action Objectives for Site DP98

The ultimate objective for any chosen remedial action is to ensure reduced risk to human health and the environment to acceptable levels at Site DP98. This will be achieved by reducing the concentrations of contaminants in the effected environmental media to below those concentrations identified in the preliminary ARARs.

These RAOs are based on the potential chemical-, physical-, and action-specific preliminary ARARs included in Section 9. Because more than one environmental medium at Site DP98 contains contaminants at concentrations greater than proposed ARARs, site-specific RAOs are listed according to environmental media.

10.3.2.1 Surface Water

- Reduce or eliminate human exposure to contaminated surface water resulting from groundwater surfacing at the base of the slope near the wetland.
- Reduce or eliminate the exposure of ecological receptors to contaminated surface water in the wetland area.

Table 10-1

Summary of Contaminants of Concern, Proposed Remedial Action Objectives, and General Response Actions for Site DP98

Media	COC	Remediation Goal	Basis for Identification as COC	General Response Action
Groundwater	Free Product	Remove floating product	ARAR	Natural attenuation
	DRO	1.5 mg/L	ARAR	Natural attenuation; Land use controls* (restrict use as drinking water source); Containment; Source removal (groundwater extraction); Ex situ treatment of extracted groundwater; In situ treatment of groundwater; and Disposal of extracted groundwater.
	GRO	1.3 mg/L	ARAR	
	RRO	1.1 mg/L	ARAR	
	Benzene	0.005 mg/L	ARAR	
	Cis-1,2-Dichloroethene	0.07 mg/L	ARAR	
	1,1-Dichloroethene	0.007 mg/L	ARAR	
	Trichloroethene	0.005 mg/L	ARAR	
	Tetrachloroethene	0.005 mg/L	ARAR	
	Vinyl Chloride	0.002 mg/L	ARAR	
Surface Water	TAH	10 µg/L	ARAR	Natural attenuation; Land use controls* (prevent exposure to future residents); Containment; Source removal (groundwater extraction); Ex situ treatment of groundwater; and disposal of extracted groundwater.
	TAqH	15 µg/L	ARAR	
Sediment	cis-1,2-Dichloroethene	0.2 mg/kg	ARAR	Natural attenuation; Land use controls (prevent future human exposure); Containment; and In situ treatment.
	Trichloroethene	0.027 mg/kg	ARAR	
Soil	GRO	300 mg/kg	ARAR	Natural attenuation; Land use controls* (prevent future human exposures); Containment; Removal; Ex situ treatment; In situ treatment; and Disposal.
	DRO	250 mg/kg	ARAR	
	RRO	10,000 mg/kg	ARAR	
	1,1-Dichloroethene	0.03 mg/kg	ARAR	
	Benzene	0.02 mg/kg	ARAR	
	Tetrachloroethene	0.03 mg/kg	ARAR	
	Cis-1,2-Dichloroethene	0.2 mg/kg	ARAR	
	Trichloroethene	0.027 mg/kg	ARAR	

* Land use controls for Site DP98 are included under the Basewide Land Use Control Management Plan for Elmendorf AFB
ARAR – applicable or relevant and appropriate requirement
COC – contaminant of concern
RRO – residual range organics
DRO – diesel range organics
GRO – gasoline range organics

10.3.2.2 Groundwater

- Select and implement remedial action alternatives that will reduce risk to human health and ecological receptors caused by exposure to contaminated groundwater surfacing near the wetland.
- Select and implement the most appropriate land use controls that will reduce or eliminate exposure to contaminated groundwater and or restrict the use of groundwater as a drinking water source while remediation is occurring.
- Select and implement alternatives that will reduce risk to human health in the event groundwater is used for drinking water.

10.3.2.3 Sediments

- Reduce or eliminate the exposure of ecological receptors to contaminated sediments in the wetland area by reducing the concentrations of contaminants.
- Select and implement the most appropriate land use control that would reduce or eliminate exposure of future residents at Site DP98 while remediation is occurring.

10.3.2.4 Soils

- Select and implement a remedial action alternative that reduces both fuel and chlorinated solvent concentrations below preliminary ARARs.
- Select and implement remedial action alternatives that do not cause physical damage to the wetland ecology.

10.4 Remediation Goals

Remedial goals are site-specific cleanup criteria selected from the preliminary ARARs included in Section 9 that meet the RAOs for Site DP98. Each remediation goal or cleanup criteria results in a specific remedial response action and applies to all COCs identified for each contaminated environmental medium. The remedial actions developed in the FS must meet these RAOs. Table 10-1 contains a listing by environmental medium of remediation goals and associated response actions specific to Site DP98. It should be noted that remediation goals are based on preliminary ARARs; final ARARs will be identified in the Record of Decision.

Chlorinated compounds are the primary risk drivers in the human health risk assessment, and therefore are considered to be higher priority for remedial action. Fuel contaminants are present at the site but pose less of a risk than chlorinated contaminants. Furthermore, the presence of fuel compounds is thought to accelerate the breakdown of chlorinated compounds by providing a carbon source and promoting anaerobic dechlorination. It may be likely that the fuel contamination is preventing further migration of the chlorinated plume. For this reason, no alternatives that solely address fuel compounds through active treatment have been developed. Remedial options that may adversely impact the remediation of chlorinated contaminants (though address fuel contaminants) will be scored less favorably during the evaluation and screening process. Based on a review of typical contaminant degradation rates, it appears unlikely that there will be significant DRO contamination remaining in the soil or groundwater at the site by the time the concentrations of chlorinated compounds reach concentrations below proposed cleanup levels. However, if residual DRO contaminant concentrations are still present above the proposed cleanup levels at that time, additional contingent remedies such as chemical or mechanical enhancements to natural attenuation or bioventing will be considered.

No risk to human health exists for exposure to surface water or sediments at Site DP98. A low level risk is present for benthic and aquatic organisms in sediment and surface water respectively. These risks are primarily from a small surface drainage area adjacent to the wetland. Estimates used for the ecological risk calculation are conservative; there is no way to determine the amount of biogenic interference taking place from the organic rich materials in the wetland, the area has standing water only after heavy rainfall, and is frozen or dry during most of the year. Further, the damage to the surrounding ecology and wetland that would likely occur during the implementation of a remedial action (such as excavation or capping) outweigh the low level risk posed by contaminated media. For these reasons, remedial options that may impact the wetlands are not evaluation for surface water and sediment media in the FS.

Section 11.0
IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

The potential remedial technologies considered for Site DP98 are identified and screened in this section. The identification and screening of remedial technologies is a four-step process. In the first step, presented in Section 11.1, general response actions are identified for each contaminated medium at the site. A general response action is a type of remedial action that, alone or in combination with other actions, satisfies the remedial action objectives identified in Section 10. Potential remedial technology types and process options are then identified that can be used to implement each general response action. The identification of technology types and process options is presented in Section 11.2.

Once the technology types and process options are identified, they undergo two screening steps, as presented in Section 11.3. The first screening step is the preliminary screening. During preliminary screening, individual process options and/or entire technology types may be eliminated from further consideration, based on technical implementability at the site. Those technologies that pass the preliminary screening step undergo a more detailed screening. During this second screening, process options are evaluated using three criteria: effectiveness, implementability, and cost. The most promising process options are retained during this screening and are included in the media-specific remedial alternatives developed for the site.

The feasibility study is based on the results of the DP98 remedial investigation, including the baseline human health and ecological risk assessments.

Chlorinated compounds are the primary risk drivers in the human health risk assessment and are therefore, considered to be higher priority for remedial action. Fuel contaminants are present at the site but pose less of a risk than chlorinated contaminants. The presence of fuel compounds has been demonstrated to accelerate the breakdown of chlorinated compounds by providing a carbon source and promoting anaerobic dechlorination. Fuel contamination may be preventing further migration of the chlorinated plume. For these reasons, no alternatives that solely address fuel compounds through active treatment have been developed. Remedial options that may adversely impact the remediation of chlorinated contaminants (though address fuel contaminants) will be scored less favorably during the evaluation and screening process.

No risk to human health exists for recreational exposures to surface water or sediments at Site DP98. A low-level risk is present for benthic and aquatic organisms in sediment and surface water, respectively. These risks are primarily from a small surface drainage area adjacent to the wetland. Estimates used for the ecological risk calculation are conservative; the area has standing water only after heavy rainfall and is frozen or dry during most of the year. Furthermore, damage to the surrounding ecology and wetland that would likely occur during the implementation of a remedial action (such as excavation or capping) outweighs the low-level risk posed by contaminated media. For these reasons, remedial options that may impact the wetlands are not evaluated for surface water and sediment media in the FS.

As discussed in Section 5, passive and active free product recovery has been attempted at Site DP98 with very limited success. For this reason, alternatives that include free product recovery will not be developed. If free product is encountered, it will be addressed in accordance with preliminary ARARs.

A level of protectiveness may be achieved through the remedial alternatives evaluated in the FS by either reducing the contaminant concentrations to below preliminary ARAR levels, or by reducing exposure to the receptors while complying with the proposed ARARs. An action that may be implemented to achieve the latter includes using land use controls to eliminate potential exposure routes (groundwater consumption). Land use controls are included in the Basewide Land Use Control Management Action Plan for Elmendorf AFB.

11.1 General Response Actions

General response actions are classes of actions that will satisfy one or more of the remedial action objectives discussed in Section 10. General response actions are identified for each affected medium present at the site. Affected media present at DP98 are surface water, groundwater, sediment, and soil. The general response actions for these media are presented in the following subsections.

11.1.1 General Response Actions for Soil

The soil medium includes soil in upland areas of the site and sediments in the wetland downgradient from the source areas. These were considered a single medium because technologies and process options to remediate soil and wetland sediment are similar. However, active alternatives (such as removal or ex-situ treatment) will be considered only for soil and not for wetlands sediment. Concentrations of DRO and RRO in soil are not differentiated from biogenic organics in the DRO range common to peat and highly organic material such as those found in the wetland at Site DP98. Reduction of the mass of contaminants near the source (upgradient of the wetland) will greatly reduce the mass of contaminants reaching the wetland. HQs for the other COPECs in wetlands sediment were less than 15. In addition, due to the sensitive nature of the wetland ecology where sediments are located, and the relatively low risk to ecological receptors from the sediments present, the benefit does not justify the risk and damage to the wetland resulting from an active treatment technology. The general response actions considered for the soil medium are:

- No action;
- Natural attenuation;
- Land use controls;
- Containment;
- Removal;
- Ex-situ treatment;
- In-situ treatment; and
- Disposal.

11.1.2 General Response Actions for Water

The water medium includes contaminated groundwater in the upper unconfined aquifer and contaminated surface water in the wetland to the north of the site. Response actions for groundwater and surface water were combined because groundwater discharges to the wetland and because remediation technologies and process options are similar. As with sediment, concentrations of DRO in surface water were not differentiated from biogenic organic interference often associated with organic rich material like those found in the wetland. The reduction of the upgradient sources will also reduce the mass of contaminants reaching the wetland. Active treatment technologies are not considered feasible for addressing contaminated surface water. Further, it is thought that contamination present in surface water is directly related to discharge of contaminated groundwater near the wetland (Section 5.7). Therefore, the general response actions considered for water are:

- No action;
- Natural attenuation;
- Land use controls;
- Containment;
- Source removal;

- Ex-situ treatment;
- In-situ treatment; and
- Disposal.

11.2 Identification of Technology Types and Process Options

Remedial technology types and process options were identified for each media-specific general response action. Technology types are general categories of actions within a general response action. For instance, physiochemical treatment, biological treatment, and thermal treatment are technology types considered under the ex-situ treatment general response action. Process options are specific processes within a technology type. For example, air sparging is a process option under the broader category of physiochemical treatment. The sources referred to for process option selection were EPA guidance documents, various government and professional organization websites, and experience at numerous other contaminated sites. Based on the evaluation of these resources, applicable technology types and process options for DP98 were identified for soil (Table 11-1) and water (Table 11-2). In accordance with NCP requirements, no action was included as one of the process options for both soil and water. The no action alternative is used as a baseline for comparison with the other technologies/alternatives.

11.3 Screening of Remedial Technology Types and Process Options

A preliminary screening was conducted on the remedial technology types and process options identified in Tables 11-1 and 11-2. This preliminary screening is presented in Section 11.3.1. Process options that passed preliminary screening then underwent a more detailed screening process, which is presented in Section 11.3.2.

11.3.1 Preliminary Screening of Remedial Technologies

A preliminary screening was conducted on the remedial technology types and process options identified in Table 11-1 for soil and sediment and in Table 11-2 for groundwater and surface water. Individual process options and/or entire technology types may be eliminated from further consideration during preliminary screening. Site-specific information was used to determine whether an entire technology type or a specific process option could be effectively implemented at the site. This site-specific information included geology, hydrogeology, type of contamination, and location of contamination, such as depth to contaminated water and soils. If the technology type or process option was screened out, the reason for rejection is provided in the comments column of the table.

11.3.2 Screening of Remedial Technologies

Those technologies passing preliminary screening underwent a more detailed screening, which is presented in this section. In this final step before the process options are combined into media-specific remedial alternatives, the retained process options were evaluated in greater detail before selecting process options for each technology type. Detailed screening of process options considered effectiveness, implementability, and cost. These evaluation criteria are described in more detail in the following paragraphs, and the screening evaluation is provided in Tables 11-3 and 11-4.

The effectiveness of a remedial process option was evaluated considering the following criteria:

- Attainment of identified RAOs for the specific affected areas or volumes;
- Adequate protection of human health and the environment, based on the screening level risk assessments (see Sections 7 and 8); and
- A proven and reliable history of success (e.g., at similar sites) with respect to the conditions at the site.

Implementability encompasses both the technical and administrative feasibility of implementing a remedial process option. The implementability of a remedial option was evaluated by considering such issues as:

- The availability of the technologies employed by the solution;
- The availability of storage and disposal services;
- The availability of necessary skilled workers to implement the technology;
- The administrative feasibility of implementing the remedial option, such as the ability to obtain the necessary permits; and
- The capability to comply with location- and action-specific ARARs or regulations.

The cost evaluation plays a limited role in this stage of the screening process and is provided only as an informational tool. Cost is not a criterion used to base a decision on whether a process option is retained or rejected. Relative capital and annual operating and maintenance (O&M) costs, rather than detailed estimates, are provided in the screening process. If a process option will require less than one year to implement/operate, than all costs are considered capital and no O&M costs are provided.

The screening costs analysis is based on engineering judgment, and each process option is evaluated as to whether costs are low, moderate, or high, relative to other process options in the same technology type. If only one process option is given within a technology type, the relative costs are determined by comparing to other process options within a general response action. If a process option is the only option within the general response action, no relative cost is assigned.

11.4 Process Options Retained

Process options retained for soil and sediment and groundwater and surface water are listed in Table 11-5. These process options were considered the most promising for the site. In Section 12, these process options will be combined into media-specific remedial alternatives for the site.

Table 11-5

Retained Process Options

Soil and Sediment Process Options	Groundwater and Surface Water Process Options
No action	No action
Natural attenuation with confirmation sampling	Monitored natural attenuation
Use of restrictions and administrative controls	Use of restrictions and administrative controls
Restrict digging	Restrict digging
Confirmation sampling	Restrict groundwater use
Shallow excavation	Long-term media monitoring
Closure of tile drain system	Extraction wells (includes high vacuum extraction)
Hot air vapor extraction (HAVE)	Granular activated carbon/liquid phase carbon adsorption
Low-temperature thermal desorption (LTTD)	Air sparging
Soil vapor extraction (SVE)	Enhanced bioremediation
Steam stripping	Steam stripping
Enhanced bioremediation	Surface water discharge
Bioventing	Deep well injection
Material reuse as backfill	
Incineration at a permitted (TSD) facility	

[This page intentionally left blank.]

Section 12.0
DEVELOPMENT AND SCREENING OF MEDIA-SPECIFIC ALTERNATIVES

This section provides the evaluation of media-specific remedial alternatives for Site DP98. The process takes into consideration the environmental conditions at Site DP98 and the RAOs that were defined in Section 10. The site was divided into two media: soil/sediment and groundwater/surface water, as described in Section 11. In this section, the process options that were retained after the process option screening in Section 11 are combined into media-specific alternatives. These media specific alternatives were then evaluated using site-specific information to further assess potential applicability to Site DP98. A detailed description and analysis of the retained alternatives is presented in Section 13.

12.1 Development and Description of Media-Specific Alternatives

The process options that were retained after the process option screening in Section 11 are summarized in Table 11-5. The process options that passed the preliminary screening described in Section 11 were combined to form candidate remedial alternatives for the two defined media at Site DP98. A total of 17 media-specific remedial alternatives were developed for treating soil/sediment and groundwater/surface water at Site DP98. These alternatives took into account the geological conditions, climate, and location of Site DP98. Technologies were chosen based on their ability to treat the COCs and otherwise satisfy the RAOs established in Section 10.

12.1.1 Soil and Sediment Alternatives

Table 12-1 lists the nine candidate remedial alternatives that were developed for addressing contaminated soil and sediment at Site DP98. This table also identifies the process options included with each alternative. The nine media-specific alternatives that were developed for the site are Alternative S1-No Action; Alternative S2-Natural Attenuation with Confirmation Sampling; Alternative S3-Limited Steam Stripping of Chlorinated Contaminated Soils; Alternative S4-Limited Source Removal of Chlorinated Contaminated Soils and Off-Site Treatment and Disposal; Alternative S5-Soil Vapor Extraction (SVE) of Chlorinated Contaminated Soils; Alternative S6-Limited Source Removal of Chlorinated Contaminated Soils and On-Site Treatment Using Low-Temperature Thermal Desorption (LTTD) and SVE; Alternative S7-Limited Source Removal of Chlorinated Contaminated Soils and On-Site Treatment Using Hot Air Vapor Extraction (HAVE) and SVE; Alternative S8-Limited Source Removal of Chlorinated Contaminated Soils and On-Site Thermal Treatment; and Alternative S9-Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal, and SVE. Each of the nine media-specific alternatives consists of a combination of media-specific process options, as discussed below.

- Alternative S1-No Action, which is required by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), consists only of the no action process option. This alternative was developed solely as a baseline for comparison with other alternatives.
- Alternative S2-Natural Attenuation with Confirmation Sampling is a combination of the following process options: natural attenuation with confirmation sampling, and digging restrictions. Digging restrictions are included to prevent access to soils until groundwater remediation goals are met.
- Alternative S3-Limited Steam Stripping of Chlorinated Contaminated Soils is a combination of the following process options: digging restrictions, steam stripping, SVE, extraction wells, and granular activated carbon (GAC)/liquid phase carbon adsorption. Digging restrictions are included to prevent access to soils until soil remediation goals are met. SVE is included

to remove and control volatilized gasses, and groundwater extraction and treatment (extraction wells and GAC/liquid phase carbon adsorption) are used for hydraulic control.

- Alternative S4- Limited Source Removal of Chlorinated Contaminated Soils and Off-Site Treatment and Disposal includes digging restrictions, removal and replacement or re-routing of drain tile system, shallow excavation, and incineration at a permitted TSD facility. Digging restrictions are included to prevent access to soils until soil remediation goals are met.
- Alternative S5- SVE of Chlorinated Contaminated Soils is a combination of the following process options: digging restrictions, and SVE. Digging restrictions are included to prevent access to soils until soil remediation goals are met.
- Alternative S6- Limited Source Removal of Chlorinated Contaminated Soils and On-Site Treatment Using LTTD and SVE includes digging restrictions, removal and replacement or re-routing of drain tile system, shallow excavation, LTTD treatment, material reuse as backfill, and SVE. This alternative is similar to S8. However, SVE is added to expand treatment to the whole site and reduce remediation time. Digging restrictions are included to prevent access to soils until soil remediation goals are met.
- Alternative S7- Limited Source Removal of Chlorinated Contaminated Soils and On-Site Treatment Using HAVE and SVE includes digging restrictions, removal and replacement or re-routing of drain tile system, shallow excavation, HAVE, material reuse as backfill, and SVE. This alternative is similar to Alternative S6, except that the ex-situ treatment option is HAVE instead of LTTD. Digging restrictions are included to prevent access to soils until soil remediation goals are met.
- Alternative S8- Limited Source Removal of Chlorinated Contaminated Soils and On-Site Thermal Treatment is a combination of the following process options digging restrictions, removal and replacement or re-routing of drain tile system, shallow excavation, thermal treatment by either LTTD or HAVE, and material reuse as backfill. Digging restrictions are included to prevent access to soils until soil remediation goals are met.
- Alternative S9- Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal, and SVE. This alternative is similar to S4. However, SVE is added to expand treatment to the whole site and reduce remediation time. Treatment and disposal include digging restrictions, and removal and replacement or re-routing of drain tile system.

The soil and sediment alternatives are described in more detail below.

12.1.1.1 Alternative S1 – No Action

No monitoring or other actions would be implemented with this alternative. This alternative would rely solely on natural attenuation to reduce concentrations of chlorinated contaminants (i.e., TCE) and fuel compounds (i.e., DRO) in soil and sediment.

12.1.1.2 Alternative S2 – Natural Attenuation with Confirmation Sampling

Under Alternative S2, no active treatment would be implemented. The drain tile system would be abandoned in place and no excavation or other active treatment would be performed. However, unlike Alternative S1, land use controls and one-time soil sampling and analysis would be utilized. Land use controls are included under the Basewide Land Use Control Management Action Plan for Elmendorf AFB. Soil samples would only be collected to determine if soil remediation goals have been met once proposed groundwater remediation goals have been reached. The heterogeneous nature of soils at Site DP98 would make it difficult to collect samples from the same soil type and location for consecutive sampling events; therefore, soil results would not be comparable and accurate trends in concentration could not be made. Monitoring natural attenuation of COCs in groundwater will also reflect changes in concentrations of COCs in soil, in particular because seasonal rises and decreases in groundwater create a smear zone, creating a direct correlation between contamination in soil and groundwater.

Digging restrictions would be maintained until soil remediation goals are met. The drain system would be removed as needed during excavation.

Confirmation soil sampling would consist of up to 15 soil samples collected throughout the site. The testing would include, but would not be limited to, the following parameters: total organic carbon, GRO, DRO/RRO, VOCs, and PAHs. Based on the sampling results, active treatment alternatives would be considered if the soil remediation goals were not met.

This alternative may also include a contingency remedial action, which would only be implemented when the remediation goals for chlorinated compounds have been reached but DRO concentrations still exceed remediation goals.

12.1.1.3 Alternative S3 – Limited Steam Stripping of Chlorinated Contaminated Soils

Alternative S3 would consist of the limited in-situ steam stripping of soils containing chlorinated contaminants at the end of the existing drain tile system north of Building 18224. Shallow SVE would be required to collect volatile off-gases from the steam stripping. Limited groundwater extraction and treatment would also be used for hydraulic control during thermal treatment. The remaining soils and sediments containing chlorinated contaminants and fuel compounds (DRO) outside the radius of influence of the thermal treatment system would be treated via natural attenuation. Natural attenuation would also be utilized to address contaminated sediments. It is assumed that the soils would be treated in one year using in-situ thermal treatment. Soil sampling would be performed at the end of the treatment period to confirm soil remediation goals have been met.

Digging restrictions would be maintained until soil remediation goals are met. Confirmation soil sampling would be identical to that described in Section 12.1.1.2. The drain system would be removed as needed during excavation.

This alternative may also include a contingency remedial action, which would only be implemented when the remediation goals for chlorinated compounds have been reached and if DRO concentrations still exceed remediation goals.

12.1.1.4 Alternative S4 – Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal

Alternative S4 would consist of a limited source removal and off-site treatment of soils containing chlorinated contaminants; natural attenuation would be used for the remaining contaminants in soil. Soils within an estimated 25-foot radius of the end of the existing drain tile system north of the building would be excavated down to 10 feet or to the water table, whichever is encountered first. Assuming that the soil from 0 to 5 feet bgs is not contaminated, the soil volume proposed for removal would be approximately 360 cubic yards. Excavated soil containing chlorinated contaminants (and any fuel compounds also present in the removed soil) would be transported off-site for treatment and disposal. It is assumed that soil containing chlorinated contaminants will require treatment prior to disposal. Off-site treatment of the chlorinated contaminated soil would consist of incineration or disposal at an EPA-permitted facility. The treated soil would then be disposed of using the least expensive means. A clean soil source would be identified for backfilling the excavation. It is assumed that one construction season would be required for the limited source removal. The remaining unexcavated contaminated soil and sediment would be treated by natural attenuation. Soil samples would be collected to determine if soil remediation goals have been met once proposed groundwater remediation goals have been reached. The drain tile system would be removed as needed during excavation. The drain tile system may need to be reinstalled and/or re-routed to control water in the building.

Digging restrictions would be maintained until soil remediation goals are met. Confirmation soil sampling would be identical to that described in Section 12.1.1.2.

This alternative may also include a contingency remedial action, which would only be implemented when the remediation goals for chlorinated compounds have been reached but DRO concentrations still exceed remediation goals.

12.1.1.5 Alternative S5 – SVE of Chlorinated Contaminated Soils

Alternative S5 would consist of the use of SVE to treat soils containing chlorinated compounds, excluding those soils in the area north and northwest of the Facility where the slope is too steep to install SVE wells. The remaining soils containing chlorinated and/or fuel contaminants would be treated via natural attenuation. SVE is assumed to require 5 years. Soil sampling would be performed once groundwater contaminants have reached cleanup levels to determine if soil concentrations are also below cleanup levels.

Digging restrictions would be maintained until soil remediation goals are met. Confirmation soil sampling would be performed in a manner identical to that described in Section 12.1.1.2.

This alternative may also include a contingency remedial action, which would only be implemented when the remediation goals for chlorinated compounds have been reached but DRO concentrations still exceed remediation goals.

12.1.1.6 Alternative S6 – Limited Source Removal of Chlorinated Contaminated Soils and On-Site Treatment Using LTTD and SVE

Alternative S6 would consist of limited source removal of soils containing chlorinated contaminants at the end of the existing drain tile system north of Building 18224, followed by on-site treatment using LTTD. Soil would be excavated in a 25 foot radius around the end of the drain tile down to 10 feet or to the water table, whichever is encountered first. Assuming that soil from 0 to 5 feet bgs is not contaminated, the soil volume proposed for removal would be approximately 360 cubic yards. Excavated soil containing chlorinated contaminants (and any fuel compounds also present in the soil removed) would be treated on-site using LTTD. All LTTD-treated soil would be backfilled into the source area excavations. It is assumed that one construction season would be required for the limited source removal and on-site treatment at the drain tile system. The drain tile system would be removed as needed during excavation. The drain tile system may need to be reinstalled and/or re-routed to control water in the building.

SVE would be used to treat remaining soils containing chlorinated contaminants above groundwater remediation goals, except those soils in the area north and northwest of the Facility where the slope is too steep to install SVE wells. The remaining unexcavated and untreated contaminated soil and sediment would be treated via natural attenuation. SVE is assumed to require 5 years. Soil samples would be collected to determine if soil remediation goals have been met once proposed groundwater remediation goals have been reached.

Digging restrictions would be maintained until soil remediation goals are met. Confirmation soil sampling would be identical to that described in Section 12.1.1.2.

This alternative may also include a contingency remedial action, which would only be implemented when the remediation goals for chlorinated compounds have been reached but DRO concentrations still exceed remediation goals.

12.1.1.7 Alternative S7 – Limited Source Removal of Chlorinated Contaminated Soils and On-Site Treatment Using HAVE and SVE

Alternative S7 would consist of limited source removal for soils containing chlorinated contaminants at the end of the existing drain tile system followed by on-site treatment. Soil within an estimated 25-foot radius of the end of the drain tile system would be removed. Soil would be excavated down to 10 feet or to the water table, whichever is encountered first. Assuming that soil from 0 to 5 feet bgs is not contaminated, the soil volume proposed for removal would be approximately 360 cubic yards. Excavated soil containing chlorinated contaminants (and any fuel compounds also present in the soil removed) would be treated on-site using HAVE. All HAVE-treated, soil would be backfilled into the source area excavations. It is assumed that one construction season would be required for the limited source removal and on-site treatment. The drain tile system would be removed as needed during excavation. The drain tile system may need to be reinstalled and/or re-routed to control water in the building.

SVE would be used to treat all remaining soils containing contaminants above groundwater remediation goals, except those soils in the area north and northwest of the Facility where the slope is too steep to install SVE wells. The remaining unexcavated and untreated, contaminated soil and sediment containing chlorinated and/or fuel contaminants would be treated via natural attenuation. Soil samples would be collected to determine if soil remediation goals have been met once proposed groundwater remediation goals have been reached and would be identical to that described in Section 12.1.1.2.

Digging restrictions would be maintained until soil remediation goals are met.

This alternative may also include a contingency remedial action, which would only be implemented when the remediation goals for chlorinated compounds have been reached but DRO concentrations still exceed remediation goals.

12.1.1.8 Alternative S8 – Limited Source Removal of Chlorinated Contaminated Soils and On-Site Treatment

Alternative S8 would consist of limited source removal of soils containing chlorinated contaminants near the existing drain tile system, followed by on-site treatment using either LTTD or HAVE. Soil within an estimated 25-foot radius of the end of the drain tile system would be removed. Soil would be excavated down to 10 feet or to the water table, whichever is encountered first. Assuming that soil from 0 to 5 feet bgs is not contaminated, the soil volume proposed for removal would be approximately 360 cubic yards. Excavated soil containing chlorinated contaminants (and any fuel compounds also present in the soil removed) would be treated on-site using either LTTD or HAVE. All treated soil would be backfilled into the source area excavation. It is assumed that one construction season would be required for the limited source removal and on-site treatment at the drain tile system. The drain system would be removed as needed during excavation. The drain may need to be reinstalled and/or re-routed to control water in the building.

The remaining unexcavated contaminated soil and sediment would be treated via natural attenuation. Soil samples would be collected to determine if soil remediation goals have been met once proposed groundwater remediation goals have been reached and would be identical to that described in Section 12.1.1.2.

Digging restrictions would be maintained until soil remediation goals are met.

This alternative may also include a contingency remedial action, which would only be implemented when the remediation goals for chlorinated compounds have been reached but DRO concentrations still exceed remediation goals.

12.1.1.9 Alternative S9 – Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal and SVE

Alternative S9 would consist of limited source removal of soils containing chlorinated contaminants at the end of the existing drain tile system, followed by off-site treatment. Soil within an estimated 25-foot radius of the end of the drain tile system would be removed. Soil would be excavated down to 10 feet or to the water table, whichever is encountered first. Assuming that soil from 0 to 5 feet bgs is not contaminated, the soil volume proposed for removal would be approximately 360 cubic yards. Excavated soil containing chlorinated contaminants (and any fuel compounds also present in the soil removed) would be transported off-site for treatment and disposal. It is assumed that soil containing chlorinated contaminants will require treatment prior to disposal. Off-site treatment of the chlorinated contaminated soil would be incinerated or disposed at an EPA-permitted facility. The treated soil would then be disposed of using the least expensive means. The portion of the drain tile system that is not disturbed by the excavation will be closed in-place. A clean soil source will be identified for backfilling the excavation. It is assumed that one construction season would be required for the limited source removal at the drain tile system. The drain tile system would be removed as needed during excavation. The drain tile system may need to be reinstalled and/or re-routed to control water in the building.

SVE would be used to treat remaining soils containing chlorinated contaminants above groundwater remediation goals, except those soils in the area north and northwest of the buildings where the slope is too steep to install SVE wells. The remaining unexcavated and untreated contaminated soil and sediment would be treated via natural attenuation. SVE is assumed to require 5 years. Soil sampling would be performed once groundwater contaminants have reached cleanup levels and would be identical to that described in Section 12.1.1.2.

Digging restrictions would be maintained until soil remediation goals are met.

This alternative may also include a contingency remedial action, which would only be implemented when the remediation goals for chlorinated compounds have been reached but DRO concentrations still exceed remediation goals.

12.1.2 Groundwater and Surface Water Alternatives

Table 12-2 lists the eight candidate remedial alternatives that were developed for addressing contaminated groundwater and surface water at Site DP98. This table also identifies the process options included with each alternative. The eight media-specific alternatives that were developed for the site are Alternative W1-No Action; Alternative W2-Monitored Natural Attenuation (MNA); Alternative W3-Limited Steam Stripping of Groundwater and MNA; Alternative W4-Air Sparging/SVE, High-Vacuum Extraction (HVE), and MNA; Alternative W5-Groundwater Extraction/Collection, Treatment, and Disposal; Alternative W6-Limited Steam Stripping of Groundwater, Air Sparging/SVE, and MNA; Alternative W7-HVE and MNA; and Alternative W8-Air Sparging/SVE and MNA. Each of the eight media-specific alternatives consists of a combination of media-specific process options, as discussed below.

- Alternative W1-No Action, which is required by the NCP, consists only of the no action process option. This alternative was developed solely as a baseline for comparison with other alternatives.
- Alternative W2-MNA is a combination of the following process options: MNA, land use controls (use restrictions, administrative controls, restrict digging, and restrict groundwater use), and long-term monitoring. The land use controls are included to prevent access to groundwater until groundwater remediation goals are met. The land use controls for Site DP98 are included under the Basewide Land Use Control Management Action Plan for Elmendorf AFB.

- Alternative W3- Limited Steam Stripping of Groundwater and MNA is a combination of the following process options: MNA, land use controls (restrict digging, restrict groundwater use), long-term monitoring, steam stripping, SVE, extraction wells, and GAC/liquid phase carbon adsorption. The land use controls are included to prevent access to groundwater until groundwater remediation goals are met. SVE is included to remove and control volatilized gases, and groundwater extraction and treatment (extraction wells and GAC/liquid phase carbon adsorption) is used for hydraulic control. MNA is included to address contaminated groundwater outside the area of steam stripping.
- Alternative W4- Air Sparging/SVE, HVE, and MNA include: MNA, land use controls (use restrictions, administrative controls, restrict digging, and restrict groundwater use), long-term monitoring, air sparging, SVE, HVE, GAC/liquid phase carbon adsorption, surface water discharge and/or deep well injection. The land use controls are included to prevent access to groundwater until groundwater remediation goals are met. SVE is always used in combination with air sparging to remove and control volatilized gases. HVE is included to address contamination below the buildings. GAC/liquid phase carbon adsorption and the two discharge options are included to treat and dispose of groundwater extracted using HVE. MNA is included to address contaminated groundwater outside the area of active treatment.
- Alternative W5- Groundwater Extraction/Collection, Treatment, and Disposal is a combination of the following process options: MNA, land use controls (use restrictions, administrative controls, restrict digging, and restrict groundwater use), long-term monitoring, extraction wells, GAC/liquid phase carbon adsorption, surface water discharge and/or deep well injection. The land use controls are included to prevent access to groundwater until groundwater remediation goals are met. GAC/liquid phase carbon adsorption and the three discharge options are included to treat and dispose groundwater extracted from the extraction wells. MNA is included to address contaminated groundwater outside the area of active treatment or following active treatment.
- Alternative W6- Limited Steam Stripping of Groundwater, Air Sparging/SVE, and MNA is a combination of MNA, land use controls (use restrictions, administrative controls, restrict digging, and restrict groundwater use), long-term monitoring, steam stripping, air sparging, SVE, extraction wells, and GAC/liquid phase carbon adsorption. The land use controls are included to prevent access to groundwater until groundwater remediation goals are met. This alternative is similar to W3. However, air sparging in combination with SVE is added to expand treatment to the whole site and reduce remediation time. MNA is included to address contaminated groundwater outside the area of active treatment or following active treatment.
- Alternative W7- HVE and MNA include MNA, Land use controls (use restrictions, administrative controls, restrict digging and restrict groundwater), long-term monitoring, high-vacuum extraction, GAC/liquid phase carbon adsorption, surface water discharge and/or deep well injection. The land use controls are included to prevent access to groundwater until groundwater remediation goals are met. GAC/liquid phase carbon adsorption and the two discharge options are included to treat and dispose groundwater extracted using HVE. MNA is included to address contaminated groundwater outside the area of active treatment.
- Alternative W8- Air Sparging/SVE and MNA include the following process options: MNA, land use controls (use restrictions, administrative controls, restrict digging, and restrict groundwater use), long-term monitoring, air sparging, and SVE. The land use controls are included to prevent access to groundwater until groundwater remediation goals are met. SVE is always used in combination with air sparging to remove and control volatilized gases. MNA is included to address contaminated groundwater outside the area of active treatment.

The groundwater and surface water alternatives are described in more detail in the following subsections.

12.1.2.1 Alternative W1 – No Action

No monitoring or other actions would be implemented with this alternative. This alternative would rely solely on natural attenuation to reduce concentrations of chlorinated contaminants (i.e., TCE) and fuel compounds (i.e., DRO) in groundwater and surface water.

12.1.2.2 Alternative W2 – Monitored Natural Attenuation

Under Alternative W2, no active treatment would be implemented. However, unlike Alternative W1, Alternative W2 would involve long-term monitoring of surface and groundwater, as well as land use controls. Monitoring would provide sufficient information to indicate that natural attenuation is degrading the COCs in accordance with the Office of Solid Waste and Emergency Response (OSWER) Directive for the use of MNA (EPA, 1997). Land use controls for Site DP98 are included under the Basewide Land Use Control Management Action Plan for Elmendorf AFB and would be implemented to restrict the usage of groundwater for domestic uses such as drinking water. Both land use controls and monitoring would be maintained until groundwater remediation goals are met.

The groundwater/surface water monitoring sampling frequencies will be based on the decision guide for the Basewide Environmental Monitoring Program. Annual sampling is assumed for cost estimating purposes. Natural attenuation occurring on-site would be modeled to provide a cleanup timeframe. Following the model, the frequency of groundwater sampling would continue to be based on the decision guide for the Basewide Environmental Monitoring Program, and further modeling would occur only if recalibration is necessary. In addition to groundwater sampling, one surface water sample would be collected at the kettle pond, as a point of compliance. The testing would include, but would not be limited to, the following parameters: nitrate/nitrite, total Kjeldahl nitrogen, total phosphorus, total organic carbon, GRO, DRO/RRO, VOCs, PAH, heterotrophic plate count, and hydrocarbon-degrading bacteria.

Enhancements such as biological or mechanical amendments to the MNA may be considered depending on remediation progress relative to cleanup levels.

12.1.2.3 Alternative W3 – Limited Steam Stripping of Groundwater and MNA

Alternative W3 would consist of limited in-situ groundwater treatment using steam stripping at the chlorinated contaminant source at the end of the existing drain tile system. The treatment system uses steam stripping to raise the temperature of the subsurface such that chlorinated contaminants (and any fuel compounds present) would be vaporized and removed through SVE. Groundwater extraction and treatment would also be used for hydraulic control during thermal treatment. In-situ groundwater treatment using steam stripping is assumed to require 1 year.

Groundwater and surface water containing chlorinated contaminants and fuel compounds that are remaining outside the radius of influence of the thermal treatment system would be treated via MNA.

Land use controls would be implemented to restrict the usage of groundwater for domestic uses such as drinking water. Both land use controls and monitoring would be maintained until groundwater remediation goals are met. Land use controls and long-term monitoring associated with MNA would be identical to that described in Section 12.1.2.2.

12.1.2.4 Alternative W4 – Air Sparging/SVE, HVE, and MNA

Alternative W4 would consist of in-situ treatment to address groundwater containing chlorinated contaminants above groundwater remediation goals, except groundwater located in the area beneath the steep slope north and northwest of the facility. Air sparging would be used to inject pressurized air into the shallow aquifer, resulting in volatilization of VOCs and enhanced biodegradation of contaminants susceptible to aerobic microbial degradation. Air sparging would be performed in conjunction with SVE to collect the off-gas. Air sparging/SVE would be used to treat groundwater containing chlorinated contaminants above groundwater remediation goals, except beneath the buildings and in the area north and northwest of the buildings where the slope is too steep to install wells. HVE would be used to extract groundwater and soil vapors beneath the buildings. Extracted vapors would be treated using a vapor-phase GAC system, and extracted groundwater would be treated in an oil/water separator and a GAC system. An emergency backup generator would be installed to provide a consistent power supply to the HVE system. Treatment using air sparging/SVE and HVE would be conducted for 5 years.

Groundwater and surface water containing chlorinated contaminants and fuel compounds that are remaining outside the radius of influence of the active treatment system would be treated via MNA.

Land use controls would be implemented to restrict the usage of groundwater for domestic uses such as drinking water. Both land use controls and monitoring would be maintained until groundwater remediation goals are met. Land use controls and the long-term monitoring associated with MNA would be identical to that described in Section 12.1.2.2.

12.1.2.5 Alternative W5 – Groundwater Extraction/Collection, Treatment, and Disposal

Alternative W5 would use groundwater extraction and treatment to treat groundwater containing chlorinated contaminants above groundwater remediation goals, except beneath the buildings and in the area north and northwest of the Facility where the slope is too steep to install wells. Beneath the buildings, HVE would be used to extract and treat groundwater and soil vapors. Soil vapors would be treated in a GAC system, and groundwater would be pumped to a treatment system where an oil/water separator and GAC would be used for treatment. Treated groundwater would then be disposed of in the wetlands, or may be injected to the lower regional aquifer. The disposal options for treated groundwater would require further evaluation during remedial design. It is assumed that 30 years would be required for groundwater extraction and treatment and 5 years would be required for the HVE system to treat the groundwater to the groundwater remediation goals. An emergency backup generator would be installed with this process to provide for continuous operation.

Groundwater and surface water containing chlorinated contaminants and fuel compounds that are remaining outside the radius of influence of the treatment system would be treated via MNA.

Land use controls would be implemented to restrict the usage of groundwater for domestic uses such as drinking water. Both land use controls and monitoring would be maintained until groundwater remediation goals are met. Land use controls and the long-term monitoring associated with MNA would be identical to that described in Section 12.1.2.2.

12.1.2.6 Alternative W6 – Limited Steam Stripping of Groundwater, Air Sparging/SVE, and MNA

Alternative W6 would consist of in-situ groundwater treatment using steam stripping at the chlorinated contaminant source at the end of the existing drain tile system. The treatment system uses steam stripping to raise the temperature of the subsurface such that chlorinated contaminants (and any petroleum hydrocarbons present) would be vaporized and removed through SVE. Groundwater extraction and treatment would also be used for hydraulic control during thermal treatment. In-situ groundwater treatment using steam stripping is assumed to require 1 year.

In-situ groundwater treatment using air sparging would be used to treat remaining groundwater containing chlorinated contaminants above groundwater remediation goals, except groundwater in the area north and northwest of the Facility where the slope is too steep to install wells. Air sparging would be performed in conjunction with SVE to collect the off-gas. Collected vapors would be treated in a GAC system. Treatment using air sparging/SVE would be conducted for 5 years.

Groundwater and surface water containing chlorinated contaminants and fuel compounds that are remaining outside the radius of influence of the active treatment system would be treated via MNA.

Land use controls would be implemented to restrict the usage of groundwater for domestic uses such as drinking water. Both land use controls and monitoring would be maintained until groundwater remediation goals are met. Land use controls and long-term monitoring associated with MNA would be identical to that described in Section 12.1.2.2.

12.1.2.7 Alternative W7 – HVE and MNA

Alternative W7 would use HVE to extract and treat groundwater containing chlorinated contaminants above groundwater remediation goals, except in the area north and northwest of the Facility where the slope is too steep to install wells. Groundwater would be pumped to a treatment system where an oil/water separator and GAC would be used to treat groundwater. HVE would also extract soil vapors, which would be treated in a GAC system. It is assumed that 5 years would be required for the HVE system to treat groundwater-to-groundwater remediation goals. An emergency backup generator would be installed with this process to provide for continuous operation. The treated wastewater from the HVE treatment system would be disposed of in the wetland or would be injected to the lower regional aquifer. The disposal options for treated groundwater would require further evaluation during remedial design.

Groundwater and surface water containing chlorinated contaminants and fuel compounds that are remaining outside the radius of influence of the active treatment system would be treated via MNA.

Land use controls would be implemented to restrict the usage of groundwater for domestic uses such as drinking water. Both land use controls and monitoring would be maintained until groundwater remediation goals are met. Land use controls and long-term monitoring associated with MNA would be identical to that described in Section 12.1.2.2.

12.1.2.8 Alternative W8 – Air Sparging/SVE and MNA

Alternative W8 would consist of in-situ treatment for groundwater containing chlorinated contaminants above groundwater remediation goals, except in area north and northwest of the Facility where the slope is too steep to install wells. Air sparging would be used to inject pressurized air into the shallow aquifer, resulting in volatilization of VOCs and enhanced biodegradation of contaminants susceptible to aerobic microbial degradation. Air sparging would be performed in conjunction with SVE to collect the off-gas. The off-gas would be treated in a GAC system. Treatment using air sparging/SVE would be conducted for 5 years.

Groundwater and surface water containing chlorinated contaminants and fuel compounds that are remaining outside the radius of influence of the active treatment system would be treated via MNA.

Land use controls would be implemented to restrict the usage of groundwater for domestic uses such as drinking water. Both land use controls and monitoring would be maintained until groundwater remediation goals are met. Land use controls and long-term monitoring associated with MNA would be identical to that described in Section 12.1.2.2.

12.2 Screening of Media-Specific Alternatives

The candidate media-specific remedial alternatives described in Sections 12.1.1 and 12.1.2 were evaluated with respect to effectiveness, implementability, and cost. These criteria are defined as follows:

- Effectiveness: This criterion considers the potential effectiveness of the media-specific alternative to protect human health and the environment; meet the chemical-specific groundwater remediation goals; achieve RAOs; and reduce the toxicity, mobility, and volume of contaminants.
- Implementability: This criterion measures both the technical and administrative feasibility of the alternative to meet action-specific groundwater remediation goals; construct, operate, and

maintain a reliable system; ensure the availability of treatment, storage, and disposal services; and ensure the availability of specialized equipment and workers.

- Cost: This criterion considers the cost relative to the other alternatives.

For all criteria, each candidate alternative was qualitatively ranked as low, moderate, or high, with high being the option with the highest effectiveness, implementability, and/or cost. The evaluation of these alternatives is presented in Table 12-3 for soil and sediment and Table 12-4 for groundwater and surface water. In addition to ranking the alternatives, the tables show whether the alternative was retained or rejected from further evaluation. In the case where an alternative was rejected, an explanation is provided.

12.3 Alternatives Not Retained for Detailed Analysis

The soil and sediment alternatives that were rejected during the screening process are listed below, along with the reason for the rejection:

- S6 Limited Source Removal of Chlorinated Contaminated Soils and On-Site Treatment Using LTTD, SVE – This soil and sediment alternative was rejected due to the potential for this alternative to disrupt naturally-occurring anaerobic degradation of chlorinated contaminants as a result of the introduction of oxygen into the subsurface. Disruption of anaerobic degradation could lead to the migration of chlorinated contaminants.

- S7 Limited Source Removal of Chlorinated Contaminated Soils and On-Site Treatment Using HAVE, SVE – This soil and sediment alternative was rejected due the potential for this alternative to disrupt naturally-occurring anaerobic degradation of chlorinated contaminants as a result of the introduction of oxygen into the subsurface. Disruption of anaerobic degradation could lead to migration of chlorinated contaminants.

- S9 Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal, SVE – This soil and sediment alternative was rejected due to the potential for this alternative to disrupt naturally-occurring anaerobic degradation of chlorinated contaminants as a result of the introduction of oxygen into the subsurface. Disruption of anaerobic degradation could lead to migration of chlorinated contaminants.

The groundwater and surface water alternatives that were rejected during the screening process are listed below along with the reason for the rejection:

- W4 Air Sparging/SVE, HVE, and MNA – This groundwater and surface water alternative was rejected due to the low effectiveness of air sparging in compact soils and the limited radius of influence of both air sparging and HVE in areas where utility corridors create channeling. This alternative was also rejected due to the potential for air sparging and HVE to disrupt naturally-occurring anaerobic degradation of chlorinated contaminants as a result of the introduction of oxygen into the subsurface. This could lead to migration of chlorinated contaminants.

- W5 Groundwater Extraction/Collection, Treatment, and Disposal and MNA – This groundwater and surface water alternative was rejected due to the potential for HVE to disrupt naturally-occurring anaerobic degradation of chlorinated contaminants as a result of the introduction of oxygen into the subsurface. This could lead to migration of chlorinated contaminants.

- W6 Limited Steam Stripping of Groundwater, Air Sparging/SVE, and MNA – This groundwater and surface water alternative was rejected due to the low effectiveness of air sparging in compact soils and the limited radius of influence of air sparging in areas where utility corridors create channeling. This alternative was also rejected due to the potential for air sparging to disrupt the naturally-occurring anaerobic degradation of chlorinated contaminants as a result of the introduction of oxygen into the subsurface. This could lead to migration of chlorinated contaminants.

- W7 HVE and MNA – This groundwater and surface water alternative was rejected due to the limited radius of influence of HVE in areas where utility corridors create channeling. This alternative was also rejected due to the potential for HVE to disrupt naturally-occurring anaerobic degradation of chlorinated contaminants as a result of the introduction of oxygen into the subsurface. This could lead to migration of chlorinated contaminants.
- W8 Air Sparging/SVE and MNA – This groundwater and surface water alternative was rejected due to the low effectiveness of air sparging in compact soils and the limited radius of influence of air sparging in areas where utility corridors create channeling. This alternative was also rejected due to the potential for air sparging to disrupt naturally-occurring anaerobic degradation of chlorinated contaminants as a result of the introduction of oxygen into the subsurface. This could lead to migration of chlorinated contaminants.

12.4 Alternatives Retained for Detailed Analysis

Soil and sediment alternatives S1-No Action; S2-Natural Attenuation With Confirmation Sampling; S3-Limited Steam Stripping of Chlorinated Contaminated Soils; S4-Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal, and MNA; S5-SVE for Chlorinated Contaminated Soils; and S8-Limited Source Removal of Chlorinated Contaminated Soils, On-Site Thermal Treatment were retained for detailed analysis. Groundwater and surface water alternatives W1-No Action; W2-MNA; and W3-Limited Steam Stripping of Groundwater and MNA were also retained. These alternatives were considered the most promising for the site, and are summarized in Table 12-5. In Section 13, these alternatives will be combined into site-wide cleanup remedy alternatives for detailed evaluation to identify the most appropriate and feasible cleanup alternative that will meet the RAOs for Site DP98.

Table 12-1

Candidate Remedial Alternatives for Soil and Sediment

M

General Response Action	Technology Type	Process Option	Alternative S1 No Action	Alternative S2 Natural Attenuation with Confirmation Sampling	Alternative S3 Limited Steam Stripping of Chlorinated Soils	Alternative S4 Limited Source Removal of Chlorinated Soils/ Off-Site Treatment and Disposal	Alternative S5 SVE	Alternative S6 Limited Source Removal of Chlorinated Soils/ On-Site LTTD/ SVE	Alternative S7 Limited Source Removal of Chlorinated Soils/ On-Site HAVE/ SVE	Alternative S8 Limited Source Removal of Chlorinated Soils/ On-Site Thermal Treatment	Alternative S9 Limited Source Removal of Chlorinated Soils/ Off-Site Treatment and Disposal/ SVE
No action	No action	No action	●								
Natural attenuation	Natural attenuation	Natural attenuation	●	●	●	●	●	●	●	●	●
Land use controls*	Access and use restrictions	Restrict digging		●	●	●	●	●	●	●	●
Monitoring	Monitoring	Confirmation Sampling		●	●	●	●	●	●	●	●
Removal	Mechanical excavation	Shallow excavation				●		●	●	●	●
Removal	Mechanical excavation	Removal and closure of drain tile system				●		●	●	●	●
Ex situ treatment	Thermal treatment	Low-temperature thermal desorption						●		●	
Ex situ treatment	Thermal treatment	HAVE							●	●	
In-situ treatment	Physiochemical	SVE			●		●	●	●		●
In-situ treatment	Thermal treatment	Steam stripping			●						
Disposal	Off-site disposal	Incineration at a permitted TSD facility				●					●
Disposal	On-site disposal	Material reuse as backfill						●	●	●	

HAVE – Hot air vapor extraction
LTTD – Low-temperature thermal desorption
SVE – Soil vapor extraction
TSD – Treatment, storage, and disposal
* Land use controls are included under the Basewide Land Use Control Management Action Plan for Elmendorf AFB.

Table 12-2

Candidate Remedial Alternatives for Groundwater and Surface Water

General Response Action	Technology Type	Process Option	Alternative W1 No Action	Alternative W2 Monitored Natural Attenuation (MNA)	Alternative W3 Limited Steam Stripping/ MNA	Alternative W4 Air Sparging/ SVE/HVE/ MNA	Alternative W5 Groundwater Extraction/ Collection/ Treatment/ Disposal	Alternative W6 Limited Steam Stripping/Air Sparging With SVE/ MNA	Alternative W7 HVE/MNA	Alternative W8 Air Sparging With SVE /MNA
No action	No action	No action	●							
Natural attenuation	Natural attenuation	Monitored natural attenuation	●	●	●	●	●	●	●	●
Land use controls*	Access and use restrictions	Restrict groundwater use		●	●	●	●	●	●	●
Monitoring	Monitoring	Long-term monitoring		●	●	●	●	●	●	●
Removal	Groundwater extraction	Extraction wells			●		●	●		
Ex-situ treatment	Physiochemical	GAC/liquid phase carbon adsorption			●	●	●	●	●	
In-situ treatment	Physiochemical	Air sparging				●		●		●
In-situ treatment	Thermal	Steam stripping			●			●		
Disposal	On-site disposal	Surface water discharge			●	●	●	●	●	
Disposal	On-site disposal	Deep well injection			●	●	●	●	●	

GAC – Granular activated carbon
LTTD – Low-temperature thermal desorption
SVE – Soil vapor extraction
* Land use controls are included under the Basewide Land Use Control Management Action Plan for Elmendorf AFB.

Table 12-3

Screening of Media-Specific Alternatives for Soil and Sediment

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
S1 **No Action**	**Low** • Low effectiveness at protecting human health and the environment in the short term. Exposure pathways would not be altered. No administrative controls to prevent the disturbance of soils. • Without monitoring, the progress of natural attenuation and accompanying risk reduction could not be assessed (long-term effectiveness). • May be capable of achieving chemical-specific soil/sediment remediation goals (residential) and media-specific RAOs, but no way to verify. • Would slowly decrease the toxicity and volume of contaminated soil through natural attenuation. Does not include monitoring; therefore, the rate and degree of contaminant reduction would not be known.	**High** • Highly feasible since no construction or operation is involved. • No off-site services required. • No specialized equipment required.	**Low**	**Retained**
S2 **Natural Attenuation with Confirmation Sampling**	**Moderate** • Moderate effectiveness at protecting human health in the short term through access restrictions and administrative controls. Confirmation soil sampling used to assess effectiveness in meeting soil/sediment remediation goals. • Land use controls* would be used to protect human health by controlling exposure to contaminated soil through digging restrictions until soil/sediment remediation goals are achieved.	**High** • Highly feasible since no construction or operation is involved. • No off-site services required. • No specialized equipment required. • Site access would need to be coordinated.	**Low**	**Retained**

Table 12-3 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
S2 **Natural Attenuation with Confirmation Sampling (Continued)**	• Ability to meet chemical-specific soil/sediment remediation goals (residential). Media-specific RAOs would not be determined until after confirmation soil sampling is performed. • Would slowly decrease the toxicity and volume of contaminated soil and sediment through natural attenuation.			
S3 **Limited Steam Stripping of Chlorinated Soils**	**Moderate** • In-situ thermal treatment would be implemented within a 25-foot radius near the end of the Building 18224 drain tile system and would include steam injection, SVE, and groundwater extraction. Remaining contaminated soils (chlorinated contaminants and fuel compounds) and sediment in the wetland (fuel compounds) would be addressed by natural attenuation. In-situ thermal treatment would be effective at protecting human health and the environment in the treatment area. • Land use controls*, such as digging restrictions would be implemented to protect human health by controlling exposure to contaminated soil until soil/sediment remediation goals are achieved. • Steam injection would have a high probability of achieving groundwater remediation goals and RAOs in the treatment area. Ability to meet chemical-specific soil/sediment remediation goals (residential). Media-specific RAOs throughout the remainder of the site would not be evaluated until confirmation soil sampling is performed.	**Low** • This combination of process options would require substantial construction, operation, and maintenance for the stream stripping, SVE and groundwater extraction. • Steam injection wells can be installed near the end of the Building 18224 drain tile. Footprint space is available for steam stripping. Very significant power requirements would be needed for steam stripping. • Carbon consumed during groundwater and off-gas treatment would require regeneration or disposal at a RCRA facility.	**High**	**Retained**

Table 12-3 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
S3 **Limited Steam Stripping of Chlorinated Soils (Continued)**	**Moderate** • Significant reduction in toxicity, mobility, and volume through treatment at the chlorinated contaminants source area near the end of the Building 18224 drain tile. In all other areas, would slowly decrease the toxicity and volume of contaminated soil and sediment through natural attenuation. • In the area of treatment, this alternative is very aggressive and would be effective at both volatilizing subsurface COCs and removing them from the subsurface via SVE and groundwater extraction wells.	**Low**	**High**	**Retained**
S4 **Limited Source Removal of Chlorinated Soils/ Off-Site Treatment and Disposal**	**Moderate** • Source removal, off-site treatment and disposal would be implemented within a 25-foot radius near the end of the Building 18224 drain tile. Remaining contaminated soils (chlorinated contaminants and fuel compounds) and sediment in the wetland (fuel compounds) would be addressed by natural attenuation. Excavation and off-site treatment would be effective at protecting human health and the environment within the excavation area. • Land use controls*, including digging restrictions, would be used to protect human health by controlling exposure to contaminated soil until soil/sediment remediation goals are achieved.	**Moderate** • Removal of chlorinated soil near the Building 18224 drain tile system would require staging space and temporary sediment erosion controls. • Excavation, transport, treatment, and backfilling would require project-specific approvals to meet action-specific soil/sediment remediation goals. • No operation or maintenance would be required after construction. • Off-site treatment and disposal facilities for soils containing chlorinated solvent are limited and would likely require shipment outside the region. Off-site treatment would require coordination.	**Moderate to High**	**Retained**

Table 12-3 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
S4 **Limited Source Removal of Chlorinated Soils/ Off-Site Treatment and Disposal (Continued)**	• Would meet chemical-specific soil/sediment remediation goals (residential). Media-specific RAOs at chlorinated contaminants source area to an estimated depth of 10 feet bgs. Ability to meet chemical-specific RAOs throughout the site would not be evaluated until confirmation soil sampling is performed. Significant reduction in toxicity, mobility, and volume through treatment at the chlorinated contaminants source area near the end of the Building 18224 drain tile. Excavation and off-site treatment would be limited to soils located at depths of less than 10 feet bgs. Would slowly decrease the toxicity and volume of contaminated soil and sediment outside the source area through natural attenuation.	• Excavation of contaminated soils would require hazardous materials precautions. Considerations include segregation of soils, excavation near the water table, and exposure to volatile contaminants during excavation. • Site access would need to be coordinated during active treatment.		
S5 **SVE for Chlorinated Soils**	**Moderate** • SVE would be implemented to address all soils containing chlorinated contaminants in the vadose zone, except where the slope is too steep to install SVE wells. Remaining contaminated soils (chlorinated and fuel contaminants) and sediments would be addressed by natural attenuation. SVE would be efficient at protecting human health and the environment. However, the operation of SVE may turn site aerobic and thereby limit anaerobic degradation of chlorinated solvent for the duration of SVE operation.	**Moderate** • SVE could be implemented without any significant impediments. • SVE system would require operation and maintenance after construction. • Carbon consumed during off-gas treatment would require regeneration or disposal at a RCRA facility.	**Moderate**	**Retained**

Table 12-3 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
S5 **SVE for Chlorinated Soils (Continued)**	**Moderate** • Land use controls* would be used to protect human health by controlling exposure to contaminated soil through digging restrictions until soil/sediment remediation goals are achieved. • Would meet chemical-specific soil/sediment remediation goals (residential) and media-specific RAOs for chlorinated solvent in vadose zone soils where SVE wells would be installed. Ability to meet chemical-specific RAOs throughout the site would not be determined until after confirmation soil sampling is performed. Impact of aerobic SVE on the treatment time for the anaerobic degradation of chlorinated solvent is not known. • Significant reduction in toxicity, mobility, and volume through treatment for chlorinated contaminant soils in the vadose zone where SVE wells would be installed and where the tight formation does not limit SVE treatment efficiency. Would slowly decrease the toxicity and volume of contaminated soil and sediment outside the treatment area through natural attenuation.	**Moderate**	**Moderate**	**Retained**

Table 12-3 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
S6 **Limited Source Removal of Chlorinated Soils and On-Site Treatment Using LTTD and SVE**	**High** • Source removal, on-site treatment using LTTD and backfill of treated soils would be implemented for a 25-foot radius near the end of the Building 18224 drain tile. SVE would be implemented to address remaining soils containing chlorinated solvent in the vadose zone, except where the slope is too steep to install SVE wells. Remaining contaminated soils (chlorinated and fuel contaminants) and sediments would be addressed by natural attenuation. Excavation and treatment of soils combined with SVE would be highly effective in protecting human health and the environment. However, the operation of SVE may turn site aerobic and thereby limit anaerobic degradation of chlorinated contaminants for the duration of SVE operation. • Land use controls* would be used to protect human health by controlling exposure to contaminated soil through digging restrictions, until soil/sediment remediation goals are achieved.	**Low** • Removal of chlorinated contaminated soil near the Building 18224 drain tile would require staging space and temporary sediment erosion controls. • Excavation, treatment, and backfilling would require project-specific approvals. • Carbon consumed during off-gas treatment would require regeneration or disposal at a RCRA facility. • Low volume of soil from chlorinated contaminants source to be treated (364 cubic yards) may not be sufficient for LTTD vendor to undergo approval process and agree to mobilize to the site. • Excavation of contaminated soils would require hazardous materials precautions. Considerations include segregation of soils, excavation near the water table, and exposure to volatile contaminants during excavation. • Site access would need to be coordinated during active treatment. • Requires mobilization of LTTD unit on-site, including obtaining unit, utilities hookup, and fuel purchase.	**High**	**Rejected** • The use of SVE for the vadose zone soils outside the chlorinated source area would provide limited additional benefit and may disrupt anaerobic degradation of chlorinated contaminants.

Table 12-3 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
S6 **Limited Source Removal of Chlorinated Soils and On-Site Treatment Using LTTD and SVE (Continued)**	**High** • Would meet chemical-specific groundwater remediation goals (residential) and media-specific RAOs throughout the site except where slope is too steep to install SVE wells and in the wetland. Ability to meet chemical-specific RAOs throughout the site would not be evaluated until confirmation soil sampling is completed. Impact of aerobic SVE on the treatment time for the anaerobic degradation of chlorinated contaminants is not known. • Significant reduction in toxicity, mobility, and volume through treatment at the chlorinated contaminant source area near the end of the Building 18224 drain tile and in vadose zone soils where SVE wells would be installed. Excavation and on-site treatment would be limited to soils located at depths of less than 10 feet bgs. Tight formation may limit SVE treatment efficiency. Would slowly decrease the toxicity and volume of contaminated soil and sediment outside the treatment area through natural attenuation.	**Low**	**High**	**Rejected**

Table 12-3 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
S7 **Limited Source Removal of Chlorinated Soils and On-Site Treatment Using HAVE, and SVE**	**High** • Source removal, on-site treatment using HAVE, and backfill of treated soils would be implemented within a 25-foot radius near the end of the Building 18224 drain tile. SVE would be implemented to address remaining soils containing chlorinated contaminants in the vadose zone, except where the slope is too steep to install SVE wells. Remaining contaminated soils (chlorinated contaminants and fuel compounds) and sediments in wetland (fuel compounds) would be addressed by natural attenuation. Excavation and treatment of soils combined with SVE would be highly effective in protecting human health and the environment. However, the operation of SVE may turn site aerobic and thereby limit anaerobic degradation of chlorinated contaminants for the duration of SVE operation. • Land use controls* would be used to protect human health by controlling exposure to contaminated soil through digging restriction, until soil/sediment remediation goals are achieved.	**Low** • Removal of chlorinated contaminants soil near the Building 18224 drain tile would require staging space and temporary sediment erosion controls. • Excavation, treatment, and backfilling would require project-specific approvals to meet action – specific soil/sediment remediation goals. • Carbon consumed during off-gas treatment would require regeneration or disposal at a RCRA facility. • Low volume of soil from chlorinated contaminants source to be treated (364 cubic yards) may not be sufficient for HAVE vendor to agree to mobilize to the site. • Excavation of contaminated soils would require hazardous materials precautions. Considerations include segregation of soils, excavation near the water table, and the exposure to volatile contaminants during excavation. • Site access would need to be coordinated during active treatment. • Requires mobilization of HAVE unit on-site, including obtaining unit, utilities hookup, and fuel purchase.	**High**	**Rejected** The use of SVE for the vadose zone soils outside the chlorinated source area would provide limited additional benefit and may disrupt anaerobic degradation of chlorinated contaminants.

Table 12-3 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
S7 **Limited Source Removal of Chlorinated Soils and On-Site Treatment Using HAVE, and SVE (Continued)**	• Would meet chemical-specific soil/sediment remediation goals (residential) and media-specific RAOs throughout the site except where slope is too steep to install SVE wells and in the wetland. Ability to meet chemical-specific RAOs throughout the site would not be fully evaluated until after confirmation soil sampling is performed. Impact of aerobic SVE on the treatment time for the anaerobic degradation of chlorinated contaminants is not known. • Significant reduction in toxicity, mobility, and volume through treatment at the chlorinated contaminants source area near the end of the Building 18224 drain tile and in vadose zone soils where SVE wells would be installed. Excavation and on-site treatment would be limited to soils located at depths of less than 10 feet bgs. Tight formation may limit SVE treatment efficiency. Would slowly decrease the toxicity and volume of contaminated soil and sediment outside the treatment area through natural attenuation.	**Low**	**High**	**Rejected**

Table 12-3 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
S8 **Limited Source Removal of Chlorinated Soils and On-Site Thermal Treatment**	**Moderate** • Source removal, on-site thermal treatment (i.e., LTTD or HAVE), and disposal would be implemented for a 25-foot radius near the end of the Building 18224 drain tile. Both HAVE and LTTD are considered equally effective. Remaining contaminated soils (chlorinated contaminants and fuel compounds) and sediments in wetland (fuel compounds) would be addressed by natural attenuation. Excavation and on-site treatment would be effective in protecting human health and the environment within the excavation area. • Land use controls* would be used to protect human health by controlling exposure to contaminated soil through digging restrictions until soil/sediment remediation goals are achieved. • Would meet chemical-specific soil/sediment remediation goals (residential) and media-specific RAOs at chlorinated contaminants source area to an estimated depth of 10 feet bgs. Ability to meet chemical-specific RAOs throughout the site would not be fully evaluated until after confirmation soil sampling is completed.	**Low** • Removal of chlorinated soil near the Building 18224 drain tile would require staging space and temporary sediment erosion controls. • Excavation, treatment, and backfilling would require project-specific approvals to meet action-specific groundwater remediation goals. • Requires mobilization of unit on-site, including obtaining unit, utilities hookup, and fuel purchase. • Excavation of contaminated soils would require hazardous materials precautions. Considerations include segregation of soils, excavation near the water table, and the exposure to volatile contaminants during excavation. • Site access would need to be coordinated during active treatment.	**Moderate to High**	**Retained**

Table 12-3 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
S8 **Limited Source Removal of Chlorinated Soils and On-Site Thermal Treatment (Continued)**	**Moderate** • Significant reduction in toxicity, mobility, and volume through treatment at the chlorinated contaminants source area near the end of the Building 18224 drain tile. Excavation and on-site treatment would be limited to soils at depths of less than 10 feet bgs. Would slowly decrease the toxicity and volume of contaminated soil and sediment outside the treatment area through natural attenuation	**Low**	**Moderate to High**	**Retained**
S9 **Limited Source Removal of Chlorinated Soils, Off-Site Treatment and Disposal, and SVE**	**High** • Source removal, off-site treatment and disposal would be implemented within a 25-foot radius near the end of the Building 18224 drain tile. SVE would be implemented to address remaining soils containing chlorinated contaminants in the vadose zone, except where the slope is too steep to install SVE wells. Remaining contaminated soils (chlorinated contaminants and fuel compounds) and sediments in wetland (fuel compounds) would be addressed by natural attenuation. Excavation and treatment of soils combined with SVE would be highly effective in protecting human health and the environment. However, the operation of SVE may turn site aerobic and thereby limit anaerobic degradation of chlorinated contaminants for the duration of SVE operation.	**Low** • Removal of chlorinated soil near the Building 18224 drain tile would require staging space and temporary sediment erosion controls. • Excavation, transport, treatment, and backfilling would require project-specific, manifesting, and approvals to meet action-specific groundwater remediation goals. • SVE system would require operation and maintenance after construction. • SVE could be implemented without any significant impediments. • Carbon consumed during off-gas treatment would require regeneration or disposal at a RCRA facility.	**Moderate to High**	**Rejected** The use of SVE in the vadose zone soils outside the chlorinated source area would provide limited additional benefit and may disrupt anaerobic degradation of chlorinated contaminants.

Table 12-3 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
S9 **Limited Source Removal of Chlorinated Soils, Off-Site Treatment and Disposal, and SVE (Continued)**	**High** • Land use controls* would be used to protect human health by controlling exposure to contaminated soil through digging restrictions, until soil/sediment remediation goals are achieved. • Would meet chemical-specific soil/sediment remediation goals (residential) and media-specific RAOs throughout the site, except where slope is too steep to install SVE wells and in the wetland. Ability to meet chemical-specific RAOs throughout the site would not be fully evaluated until after confirmation soil sampling is performed. Impact of aerobic SVE on the treatment time for the anaerobic degradation of chlorinated contaminants is not known. • Significant reduction in toxicity, mobility, and volume through treatment at the chlorinated contaminants source area near the end of the Building 18224 drain tile and in vadose zone soils where SVE wells would be installed. Excavation and off-site treatment would be limited to soils located at depths of less than 10 feet bgs. Tight formation may limit SVE treatment efficiency. Would slowly decrease the toxicity and volume of contaminated soil and sediment outside the treatment area through natural attenuation.	**Low** • Off-site treatment and disposal facilities for chlorinated contaminants soils are limited, and shipment outside the region is assumed. Off-site treatment would require coordination. • Excavation of contaminated soils would require hazardous materials precautions. Considerations include segregation of soils, excavation near the water table, and exposure to volatile contaminants during excavation. • Site access would need to be coordinated during active treatment.	**Moderate to High**	**Rejected**

*Land Use Controls are included under the Basewide Land Use Control Management Action Plan for Elmendorf AFB.

Groundwater remediation goals - Applicable or relevant and appropriate requirements

COCs – Contaminants of concern
HAVE – Hot air vapor extraction
LTTD – Low-temperature thermal desorption
MNA – Monitored natural attenuation
RAOs – Remedial action objectives
RCRA – Resource Conservation and Recovery Act
SVE – Soil vapor extraction

Table 12-4

Screening of Media-Specific Alternatives for Groundwater and Surface Water

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
W1 **No Action**	**Low** • Low effectiveness at protecting human health and the environment in the short term. Human and environmental receptors would be exposed to contaminated surface water until COCs degrade to acceptable levels. • Without monitoring, the progress of natural attenuation and accompanying reduction in risk could not be assessed (long-term effectiveness). In addition, no action leaves open the possibility that future base personnel and residents might use contaminated upper aquifer groundwater. • May be capable of achieving chemical-specific groundwater remediation goals (residential) and media-specific RAOs, but no way to verify. • Would slowly decrease the toxicity and volume of contaminated groundwater through natural attenuation. Does not include monitoring; therefore, the rate and degree of contaminant reduction would not be known.	**High** • Highly feasible since no construction or operation is involved. • No approvals required. • No off-site services required. • No specialized equipment required.	**Low**	**Retained**
W2 **Monitored Natural Attenuation**	**Moderate** • Moderate effectiveness at protecting human health in the short term through use restrictions and administrative controls. Effectiveness of MNA cannot be fully evaluated until groundwater modeling is performed.	**High** • Highly feasible since no construction or operation is involved. • No approvals required. • No off-site services required. • No specialized equipment required. • Site access would need to be coordinated.	**Low**	**Retained**

Table 12-4 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
W2 **Monitored Natural Attenuation (Continued)**	**Moderate** • Land use controls* would be used to protect human health by controlling exposure to contaminated groundwater through digging and groundwater use restrictions until groundwater remediation goals are achieved. • Ability to meet chemical-specific groundwater remediation goals (residential) and media-specific RAOs cannot be fully evaluated until modeling is performed. • Would slowly decrease the toxicity and volume of contaminated groundwater and surface water through natural attenuation. The rate and degree of contaminant reduction would be determined through groundwater monitoring and modeling.	**High**	**Low**	**Retained**
W3 **Limited Steam Stripping of Groundwater and MNA**	**Moderate** • In-situ thermal treatment would be implemented within a 25-foot radius near the end of the Building 18224 drain tile and would include steam injection, SVE, and groundwater extraction. Remaining contaminated groundwater (chlorinated contaminants and fuel compounds) and surface water in the wetland (fuel compounds) would be addressed by MNA. This combination of process options would be effective at protecting human health and the environment in the treatment area. Effectiveness of MNA would not be fully evaluated until modeling is performed. • Migration of contaminants resulting from the application of heat to the subsurface must be controlled for thermal treatment to be effective.	**Low** • Steam would be generated on-site and injected into the subsurface. The insulated piping would be connected to a mobile steam generation plant. Existing PVC monitoring wells within the treatment zone would require removal prior to steam treatment. This system would require continual monitoring and maintenance by a trained operator. The steam plant/power plant would need a reliable power source for operation. • Action-specific groundwater remediation goals would be met for air discharge and well construction. • Carbon consumed during groundwater and off-gas treatment would require regeneration or disposal at a RCRA facility. • Site access would need to be coordinated for both active treatment and MNA.	**High**	**Retained**

Table 12-4 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
W3 Limited Steam Stripping of Groundwater and MNA (Continued)	**Moderate** • Land use controls* would be used to protect human health by controlling groundwater use until groundwater remediation goals are achieved. • Chlorinated Contaminants (TCE) and fuel compounds (DRO) in groundwater within the thermal treatment area would be reduced to levels below groundwater remediation goals. Remaining contaminated groundwater and surface water would be addressed by MNA. • RAOs would be met for chlorinated contaminants and fuel compounds within the treatment area. Ability to meet chemical-specific RAOs throughout the site cannot be fully evaluated until MNA and groundwater modeling is performed. • Chlorinated and fuel compounds would be vaporized and removed in the thermal treatment areas. Would slowly decrease the toxicity and volume of contaminated groundwater and surface water outside the treatment area through MNA. The rate and degree of contaminant reduction using natural attenuation would be determined through modeling.	**Low**	**High**	**Retained**

Table 12-4 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
W4 **Air Sparging/ SVE, HVE, and MNA**	**Moderate** • Air sparging/SVE would be used to treat groundwater containing chlorinated contaminants except under buildings and where the slope is too steep to install air sparging/SVE wells. Sparging would have limited effectiveness in compact soils and channeling may occur. HVE would be used to treat groundwater containing chlorinated and fuel compounds beneath buildings. However, presence of higher permeability zones (utility corridors) would limit effectiveness by reducing the radius of influence. Remaining contaminated groundwater would be addressed by MNA. However, the operation of air sparging and HVE may turn the site aerobic and thereby limit anaerobic degradation of chlorinated contaminants for the duration of air sparging and HVE. Effectiveness of MNA cannot be fully evaluated until groundwater modeling is performed. Treatability tests would be needed to verify effectiveness. • Land use controls* would be used to protect human health by controlling exposure to contaminated groundwater through digging and groundwater use restrictions until groundwater remediation goals are achieved. • Air sparging/SVE has potential to meet groundwater remediation goals for chlorinated contaminants. HVE would be used to treat contaminants underneath the DP98 buildings. Ability to meet chemical-specific groundwater remediation goals (residential) and media-specific RAOs throughout the site cannot be fully evaluated until groundwater modeling is performed.	**Moderate** • In-situ air sparging and HVE systems could not be reliably operated in the wintertime. A secure power source would be needed to reliably operate the treatment systems outside winter months. • Action-specific groundwater remediation goals would be met for air discharges and well construction. • Carbon consumed during groundwater and off-gas treatment would require regeneration or disposal at a RCRA facility. • System could be remotely operated but requires a trained operator to be present on a daily to weekly basis. • Equipment for technology readily available. • Site access would need to be coordinated for both active treatment and MNA.	**Moderate**	**Rejected** Low effectiveness for air sparging due to compact soils, channeling, and limited radius of influence. Air sparging/SVE and HVE both add oxygen, which may disrupt the anaerobic degradation of chlorinated contaminants.

Table 12-4 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
W4 **Air Sparging/ SVE, HVE, and MNA (Continued)**	**Moderate** • Chlorinated contaminants would be volatilized and removed in the treatment area. Would slowly decrease toxicity and volume of contaminated groundwater and surface water outside the treatment area through MNA. The rate and degree of contaminant reduction using natural attenuation would be determined through modeling.	**Moderate**	**Moderate**	**Rejected**
W5 **Groundwater Extraction/ Collection, Treatment. and Disposal and MNA**	**Moderate** • Groundwater extraction and treatment with GAC would be used to treat groundwater containing chlorinated contaminants and fuel compounds, except under the buildings and where the slope is too steep to install extraction wells. HVE would be used to treat groundwater containing chlorinated contaminants and fuel compounds beneath buildings. However, presence of higher permeability zones (utility corridors) would limit effectiveness by reducing the radius of influence. Remaining contaminated groundwater would be addressed by MNA. However, the operation of HVE may turn the site aerobic and thereby limit anaerobic degradation of chlorinated contaminants for the duration of HVE. Effectiveness of MNA cannot be fully evaluated until modeling is performed. Treatability tests would be needed to verify effectiveness. • Land use controls* would be used to protect human health by controlling exposure to contaminated groundwater through digging and groundwater use restrictions until groundwater remediation goals are achieved.	**Moderate** • The technical feasibility of extracting groundwater from the site for aboveground treatment cannot be fully evaluated at this time. Data gaps exist concerning the volume of water that may be pumped. • Action-specific groundwater remediation goals would be met for air discharge, well construction, and disposal of treated water into the wetland (Clean Water Act), or into a deep well. • A secure power source would be needed to reliably operate the pump and treat system and the HVE system in winter months. • Disposal of treated effluent would be through a combination of disposal into the wetland or into a deep well, depending on the time of year and hydrological modeling. Disposal would require agency approval. • GAC consumed during treatment would require regeneration or disposal at a RCRA facility. • System could be remotely operated but requires a trained operator to be present on a daily to weekly basis.	**Moderate/High**	**Rejected** HVE adds oxygen which may disrupt anaerobic degradation of chlorinated contaminants.

Table 12-4 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
W5 Groundwater Extraction/ Collection, Treatment. and Disposal and MNA (Continued)	**Moderate** • The ability to achieve RAOs in groundwater for chlorinated contaminants and fuel compounds is dependent upon the amount of groundwater pumped. The ability to achieve groundwater remediation goals is also dependent on upland source removal. Pump and pilot testing would be required to fully evaluate effectiveness and implementability of pump and treat. Ability of natural attenuation to meet chemical-specific groundwater remediation goals (residential) and media-specific RAOs for the remaining contamination would not be fully evaluated until groundwater modeling is completed. • Provides for high reduction in the volume of affected groundwater and surface water through treatment with GAC, as long as hydrologic conditions allow for adequate pumping. Would slowly decrease toxicity and volume of contaminated groundwater and surface water outside the treatment area through MNA. The rate and degree of contaminant reduction using natural attenuation would be determined through modeling.	**Moderate** • Site access would need to be coordinated for both active treatment and MNA.	**Moderate/High**	**Rejected**
W6 Limited Steam Stripping of Groundwater, Air Sparging/ SVE, and MNA	**High** • In-situ thermal treatment would be implemented within a 25-foot radius near the end of the Building 18224 drain tile and would include steam injection, SVE, and groundwater extraction. Air sparging/SVE would be used to treat remaining groundwater containing chlorinated contaminants, except where the slope is too steep to install air sparging/SVE wells. Air sparging would have limited effectiveness in compact soils and channeling may occur.	**Low** • The treatment systems could not be reliably operated in the wintertime. Steam would be generated on-site and injected into the subsurface. A network of insulated piping would be connected to a mobile steam generation plant. Existing PVC monitoring wells within the treatment zone would require removal prior to steam treatment. This system would require continual monitoring and maintenance by a trained operator.	**High**	**Rejected** Low effectiveness for air sparging due to compact soils, channeling, and limited radius of influence. Air sparging/SVE adds oxygen, which may disrupt the anaerobic degradation of chlorinated contaminants.

Table 12-4 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
W6 Limited Steam Stripping of Groundwater, Air Sparging/ SVE, and MNA (Continued)	**High** • Presence of higher permeability zones (utility corridors) would also limit effectiveness by reducing the radius of influence. In addition, the operation of the air sparging system may turn the site aerobic and thereby limit anaerobic degradation of chlorinated contaminants for the duration of air sparging. Remaining contaminated groundwater would be addressed by MNA. Effectiveness of MNA would not be fully evaluated until groundwater modeling is performed. Treatability tests would be needed to verify effectiveness. • Migration of contaminants resulting from the application of heat to the subsurface must be controlled for thermal treatment to be effective. • Land use controls* would be used to protect human health by controlling exposure to contaminated groundwater through digging and groundwater use restrictions until groundwater remediation goals are achieved. • Chlorinated contaminants (TCE) and fuel compounds (DRO) in groundwater within the thermal treatment area would be reduced to levels below groundwater remediation goals. Chlorinated contaminants outside of the thermal treatment area would be reduced to levels below groundwater remediation goals through air sparging. Remaining contaminated groundwater and surface water would be addressed by MNA. Ability of natural attenuation to meet chemical-specific groundwater remediation goals (residential) and media-specific RAOs would not be fully evaluated until groundwater modeling is performed.	**Low** • In addition, the treatment systems would need a reliable power source for operation. The presence of utility corridors may lead to uneven treatment while air emissions may be a concern for workers in the DP98 buildings. • Action-specific groundwater remediation goals would be met for air discharges and well construction. • Carbon consumed during off-gas treatment would require regeneration or disposal at a RCRA facility. • Steam equipment is specialized but is readily available. Scheduling of contractor for installation may require coordination. • Site access would need to be coordinated for both active treatment and MNA.	**High**	**Rejected**

Table 12-4 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
W6 **Limited Steam Stripping of Groundwater, Air Sparging/ SVE, and MNA (Continued)**	**High** • RAOs would be met for TCE and DRO within the treatment area. Ability to meet chemical-specific RAOs throughout the site would not be fully evaluated until modeling is performed. • Chlorinated contaminants would be volatilized and removed in the treatment area. Would slowly decrease toxicity and volume of contaminated groundwater and surface water outside the treatment area through MNA. The rate and degree of contaminant reduction using MNA would be determined through modeling.	**Low**	**High**	**Rejected**
W7 **HVE and MNA**	**Moderate** • HVE would be used to treat groundwater containing chlorinated contaminants, except where the slope is too steep to install HVE wells. Presence of higher permeability zones (utility corridors) would limit effectiveness by reducing the radius of influence. In addition, the operation of the HVE system may turn the site aerobic and thereby limit anaerobic degradation of chlorinated contaminants for the duration of HVE. Remaining contaminated groundwater would be addressed by MNA. Effectiveness of MNA would not be fully evaluated until groundwater modeling is performed. Treatability tests would be needed to verify effectiveness. • Land use controls* would be used to protect human health by controlling exposure to contaminated groundwater through digging and groundwater use restrictions until groundwater remediation goals are achieved.	**Moderate** • The HVE systems could not be reliably operated in the wintertime. A secure power source would be needed to reliably operate the treatment system outside winter months. • Action-specific groundwater remediation goals would be met for air discharges and well construction. • Carbon consumed during groundwater and off-gas treatment would require regeneration or disposal at a RCRA facility. • System could be remotely operated but requires a trained operator to be present on a daily to weekly basis. • Equipment for technology readily available. • Site access would need to be coordinated for both active treatment and MNA.	**Moderate/High**	**Rejected** HVE may disrupt anaerobic degradation of chlorinated contaminants.

Table 12-4 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
W7 **HVE and MNA (Continued)**	**Moderate** • HVE has potential to meet groundwater remediation goals for chlorinated contaminants. Ability to meet chemical-specific groundwater remediation goals (residential) and media-specific RAOs throughout the site would not be fully evaluated until groundwater modeling is performed. • Chlorinated contaminants would be volatilized and removed in the treatment area. Would slowly decrease toxicity and volume of contaminated groundwater and surface water outside the treatment area through MNA. The rate and degree of contaminant reduction using natural attenuation would be determined through groundwater modeling.	**Moderate**	**Moderate/High**	**Rejected**
W8 **Air Sparging/ SVE and MNA**	**Moderate** • Air sparging/SVE would be used to treat groundwater containing chlorinated contaminants, except where the slope is too steep to install air sparging/SVE wells. Air sparging would have limited effectiveness in compact soils and channeling may occur. Presence of higher permeability zones (utility corridors) would limit effectiveness by reducing the radius of influence. In addition, the operation of the air sparging system may turn the site aerobic and thereby limit anaerobic degradation of chlorinated contaminants for the duration of air sparging. Remaining contaminated groundwater would be addressed by MNA. Effectiveness of MNA would not be fully evaluated until ground modeling is performed. Treatability tests would be needed to verify effectiveness.	**Low** • The in-situ sparging system could not be reliably operated in the wintertime. • The ability to safely implement sparging technologies near the DP98 buildings is questionable. The presence of utility corridors may lead to uneven treatment, while air emissions may be a concern for workers in the DP98 buildings. • Action-specific groundwater remediation goals would be met for air discharges and well construction. • Carbon consumed during off-gas treatment would require regeneration or disposal at a RCRA facility. • System could be remotely operated but requires a trained operator to be present on a daily to weekly basis. • Equipment for technology readily available.	**Moderate**	**Rejected** Low effectiveness for air sparging due to compact soils, channeling, and limited radius of influence. Air sparging/SVE adds oxygen, which may disrupt the anaerobic degradation of chlorinated contaminants.

Table 12-4 (Continued)

Alternative	Effectiveness	Implementability	Relative Cost	Evaluation Result
W8 Air Sparging/ SVE and MNA (Continued)	**Moderate** • Land use controls* would be used to protect human health by controlling exposure to contaminated groundwater through digging and groundwater use restrictions until groundwater remediation goals are achieved. • Air sparging/SVE has potential to meet groundwater remediation goals for chlorinated contaminants. Ability to meet chemical-specific groundwater remediation goals (residential) and media-specific RAOs throughout the site would not be fully evaluated groundwater modeling is performed. • Chlorinated contaminants would be volatilized and removed in the treatment area. Would slowly decrease toxicity and volume of contaminated groundwater and surface water outside the treatment area through MNA. The rate and degree of contaminant reduction using MNA would be determined through groundwater modeling.	**Low** • Site access would need to be coordinated for both active treatment and MNA.	**Moderate**	**Rejected**

* Land use controls are included under the Basewide Land Use Control Management Action Plan for Elmendorf AFB.
Groundwater remediation goals – Applicable or relevant and appropriate requirements
COCs – Contaminants of concern
DRO – Diesel range organics
GAC – Granular activated carbon
LTTD – Low-temperature thermal desorption
RAOs – Remedial action objectives
RCRA – Resource Conservation and Recovery Act
SVE – Soil vapor extraction
TCE – Trichloroethene

Table 12-5

Media-Specific Alternatives Retained for Detailed Analysis

Soil and Sediment Alternatives	Groundwater and Surface Water Alternatives
Alternative S1 – No Action	Alternative W1 – No Action
Alternative S2 – Natural Attenuation with Confirmation Sampling	Alternative W2 – Monitored Natural Attenuation
Alternative S3 – Limited Steam Stripping of Chlorinated Contaminated Soils	Alternative W3 – Limited Steam Stripping of Groundwater and MNA
Alternative S4 – Limited Source Removal for Chlorinated Contaminated Soil and Off-Site Treatment and Disposal	
Alternative S5 – SVE for Chlorinated Contaminated Soils	
Alternative S8 – Limited Source Removal of Chlorinated Contaminated Soils and On-Site Thermal Treatment	

Note: All media-specific alternatives include land use controls (LUC) except S1 and W1. Land use controls are included under the Basewide Land Use Control Management Action Plan for Elmendorf AFB.

[This page intentionally left blank.]

Section 13.0
DETAILED ANALYSIS OF ALTERNATIVES

In this section, the media-specific alternatives are combined into sitewide alternatives, developed, described, and evaluated. The development of the alternatives is provided in Section 13.1, which includes an explanation of how the media-specific alternatives were combined into sitewide alternatives. A description of the sitewide alternatives developed for Site DP98 is also included in this section. The methodology used for the evaluation of the sitewide alternatives is provided in Section 13.2. The detailed evaluation of the sitewide alternatives using seven of the nine CERCLA criteria is presented in Section 13.3 (the two remaining criteria will be evaluated in the Proposed Plan and Record of Decision (ROD) following public comment); Section 13.4 presents the comparative evaluation of the remedial action alternatives.

13.1 Development and Description of Sitewide Alternatives

The media-specific alternatives that were retained after alternative screening in Section 12 are summarized in Table 12-5. Soil and sediment alternatives S1-No Action; S2-Natural Attenuation with Confirmation Sampling; S3-Limited Steam Stripping of Chlorinated Contaminated Soils; S4-Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment, and Disposal; S5-SVE for Chlorinated Soils; and S8-Limited Source Removal of Chlorinated Contaminated Soils and On-Site Thermal Treatment are retained for detailed analysis. Groundwater and surface water alternatives W1-No Action; W2-Monitored Natural Attenuation; and W3-Limited Steam Stripping of Groundwater and MNA are also retained. The media-specific alternatives that were retained after the alternative screening in Section 12 are combined into comprehensive alternatives that address the entire site. Table 13-1 lists the sitewide remedial alternatives and identifies the media-specific alternatives included in each sitewide alternative. A discussion of the rationale used in combining the media-specific alternatives into sitewide alternatives is provided in Section 13.1.1, and a description of each of the sitewide alternatives is provided in Sections 13.1.2 through 13.1.6

13.1.1 Development of Sitewide Alternatives

Six sitewide alternatives were developed for the site: Alternative 1-No Action; Alternative 2-Monitored Natural Attenuation; Alternative 3-Limited Steam Stripping of Chlorinated Soils and Groundwater and Groundwater MNA; Alternative 4-Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal, and Groundwater MNA; Alternative 5-Limited Source Removal of Chlorinated Contaminated Soils, On-Site Treatment and Disposal, and Groundwater MNA; and Alternative 6-SVE for Soil and Groundwater MNA. These alternatives primarily address media contaminated with chlorinated compounds. If warranted, active remediation of petroleum-contaminated media may be considered if natural attenuation is insufficient at reducing contaminant levels.

Each of the six sitewide alternatives consists of a combination of one soil and sediment alternative and one groundwater and surface water alternative.

- Alternative 1-No Action, which is required by the NCP, combines Alternative S1-No Action and Alternative W1-No Action. This alternative was developed solely as a baseline for comparison with the other alternatives.
- Alternative 2-Monitored Natural Attenuation is a combination of the soil-specific alternative S2-Natural Attenuation with Confirmation Sampling and the water-specific alternative W2-Monitored Natural Attenuation. Combining the two media-specific natural attenuation alternatives creates the least aggressive and the least invasive of the sitewide alternatives being considered for the site.

Table 13-1

Candidate Sitewide Remedial Alternatives

Media-Specific Alternative	**Alternative 1 No Action**	**Alternative 2 Monitored Natural Attenuation**	**Alternative 3 Limited Steam Stripping of Chlorinated Contaminated Soils and GW and GW MNA**	**Alternative 4 Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal, and GW MNA**	**Alternative 5 Limited Source Removal of Chlorinated Contaminated Soils, On-Site Thermal Treatment and Disposal, and GW MNA**	**Alternative 6 SVE for Soil and GW and GW MNA**
Soil and Sediment						
S1: No Action	●					
S2: Monitored Natural Attenuation		●				
S3: Limited Steam Stripping of Chlorinated Contaminated Soils and MNA			●			
S4: Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal, and MNA				●		
S5: SVE for Chlorinated Contaminated Soils and MNA						●
S8: Limited Source Removal of Chlorinated Contaminated Soils and Treatment Using On-Site LTTD and Natural Attenuation					●	
Groundwater and Surface Water						
W1: No Action	●					
W2: Monitored Natural Attenuation		●		●	●	●
W3: Limited Steam Stripping of Groundwater and MNA			●			

GW – Groundwater
LTTD – Low-temperature thermal desorption
MNA – Monitored natural attenuation
SVE – Soil vapor extraction
All alternatives except Alternative 1 (S1 & W1) contain land use controls, which are included under the Basewide Land Use Control Management Action Plan for Elmendorf AFB.
All alternatives assume no active treatment of DRO in soil, groundwater, sediment, and surface water.

- Alternative 3- Limited Steam Stripping of Chlorinated Contaminated Soils and Groundwater and Groundwater MNA is a combination of Alternative S3-Limited Steam Stripping of Chlorinated Contaminated Soils and Alternative W3-Limited Steam Stripping of Groundwater and MNA. Treatment would be limited only to soil and groundwater located near the end of the drain tile north of Building 18224, the location with the highest concentrations of chlorinated contaminants. Since chlorinated compounds have been detected above preliminary ARARs in both groundwater and soil, and steam stripping, which includes SVE and groundwater extraction, is capable of addressing both groundwater and soil, steam stripping was selected for both media in this alternative. This alternative is the most aggressive sitewide alternative being considered for the site, and as such could result in the greatest reduction in cleanup timeframes for source area soils and groundwater when compared to the other alternatives. Both residual soil contamination and residual groundwater contamination outside of the treatment area are being addressed through natural attenuation with scheduled periodic groundwater monitoring and a one-time confirmation soil sampling event.
- Alternative 4-Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal, and Groundwater MNA is a combination of soil-specific alternative S4-Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal, and groundwater-specific alternative W2-Monitored Natural Attenuation. Excavation would be limited only to soil located near the end of the drain tile north of Building 18224, where the highest concentrations of chlorinated compounds have been detected. This alternative is slightly more aggressive than Alternative 2. Limited source removal could potentially reduce cleanup timeframes in the source area when compared to Alternative 2, but this alternative also relies on natural attenuation for reducing concentrations below preliminary ARARs in soil. Groundwater and contaminated soil below the water table are addressed through natural attenuation with scheduled periodic groundwater monitoring and a one-time confirmation soil sampling event.
- Alternative 5-Limited Source Removal of Chlorinated Contaminated Soils, On-Site Treatment and Disposal, and Groundwater MNA is a combination of soil-specific alternative S8-Limited Source Removal of Chlorinated Soils and On-Site Thermal Treatment and Disposal, and groundwater-specific alternative W2-Monitored Natural Attenuation. Excavation would be limited only to soil located near the end of the drain tile north of Building 18224, where the highest concentrations of chlorinated compounds have been detected. This alternative is similar to Alternative 4, except soil treatment would be accomplished using a mobile thermal soil treatment unit. Limited source removal could potentially reduce cleanup timeframes in the source area when compared to Alternative 2, but this alternative also relies on natural attenuation for reducing concentrations below preliminary ARARs in soil. Groundwater and contaminated soil below the water table are addressed through natural attenuation with schedule periodic groundwater monitoring and a one-time confirmation soil sampling event.
- Alternative 6- SVE for Soil and Groundwater MNA combines soil-specific alternative S5-SVE for Chlorinated Contaminated Soils, and groundwater-specific alternative W2-Monitored Natural Attenuation. This option uses SVE to treat all vadose-zone soil containing chlorinated compounds at concentrations above the preliminary ARARs. The scope of the SVE is not limited to the area near the end of the drain tile north of Building 18224, as are the active remedial measures proposed in Alternatives 3, 4 and 5. This alternative could potentially reduce cleanup timeframes outside the source area when compared to Alternatives 3, 4 and 5, because more of the contaminated soil is addressed with this alternative. Cleanup timeframes, however, are expected to be longer than with Alternative 3 because groundwater and contaminated soil below

the water table are addressed only through natural attenuation with scheduled periodic groundwater monitoring and a one-time confirmation soil sampling event.

The alternatives were developed to create a range of treatment options for the site while limiting the choices to a reasonable number. The combination of alternatives presented in this FS should not be considered final. Alternatives may be added or deleted or the combination of soil and groundwater sitewide alternatives may be modified based on public or agency comments. The alternatives currently being considered for the site are described in the sections below.

13.1.2 Alternative 1 – No Action

The no action alternative combines media-specific Alternatives S1 and W1. For this alternative, no action would be implemented and no monitoring would be performed at the site. The land use controls that are currently in place at Site DP98 would not be maintained. This alternative would rely solely on natural attenuation to reduce concentrations of TCE and DRO in soil and groundwater. This alternative was retained in accordance with the NCP to provide a baseline for comparison with the other alternatives. There are no costs associated with this alternative.

13.1.3 Alternative 2 – Monitored Natural Attenuation

Alternative 2 is a combination of media-specific Alternatives S2 and W2. For this alternative, soil, sediment, groundwater, and surface water would be treated by natural attenuation, which is the breakdown of contaminants without artificial stimuli. Natural attenuation occurs due to degradation processes such as biological breakdown, chemical and physical processes, and volatilization. Surface water and groundwater monitoring are used to determine whether the COCs are degrading naturally in both groundwater and soil. Monitoring would provide sufficient information to indicate that natural attenuation is degrading the COCs in accordance with the OSWER Directive for the use of monitored natural attenuation (EPA, 1997). Once monitoring has indicated that cleanup goals have been attained in groundwater, soil sampling will be conducted to confirm soil ARARs are met. Natural attenuation in soil will not be monitored prior to collecting confirmation samples because the heterogeneous nature of soils at DP98 would make it difficult to collect samples from the same soil type and location in contiguous sampling events. Soil sample results would not be comparable and accurate trends in concentrations could not be made. Monitoring natural attenuation of COCs in groundwater will provide some indication of degradation of COCs in soil because seasonal fluctuations in groundwater create a smear zone, resulting in a direct correlation between groundwater and soil concentrations. This alternative also includes land use controls for all media and in-place abandonment of the existing drain tile system. No active treatment would be implemented.

Land use controls for Site DP98 are included under the Basewide Land Use Control Management Plan for Elmendorf AFB. These controls include groundwater and surface water use restrictions for areas of groundwater and surface water contamination and digging restrictions for areas with soil contamination. Excavated contaminated soil above ARARs may not be moved from this site to other locations on base. Land use controls would remain in place until preliminary ARARs are achieved.

Frequencies for groundwater/surface water sampling will be based on the decision guide for the Elmendorf Basewide Environmental Monitoring. Natural attenuation occurring on-site would be modeled to provide a cleanup timeframe according to the OSWER Directive to determine effectiveness and rate of natural attenuation. In addition to groundwater sampling, surface water samples would be collected during each sampling round from the Kettle pond as a point of compliance. The analytical testing of water samples would include, but would not be limited to, the following parameters: nitrate/nitrite, total Kjeldahl nitrogen, total phosphorus, total organic carbon, GRO, DRO/RRO, VOCs, PAH, heterotrophic plate count, and hydrocarbon-degrading bacteria. Seventy-five years is assumed for costing the groundwater-monitoring portion of this alternative. Additional data and modeling will be required to verify this assumption.

Soil samples would be collected to confirm natural attenuation of contamination in soils/sediment. This would occur after preliminary groundwater RAOs have been achieved. Confirmation sampling would consist of up to 15 soil samples collected throughout the site. The testing would include, but would not be limited to, the following parameters: total organic carbon, GRO, DRO/RRO, VOCs, and PAH. Based on sampling results, active treatment alternatives would be considered if soil remediation goals have not been met.

Based on results from groundwater modeling, active treatment alternatives would be considered if the treatment timeframe is found to be unacceptable. In addition, if DRO concentrations remain above RAOs in soil once RAOs for chlorinated contaminants have been met, other alternatives to enhance remediation may also be implemented.

13.1.3.1 Cleanup Timeframes

Cleanup timeframes, the predicted time it may take for chemicals in groundwater and soil to attenuate naturally to preliminary ARAR levels, were approximated using computer models. Several assumptions were made in order to predict cleanup timeframes for Alternative 2. Assumptions are as follows:

- Cleanup timeframes assume that no active treatment of contaminants will take place, but are based only on MNA for groundwater and natural attenuation for soil.
- Predicted TCE cleanup timeframe assumes that soil will not further contribute TCE to groundwater, and TCE in groundwater will steadily decay.
- Predicted DRO cleanup timeframes assume that soil will contribute a decreasing amount of DRO to groundwater, and DRO in groundwater will steadily decay.
- Maximum TCE and DRO concentrations detected at Site DP98 were used.
- Cleanup timeframes are based on first order rate constants. Depending on the value of the first order rate constant used for biodegradation, the time required to meet screening criteria may range from 0.15 to364 years.
- Published first order rate constants for TCE ranged from 0.06 yr^{-1} to 146.0 yr^{-1}. A value of 0.62 yr^{-1} was used to calculate TCE cleanup timeframes for Site DP98.
- The first order rate constant for DRO (0.3 yr^{-1}) was calculated from an average of rate data for xylenes, naphthalene, and phenanthrene.

Based on available data and the above assumptions, under Alternative 2 the cleanup timeframes are 23 to 48 years for soil and 35 to 75 years for groundwater. Contaminant-specific cleanup timeframes are as follows:

<u>Unsaturated soil</u>: 31 to 48 years for DRO and 23 years for TCE.

<u>Saturated Soil</u>: 47 to 48 years for DRO and 35 years for TCE.

<u>Groundwater</u>: 49 to 75 years for DRO and 35 to 55 years for TCE.

Cleanup timeframes are approximate and should only be used for comparison between options.

Figure 13-1. Alternative 3 Approximate Area for Thermal Treatment

13.1.4 Alternative 3 – Limited Steam Stripping of Chlorinated Contaminated Soils and Groundwater and Groundwater MNA

Alternative 3 is a combination of media-specific Alternatives S3 and W3 (see Figure 13-1). For this alternative, soil and groundwater in the vicinity of the drain tile system at Building 18224 would be treated by in-situ thermal treatment. The remaining contaminated soil and sediment throughout the site would be treated via natural attenuation, and remaining groundwater and surface water would be treated through MNA. The drain tiles system extending from Building 18224 would be abandoned in place. Land use controls and monitoring would also be used for this alternative. Additional specific information on this alternative is included below.

13.1.4.1 Thermal Treatment for Soil and Groundwater

Alternative 3 includes in-situ thermal treatment of contaminated soil and groundwater in the vicinity of the drain tile system at Building 18224. The treatment area is defined as the area within a 25-foot radius of the end of the drain tile north of Building 18224, where chlorinated compounds were detected in soil and groundwater above the preliminary ARARs. The treatment area would extend to a depth of 35 feet bgs. The treatment system includes steam stripping, vapor extraction, and groundwater extraction and treatment. The application of steam to unsaturated soil, aquifer media, and groundwater would raise the temperature of the subsurface such that chlorinated and fuel compounds would be vaporized and removed. It is assumed that approximately 2,500 cubic yards of soil and aquifer media would be treated by this technology. Additional soil characterization prior to excavation may change this estimate.

Steam would be generated on-site and injected into the subsurface. This would be supplemented by groundwater extraction and vapor extraction. Migration of contaminants would be controlled during steam stripping by controlling the steam injection rate, using vapor extraction for vapor control, and groundwater extraction for hydraulic control. The system would require continual monitoring and maintenance for system operation. Steam recovered from the SVE wells would be condensed, combined with the extracted groundwater, and treated on-site using a combination of oil/water separator and carbon adsorption system. Pilot testing would be required to determine exact design criteria, radius of influence, and carbon requirements. It is estimated that the in-situ thermal system would require two construction seasons to remediate the target area: one season to mobilize the site, construct, test and operate the system (45 days is estimated for treatment); and one season to confirm treatment and demobilize the site.

13.1.4.2 Natural Attenuation

Soil and groundwater remaining outside of the treatment area would be allowed to degrade naturally in this scenario. Natural attenuation would also be utilized for the sediment in the wetland area. Periodic monitoring of groundwater would be required to document degradation rates and verify cleanup timeframes. After water ARARs have been met, soil sampling would be conducted to confirm soil ARARs have also been met. Monitoring requirements for this alternative would be identical to the requirements for Alternative 2 (see Section 13.1.3).

13.1.4.3 Land Use Controls

Land use controls, including restrictions on digging and groundwater use, would be in place for the duration of MNA. A description of the land use controls is provided in Section 13.1.3.

13.1.4.4 Cleanup Timeframes

Cleanup timeframes for Alternative 3 include the assumption that soil and groundwater contamination within the treatment area (the outlet of the drain tile system to the north of Building 18224) will meet preliminary ARARs within 45 days of startup of the system. Outside of the treatment area, contaminated groundwater will undergo MNA and soil will undergo natural attenuation without monitoring. Additional assumptions used to estimate cleanup timeframes for Alternative 3 are listed in Section 13.1.3.1 under Alternative 2. Based on available data and the above assumptions, under

Alternative 3 the cleanup timeframes are 9 to 50 years for soil and 25 to 75 years for groundwater. Contaminant-specific cleanup timeframes are as follows:

Unsaturated soil: 16 to 48 years for DRO and 9 years for TCE.

Saturated Soil: 37 to 50 years for DRO and 22 years for TCE.

Groundwater: 40 to 75 years for DRO and 25 to 35 years for TCE.

Cleanup timeframes are approximate and should only be used for comparison between options.

13.1.5 Alternative 4 – Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal, and Groundwater MNA

Alternative 4 is a combination of media-specific Alternatives S4 and W2 (see Figure 13-2). For this alternative, a limited source removal of soils containing chlorinated compounds near the existing drain tile system would be conducted. Excavated soil containing chlorinated contaminants (and any fuel compounds also present in the removed soil) would be transported off-site for treatment and disposal. Remaining contaminated soil and sediment in the wetland would be treated by natural attenuation, and groundwater throughout the site would be treated via MNA. Land use controls and monitoring would also be used for this alternative. The drain tile system at Building 18224 would be abandoned in place. Additional specific information on this alternative is described below.

13.1.5.1 Limited Source Removal of Chlorinated Contaminated Soils and Off-Site Treatment and Disposal

In this scenario, chlorinated contaminated soils within an approximate 25-foot radius from the end of the drain tile north of Building 18224 would be removed. Soil would be excavated down to 10 feet or to the water table, whichever is encountered first. Assuming that soil from 0 to 5 feet bgs is not contaminated, the soil volume proposed for this limited removal is estimated to be approximately 360 cubic yards. Additional soil characterization prior to excavation may change this estimate. For this FS, it is assumed that excavated soils would be transported to a treatment facility in the lower 48 states for treatment (incineration) prior to disposal. When treatment is completed, the material would be sampled to ensure that cleanup levels have been attained. A source of clean soil will be identified for backfilling the excavation. It has been assumed that one construction season would be required for the limited source removal at the drain tile system.

13.1.5.2 Natural Attenuation

Soil and groundwater remaining outside of the excavation area would be allowed to degrade naturally in this scenario. Natural attenuation would also be utilized for sediment in the wetland. Periodic monitoring of groundwater would be required to document degradation rates and verify a cleanup timeframe. After groundwater ARARs have been, soil sampling would be conducted to confirm soil ARARs have been met. Monitoring requirements for this alternative are identical to the requirements for Alternative 2 (see Section 13.1.3).

13.1.5.3 Land Use Controls

Land use controls, including restrictions on digging and groundwater use, would be in place for the duration of MNA. A description of the land use controls is provided in Section 13.1.3.

13.1.5.4 Cleanup Timeframes

Cleanup timeframes for Alternative 4 include the assumption that soil and groundwater contamination within the treatment area (the outlet of the drain tile system to the north of Building 18224) will meet preliminary ARARs within 1 year of remedial action. Outside the treatment area, contaminated groundwater will undergo MNA and contaminated soil will undergo natural attenuation without monitoring. Additional assumptions used to estimate cleanup timeframes for Alternative 4 are listed in Section 13.1.3.1 under Alternative 2.

Based on available data and the above assumptions, under Alternative 4 the cleanup timeframes are 28 to 50 years for soil and 35 to 75 years for groundwater. Contaminant-specific cleanup timeframes are as follows:

Unsaturated soil: 28 to 50 years for DRO and 18 years for TCE.

Saturated Soil: 47 to 48 years for DRO and 35 years for TCE.

Groundwater: 49 to 75 years for DRO and 35 to 55 years for TCE.

Cleanup timeframes are approximate and should only be used for comparison between options.

13.1.6 Alternative 5 – Limited Source Removal of Chlorinated Contaminated Soils, On-Site Thermal Treatment and Groundwater MNA

Alternative 5 is a combination of media-specific Alternatives S8 and W2 (see Figure 13-2). This alternative is similar to Alternative 4, except the excavated soil containing chlorinated contaminants (and any fuel compounds also present in the removed soil) would be treated at a designated area on-base using a mobile thermal treatment unit. Similar to Alternative 4, remaining contaminated soil and sediment would be treated via natural attenuation, and remaining groundwater and surface water would be treated via MNA and land use controls would be used. Additional specific information on this alternative is described below.

13.1.6.1 Limited Source Removal of Chlorinated Soils and On-Site Treatment and Disposal

In this scenario, the primary area of chlorinated contaminated soils would be removed. The excavation limits for this scenario are identical to Alternative 4 (See Section 13.1.5.1). The excavated soil would then be treated at a designated area on-base, using LTTD treatment process. A mobile treatment unit would be set up at a designated area on-base and, soil would be treated on site. The unit would be equipped with an air scrubber to ensure air emissions associated with chlorinated contaminants are within regulatory levels.

When treatment is completed, the material would be sampled to confirm that cleanup levels have been attained. The treated soil would either be used as backfill for the excavation or deposited in the Elmendorf Landfill as clean fill. A source of clean soil will be identified for backfilling the excavation. It has been assumed that one construction season would be required for the limited source removal at the end of the drain tile.

13.1.6.2 Natural Attenuation

Soil and groundwater remaining outside of the excavation area would be allowed to degrade naturally in this scenario. Natural attenuation would also be utilized for soil outside the excavation area and sediment in the wetland. Periodic monitoring (MNA) would be required to document degradation rates and verify cleanup timeframes for groundwater and surface water. After water ARARs have been met, soil sampling would be conducted to confirm soil ARARs have been met. Monitoring requirements for this alternative are identical to the requirements for Alternative 2 (see Section 13.1.3).

13.1.6.3 Land Use Controls

Land use controls, including restrictions on digging and groundwater use, would be in place until monitoring confirms that natural attenuation has achieved cleanup goals. A description of the land use controls is provided in Section 13.1.3.

Figure 13-2. Alternative 4 Excavation Area

13.1.6.4 Cleanup Timeframes

Cleanup timeframes for Alternative 5 include the assumption that soil and groundwater contamination within the treatment area (the outlet of the drain tile system to the north of Building 18224) will meet preliminary ARARs within 1 year of remedial action. Outside the treatment area, contaminated groundwater will undergo MNA and contaminated soil will undergo natural attenuation without monitoring. Additional assumptions used to estimate cleanup timeframes for Alternative 5 are listed in Section 13.1.3.1 under Alternative 2.

Based on available data and the above assumptions, under Alternative 5 the cleanup timeframes are 28 to 50 years for soil and 35 to 75 years for groundwater. Contaminant-specific cleanup timeframes are as follows:

Unsaturated soil: 28 to 50 years for DRO and 18 years for TCE.

Saturated Soil: 47 to 48 years for DRO and 35 years for TCE.

Groundwater: 49 to 75 years for DRO and 35 to 55 years for TCE.

Cleanup timeframes are approximate and should only be used for comparison between options.

13.1.7 Alternative 6 – SVE for Soil and Groundwater MNA

Alternative 6 is a combination of media-specific Alternatives S5 and W2 (see Figure 13-3). For this alternative, soils containing chlorinated compounds above preliminary ARARs, except those soils in the area north and northwest of the buildings where the slope is too steep, would be treated by SVE. The remaining contaminated soil/sediment and groundwater/surface water throughout the site would be treated via natural attenuation and MNA, respectively. Land use controls and monitoring would also be used for this alternative. Additional specific information on this alternative is described below.

13.1.7.1 SVE

In this alternative, soils containing chlorinated compounds above preliminary ARARs, except those soils in the area north and northwest of the buildings where the slope is too steep to install SVE wells, would be treated via SVE. For this FS, it is assumed that a total of fifteen 4-inch SVE wells would be installed in the vadose-zone to treat the TCE contamination; the wells are assumed to have a radius of influence of 30 feet. The wells would be connected to a vacuum blower via a common header so that negative pressure would induce airflow through the contaminated soil into the SVE wells. Volatile compounds would partition into the vapor phase where they could be collected by the wells. Activated carbon would be used to adsorb the contaminants from the vapor phase. Periodic regeneration or replacement of the carbon would remove the contaminants from the site. The concentration of organic vapor in the extraction wells would be measured periodically to document vapor extraction rates, and soil sampling would be required to confirm that soil remediation goals were achieved. It is assumed that SVE would be performed for 5 years at Site DP98. Pilot testing would be required to determine exact design criteria, radius of influence, and carbon requirements.

13.1.7.2 Natural Attenuation

The remaining Soil/sediment and groundwater/surface water remaining outside of the treatment area and residual contamination within the treatment area would be addressed via natural attenuation and MNA, respectively. Periodic groundwater monitoring (MNA) would be required to document degradation rates and verify cleanup timeframe. After water ARARs have been met, soil sampling would be conducted to confirm soil ARARs have been met. Monitoring requirements for this alternative would be identical to the requirements for Alternative 2 (see Section 13.1.3).

13.1.7.3 Land Use Controls

Land use controls, including restrictions on digging and groundwater use, would be in place for the duration of MNA. A description of the land use controls is provided in Section 13.1.3.

13.1.7.4 Cleanup Timeframes

Cleanup timeframes for Alternative 6 include the assumption that soil and groundwater contamination within the treatment area (the outlet of the drain tile system to the north of Building 18224) will meet preliminary ARARs within 5 years of treatment startup. Outside the treatment area, contaminated groundwater will undergo MNA and contaminated soil will undergo natural attenuation with confirmation sampling. Additional assumptions used to estimate cleanup timeframes for Alternative 6 are listed in Section 13.1.3.1 under Alternative 2.

Based on available data and the above assumptions, under Alternative 6, the cleanup timeframes are 15 to 48 years for soil and 35 to 75 years for groundwater. Contaminant-specific cleanup timeframes are as follows:

Unsaturated soil: 16 to 48 years for DRO and 15 years for TCE.

Saturated Soil: 47 to 48 years for DRO and 35 years for TCE.

Groundwater: 50 to 75 years for DRO and 35 to 55 years for TCE.

Cleanup timeframes are approximate and should only be used for comparison between options.

13.2 Technical Approach for the Detailed Analysis

Each alternative was evaluated using seven of the nine CERCLA criteria: overall protection of human health and the environment; compliance with preliminary ARARs; long-term effectiveness; short-term effectiveness; reduction of toxicity, mobility, and volume of contaminated media through treatment; technical and administrative implementability; and cost of implementation. The two remaining CERCLA criteria, state acceptance and community acceptance, will be addressed during the Proposed Plan and ROD Phases. The criteria are divided into three categories: threshold factors, balancing factors, and modifying considerations. Threshold factors are those conditions that must be met for the alternative to be viable. The threshold criteria include overall protection of human health and the environment and compliance with preliminary ARARs. Balancing factors are the conditions that are the primary basis for comparing alternatives and include long-term effectiveness; short-term effectiveness; reduction of toxicity, mobility, and volume of contaminants through treatment; technical and administrative implementability; and cost of implementation. Modifying considerations address agency and community concerns through the final two criteria: state acceptance and community acceptance. The evaluation criteria used in the detailed analysis and brief definitions of each are shown on Table 13-2. A more detailed description of each criterion is presented in the subsections below. The evaluation of each alternative using these criteria is presented in Section 13.3.

To measure the degree that the alternatives fulfill each evaluation criterion, a relative numerical rating system was used (see Table 13-3). The numerical values reflect the relative ability of the alternative to meet the criterion. Ratings of “0” to “5” were assigned to each alternative for each criterion, with 0 indicating the criterion is not met and 5 indicating the criterion is fully met. Table 13-3 describes the subjective factors used to evaluate how well the evaluation criteria are met by the alternatives. The scores provided are not absolute numbers, but relative numbers designed to provide a preliminary ranking of the alternatives and numerically represent the trade-offs between the different alternatives. The alternatives were numerically rated in Section 13.3. These numerical ratings were then used in the comparative analysis in Section 13.4.

Insert 13-3 (11x17) here

[This page intentionally left blank.]

Table 13-2

Evaluation Criteria for Detailed Analysis

Criterion Type	Evaluation Criterion	Definition
Threshold factors	Overall protection of human health and the environment	Protection of both human health and the environment is achieved through the elimination, reduction, or control of contaminated media. All migration pathways must be addressed.
	Compliance with remediation goals	Complies with preliminary applicable or relevant and appropriate requirements of RCRA, CWA, SDWA, and state and local regulations and codes.
Balancing factors	Long-term effectiveness	Protects human health and the environment after the remedial action objectives have been met.
	Reduction of toxicity, mobility, and volume of contaminants through treatment	Treats the media and reduces the toxicity, mobility, and/or volume of the contaminated media.
	Short-term effectiveness	Protects human health and the environment during construction and implementation. Degree of threat and the time period to achieve remedial action objectives are also considered.
	Technical and administrative implementability	There are no administrative barriers (i.e., no zoning limitations). The availability of materials and personnel, site features such as available space and topography, frequency of required visits for operation and maintenance, and impacts upon ongoing operations are considered. The technical status of alternatives is also considered; theoretical technologies with only limited bench-scale evaluation are considered less implementable than fully proven processes.
	Cost of implementation	Costs include design, construction, start-up, monitoring, and maintenance.
Modifying considerations	State acceptance	The state's (or other regulatory agency's) preference among, or concerns about, alternatives.
	Community acceptance	The community's preferences among, or concerns about, alternatives.

CWA – Clean Water Act
RCRA – Resource Conservation and Recovery Act
SDWA – Safe Drinking Water Act

For each alternative, a total score and an effectiveness-to-cost quotient were also calculated. The scores received for overall protection of human health and the environment; compliance with ARARs; long-term effectiveness; reduction in toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost are summed for the total score. The scores received for overall protection of human health and the environment; compliance with preliminary ARARs; long-term effectiveness; reduction in toxicity, mobility, and volume through treatment; and short-term effectiveness are summed and divided by the total present worth cost (in millions of dollars) for the effectiveness-to-cost-quotient. The higher the effectiveness-to-cost quotient, the more cost effective the alternative. Note that the total score and the effectiveness-to-cost quotient assume that each of the CERCLA criteria are equally important, since each are numerically weighted the same. The total score and the effectiveness-to-cost quotient are presented in Section 13.4.

13.2.1 Overall Protection of Human Health and the Environment

This criterion requires that remedial alternatives adequately protect human health and the environment from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the site. This is achieved by eliminating, reducing, or controlling exposures to contaminants at levels established by the RAOs. This mandatory requirement is the primary objective of the remedial program.

The criterion of overall protection of human health and the environment is an integration of the other criteria, particularly long-term effectiveness and permanence, short-term effectiveness, and compliance with preliminary ARARs. The integration includes consideration of how risks posed through each exposure pathway are eliminated, reduced, or controlled by the alternative. Evaluation of this criterion also includes consideration of whether any unacceptable short-term or cross-media effects are posed by an alternative.

13.2.2 Compliance with Preliminary ARARs

This criterion requires that remedial alternatives attain preliminary ARARs defined from federal and state environmental and public health laws, or provide justification for invoking a waiver. Preliminary ARARs include those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that are either:

- Applicable and specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a cleanup site, or
- Relevant and appropriate and address problems or situations sufficiently similar to those encountered at the site that their use is suited to the particular site.

Preliminary ARARs are divided into three primary categories: chemical-specific, location-specific, and action-specific. In general, chemical- and location-specific preliminary ARARs provide the basis for determining the objectives and goals of the remedial action, whereas the action-specific preliminary ARARs provide the basis for determining how the remedial action will be carried out.

13.2.3 Long-Term Effectiveness and Permanence

Remedial alternatives will be assessed for long-term effectiveness and permanence and the degree of certainty that the alternative will prove successful. The following factors will be considered, as appropriate:

- Nature and magnitude of total residual risks in terms of amounts; potential for exposure of human and environmental receptors; concentrations of hazardous substances, pollutants, or contaminants remaining following implementation of a remedial alternative; and the persistence, toxicity, mobility, and propensity to bioaccumulate hazardous substances and constituents;
- The type, degree, and adequacy of long-term management required for untreated substances and treatment residuals, including engineering controls, land use controls, monitoring, and operation and maintenance;
- Long-term reliability of the engineering and land use controls, including uncertainties associated with treatment standards and with land disposal of untreated hazardous substances, pollutants, and contaminants; and
- Potential need for replacement of the remedy and continuing need for repairs to maintain the performance of the remedy.

Table 13-3

Remedial Alternative Evaluation Criteria Rating System

Evaluation Criterion	Condition	Value
Overall protection of human health and the environment	Is protective	5
	Is not protective	0
Compliance with remediation goals	Complies with remediation goals	5
	Does not comply	0
Long-term effectiveness	Once cleanup is completed, there is minimal release potential	5
	Contaminants not removed or destroyed	0
Reduction of toxicity, mobility, and volume of contaminants through treatment	Eliminates toxicity, mobility, and volume	5
	No reduction or no treatment	0
Short-term effectiveness – risks	Minimal risks created by implementation	5
	Significant risks created by implementation	0
Short-term effectiveness – time until RAOs achieved	RAOs are achieved quickly	5
	RAOs are achieved slowly	0
Technical and administrative implementability	Alternative proven, all materials and personnel available, little effect on site operations in area	5
	Alternative not proven, materials and personnel not readily available, significant compliance issues, major impact on site operations in area	0
Cost of implementation	Estimates total costs including capital and O&M.	$
State acceptance	Not evaluated	NA
Community acceptance	Not evaluated	NA

$ – actual dollar value used
NA – Not applicable
RAOs – Remedial action objectives

13.2.4 Reduction of Toxicity, Mobility, and Volume of Contaminants through Treatment

The degree to which alternatives employ active treatment that reduces toxicity, mobility, and volume will be assessed. Alternatives will be identified that, at a minimum, use active treatment to address the principal threats posed to the site and local environment. The following factors will be considered as appropriate:

- Treatment processes and the materials to be treated;
- Amount of hazardous substances, pollutants, or contaminants to be destroyed or treated;
- Degree to which the active treatment is irreversible; and
- Quantity of residuals that will remain following active treatment, considering the persistence, toxicity, mobility, and propensity to bioaccumulate such hazardous substances and constituents.

13.2.5 Short-Term Effectiveness

Each alternative will be evaluated in terms of its effectiveness in protecting human health and the environment during the construction and implementation of the remedy until the response objectives have been met. The following factors will be considered:

- Short-term risks that might be posed to the community during implementation of the alternative;

- Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures;
- Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigation measures during the implementation; and
- Time until protection is achieved.

13.2.6 Implementability

The technical and administrative feasibility of each alternative will be evaluated by considering the following factors as appropriate:

- Degree of difficulty or uncertainty associated with construction and operation of the selected technology;
- Expected operational reliability of the selected technologies and the ability to undertake additional or supplemental action, if required;
- Ability to reliably monitor the effectiveness of the remedy;
- Availability of necessary equipment and specialists;
- Available capacity and location of needed treatment, storage, and disposal services;
- Site access and frequency of required visits for operation and maintenance;
- Availability of prospective technologies under consideration; and
- Impact on current operations at the facility.

13.2.7 Cost of Implementation

The estimated cost of implementation for each alternative is included on a present worth basis. Estimated costs include the sum of direct capital costs, indirect capital costs, and O&M costs.

13.2.8 State Acceptance

The potential technical and administrative issues and concerns the state regulatory agencies may have regarding each of the alternatives will be considered. This criterion will be addressed in the ROD, after agency comments on the RI/FS report and the proposed plan have been received and resolved.

13.2.9 Community Acceptance

The issues and concerns the public may have regarding each of the alternatives will be evaluated. This criterion will be addressed in the ROD, after comments on the RI/FS report and the proposed plan have been received and resolved.

13.3 Detailed Evaluation

The six alternatives described in Section 13.1 were evaluated using seven of the nine CERCLA criteria, as described in Section 13.2. The intent of this evaluation is not to compare the alternatives against each other, but to evaluate each alternative against the criteria and to identify the advantages and disadvantages of each alternative. A comparative evaluation of the alternatives is provided in Section 13.4. Each remedial alternative was assessed in terms of the evaluation criteria and assigned a numerical rating for each criterion. Ratings of 0 to 5 were assigned to each alternative for each criterion, with 0 indicating the criterion is not met and 5 indicating the criterion is fully met. The evaluations are presented in Tables 13-4 through 13-8. A separate table is provided for each of the six alternatives:

- Alternative 1: S1 and W1 – No Action

- Alternative 2: S2 and W2 – Monitored Natural Attenuation
- Alternative 3: S3 and W3 – Limited Steam Stripping of Chlorinated Contaminated Soils and Groundwater and MNA
- Alternative 4: S4 and W2 – Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal, and MNA
- Alternative 5: S8 and W2 – Limited Source Removal of Chlorinated Contaminated Soils, On-site Treatment and Disposal, and Natural Attenuation
- Alternative 6: S5 and W2 - SVE for Soil and MNA

13.4 Comparative Evaluation

The comparative evaluation of the six remedial alternatives considered for Site DP98 is presented in Table 13-9 and discussed in more detail in the following subsections. A separate discussion has been prepared for each criterion. The purpose of the comparative evaluation is to identify the relative advantages of each alternative for each criterion. This comparative evaluation is in contrast to the detailed evaluation in which the same criteria were used to independently evaluate each alternative relative to achieving the RAOs. The comparative analysis is intended to identify the criteria that must be balanced in the remedy selection process.

In the following subsections, the alternative that best satisfies each criterion is presented first with subsequent alternatives discussed below.

13.4.1 Overall Protection of Human Health and the Environment

All of the alternatives, with the exception of Alternative 1, include land use controls to protect human health and the environment. Land use controls, however, can only provide partial protection; overall protection is contingent on the effectiveness of the treatment technologies. Alternatives 3, 4, 5, and 6 were given a ranking of 4 for overall protection of human health and the environment. These alternatives provide for some level of active treatment for chlorinated contamination at the source area that should shorten the overall exposure time at the site. Alternative 2 was given a ranking of 3, because it does not provide for any active treatment at the site. Alternative 1 was given a ranking of 0 because contaminants would remain in place for a longer time and no action would be taken to protect human health. None of the alternatives were ranked higher than 4, because none of the alternatives includes active remediation of the contamination throughout the entire site.

13.4.2 Compliance with Preliminary ARARs

For compliance with ARARs, Alternatives 3, 4, 5, and 6 were given the highest ranking, 5, because they are expected to eventually achieve both chemical- and action-specific preliminary ARARs. Alternative 2 was ranked at a 4, lower than Alternatives 3, 4, 5 and 6, because it may take longer to achieve the ARARs without active treatment. Alternative 1 was again given a ranking of 0 due to the lack of monitoring to determine if the alternative eventually meets chemical-specific preliminary ARARs.

13.4.3 Long-Term Effectiveness and Permanence

Alternative 3 was ranked at a 4 for long-term effectiveness because the alternative will address both TCE and DRO in soil and groundwater. Alternatives 4, 5, and 6 were given a ranking of 3 for long-term effectiveness, while Alternative 2 was given a ranking of 2, and Alternative 1 was given a ranking of 0. Alternatives 4, 5, and 6 were given a ranking of 3 because some active treatment of contaminated soil is included in these alternatives. Alternative 2 was ranked at 2 because it lacked active treatment, and Alternative 1 was given a 0 ranking because it lacked the monitoring which would be needed to measure performance. None of the alternatives provide for active treatment in the downgradient wetland area. Because of this, the treatment time for MNA is the same for all of the alternatives regardless of the type of source area treatment. Theoretically, all of the alternatives, including Alternative 1, will cleanup the site via natural attenuation. The actual cleanup time cannot be determined until groundwater modeling is performed.

13.4.4 Reduction of Toxicity, Mobility, and Volume of Contaminants through Treatment

The RAOs for this criterion specifically address the degree to which active treatment is employed to reduce toxicity, mobility, and volume of contamination at the site. Alternative 3 was given a ranking of 4 because thermal treatment will reduce contaminant concentrations in both soil and groundwater. Alternatives 4, 5, and 6 were ranked at 3 because none of these alternatives actively treat groundwater. Alternative 2 was ranked at 2 because it lacked any active treatment, and Alternative 1 was given a ranking of 0 because it lacked the monitoring which would be needed to measure the reduction of contaminants at the site.

13.4.5 Short-Term Effectiveness

Alternatives 1 and 2 were ranked at 3 because there are minimal short-term risks associated with the implementation of land use controls; however, both alternatives lacked the monitoring which would be needed to determine when RAOs are met at the site. Alternative 3 was given a ranking of 2 because, although RAOs will be achieved quicker in the areas where the active treatment is being performed, there are relatively high potential exposure risks associated with the thermal treatment. Alternatives 4 and 5 were given rankings of 3 because, although RAOs will be achieved quicker in the areas where the active treatment is being performed, there are limited exposure issues associated with excavation. Alternative 6 was also given a ranking at 3 because, although RAOs will be achieved quicker in the areas where the active treatment is being performed, there is some risk due to the installation and operation of SVE equipment. Although Alternatives 3, 4, 5, and 6 include some active treatment, the time to achieve RAOs is identical for all alternatives for the portions of the site where no active treatment is being implemented. The actual time to achieve the RAOs cannot be determined until groundwater modeling is performed.

13.4.6 Implementability

Technical and administrative implementability was the next criterion to be evaluated. Overall, Alternative 1 was ranked at 5. This alternative is the most implementable because there are no actions associated with the alternative. Alternative 2 was ranked at 4; although there are only minimal technical and administrative problems associated with implementing land use controls and a monitoring program, there will be some administrative issues associated with site access for long-term monitoring. Of the alternatives that include treatment, Alternatives 4 and 5 were given a ranking of 3. Although there is a higher level of coordination that would have to occur for offsite treatment of soil, the overall treatment time would be shorter, thereby limiting site access issues. Alternative 6 was given a ranking of 2. Alternative 6 is the most technically implementable; however, it would be operated for approximately 5 years compared to Alternatives 4 or 5, which would only require 1 year. Because Alternative 3 could require more infrastructure development to install and operate than other alternatives, and because it is a complicated system to operate, it was given a ranking of 1 for this category.

13.4.7 Cost of Implementation

The alternatives were not ranked according to cost; therefore, cost is not included in the total score for each alternative in Table 13.10. Of the alternatives, Alternative 3 was the most expensive followed by Alternatives 6, 4, 5, 2 and 1.

13.4.8 Conclusion

Table 13-10 summarizes the comparative rankings and provides a cumulative score for each alternative. The total score includes the ranking for all criteria, including implementability and cost. In scoring the alternatives, Alternatives 4 and 5 are ranked highest with total scores of 21, followed by Alternatives 3 and 6, with total scores of 20, and Alternatives 2 and 1, with total scores of 18 and 9, respectively. In addition, Table 13-10 summarizes the total effectiveness score, which includes all ranking except implementability and cost. The total effectiveness scores were then used to calculate the effectiveness-to-cost ratio. Table 13-11 summarizes the costs and the effectiveness-to-cost ratio for each alternative. (The effectiveness-to-cost ratio is calculated by dividing the total effectiveness score by the total present worth in millions of dollars.) For effectiveness-to-cost quotients, Alternative 2 ranks highest with a ratio of 7.8, and the second best ratios are 6.5 for Alternative 6 and 6.4 for Alternatives 4 and 5.

Table 13-4

Detailed Analysis of Alternative 1: No Action

Evaluation Criterion	Evaluation	Numerical Rating
Overall protection of human health and the environment	Alternative 1 would not be protective of human health and the environment. Future residents could still be exposed to chlorinated compounds in soil and groundwater, and ecological receptors could still be exposed to contaminants in surface water, and fuel compounds in surface water and sediment, until contaminants in these media degrade to acceptable levels. The site would pose unacceptable risks to current site works and future residents under this alternative. Without monitoring, the progress of the natural attenuation and accompanying reduction in risk could not be assessed (long-term effectiveness). In addition, current base personnel and future residents might use contaminated upper aquifer groundwater. Access to the site would remain unchanged.	0
Compliance with remediation goals	Alternative 1 may meet chemical-specific RAOs for contaminants in soil/sediment and groundwater/surface water. Action-specific remediation goals would not be invoked. However, no monitoring would be performed to determine if remediation goals are met.	0
Long-term effectiveness	Residual risks would be identical to existing risks because no actions would be implemented with this alternative, although risks would decline with time because contaminants would be slowly degraded by natural attenuation. However, there would be no monitoring to document reduction or land use controls to prevent access to the site or exposure to contaminated media.	0
Reduction of toxicity, mobility, and volume of contaminants through treatment	Does not provide for active treatment. Toxicity of chlorinated and fuel contaminants in soil and water may be reduced through natural attenuation, but no monitoring is included to verify the reduction.	0
Short-term effectiveness	The no action alternative does not include any construction with which there might be any associated risks to workers, the community, or the environment. RAOs would not be achieved for an undeterminable time, and natural attenuation would not be documented.	3
Technical and administrative implementability	There would be no construction and no process options implemented under this alternative.	5
Cost of implementation	$0	$0
State acceptance	NE	NE
Community acceptance	NE	NE

NE – Not evaluated at this time, but will be evaluated once public and agency comments are received.
RAOs – Remedial action objectives

Table 13-5

Detailed Analysis of Alternative 2: Monitored Natural Attenuation

Evaluation Criterion	Evaluation	Numerical Rating
Overall protection of human health and the environment	Land use controls* and environmental monitoring contained in Alternative 2 would render the alternative protective of human health and the environment. Current facility workers and future residents would be protected from exposure to contaminants in soil and groundwater, the progress of the natural attenuation and accompanying reduction in risk would be monitored to determine long-term effectiveness, and soil and water use would be restricted. Since no active treatment would be performed under this scenario, however, environmental risks from contaminants would be present throughout the site until natural attenuation is complete and RAOs are achieved.	3
Compliance with remediation goals	EPA guidance applicable to monitored natural attenuation would apply and would be implemented at the site (EPA OSWER Directive 9200-4.17p). Chemical-specific RAOs for contaminants in soil/sediment and groundwater/surface water would be met after years of natural attenuation, and land use controls* would be in place to meet location- and action-specific RAOs.	4
Long-term effectiveness	Monitoring to document reduction in contaminant concentration and land use controls* to prevent access to the site would be in place until contaminant concentrations are less than RAOs. Monitoring and land use controls are effective, reliable methods of protecting human health and the environment. Although risks would decline with time because contaminants would be slowly degraded by natural attenuation, the time required to reduce the contamination to residential cleanup levels may be extensive. However, cleanup time frames could be significantly different from the current estimated values. These values would not be determined until groundwater modeling is performed.	2
Reduction of toxicity, mobility, and volume of contaminants through treatment	Alternative 2 does not provide for active treatment. Toxicity of chlorinated and fuel contaminants in soil and water would be reduced through natural attenuation and MNA only.	2
Short-term effectiveness	There would be minimal risk to workers, the community, or the environment during sampling events. RAOs would not be achieved for a very long time. The actual time for natural attenuation to achieve preliminary chemical-specific RAOs would not be determined until groundwater modeling is performed.	3

Table 13-5 (Continued)

Evaluation Criterion	Evaluation	Numerical Rating
Technical and administrative implementability	There would be minimal construction associated with this alternative. The effectiveness of this alternative could be reliably monitored through groundwater, surface water, soil, and sediment sampling. There would be some coordination involved to obtain access to the site for sampling.	4
Cost of implementation	$1,790,000	$1,790,000
State acceptance	NE	NE
Community acceptance	NE	NE

* Land use controls are included under the Basewide Land Use Control Management Action Plan for Elmendorf AFB
EPA – U.S. Environmental Protection Agency
MNA – Monitored natural attenuation
NE – Not evaluated at this time, but will be evaluated once public and agency comments are received.
OSWER – Office of Solid Waste and Emergency Response
RAOs – Remedial action objectives

Table 13-6

Detailed Analysis of Alternative 3: Limited Steam Stripping of Chlorinated Contaminated Soils and Groundwater and MNA

Evaluation Criterion	Evaluation	Numerical Rating
Overall protection of human health and the environment	Land use controls* and environmental monitoring contained in Alternative 3 would render the alternative protective of human health and the environment. Human receptors would be protected from exposure to contaminants in soil/sediment and groundwater/surface water. The progress of the natural attenuation and accompanying reduction in risk would be monitored to determine long-term effectiveness, and soil and water use would be restricted. There would be limited active treatment in the source area under this alternative. Rapid reduction of risks would occur within the active treatment area. Since no active treatment would be performed for the downgradient wetland area, however, environmental risks from both contaminants would be present at the site until natural attenuation is complete and RAOs are achieved.	4
Compliance with remediation goals	Chemical-specific remediation goals for chlorinated and fuel contaminants in soil and groundwater would be met in approximately 1 year within the thermal treatment zone only. In all other areas, RAOs for chlorinated and fuel compounds in soil/sediment and groundwater/surface water would be met after natural attenuation is complete. Discharge of thermally treated groundwater must meet the requirements of the Federal Clean Water Act – NPDES Program (40 CFR Part 131) and the Alaska Water Quality Standards (18 AAC 70.20). Air emissions from SVE, which is part of the thermal treatment system, must meet regulatory requirements of the Alaska Clean Air Act (18 AAC 50). Wells would be installed in accordance with regulatory requirements (18 AAC 75.345(j) and Recommended Practices for Monitoring Well Design, Installation and Decommissioning). Outside the active treatment area, groundwater MNA and natural attenuation for soil/sediment would be utilized. Therefore, EPA guidance applicable to MNA would apply (EPA OSWER Directive 9200-4.17p). Land use controls* would be in place to meet location- and action-specific remediation goals.	5
Long-term effectiveness	Active remediation would continue within a 25-foot radius of the source area until concentrations in soil and groundwater are below RAOs. Therefore, once active treatment has been completed, residual risks would be acceptable in the source area. Groundwater/surface water MNA and soil/sediment natural attenuation would be utilized for the remainder of the site. Natural attenuation and land use controls are effective, reliable methods of protecting human health and the environment. Although risks would decline with time because contaminants would be slowly degraded by natural attenuation, the time required to reduce the contamination to residential cleanup levels would not be determined until groundwater modeling is performed.	4

Table 13-6 (Continued)

Evaluation Criterion	Evaluation	Numerical Rating
Reduction of toxicity, mobility, and volume of contaminants through treatment	The application of steam to soil and groundwater at the source area would raise the temperature of the subsurface such that contaminants would be vaporized and removed. Contaminated groundwater would be extracted and treated using GAC. The contaminants adsorbed to the GAC would be disposed of or destroyed when the GAC is regenerated. Alternative 3 only provides for active treatment over a small area; contamination in soil/sediment and groundwater/surface water across the rest of the site would be reduced through natural attenuation or MNA only.	4
Short-term effectiveness	Human and ecological exposures could increase if the steam stripping causes the spread of contamination to surface water or air. These risks could be controlled through proper design and operation of the system, including the use of SVE, groundwater extraction, and careful control of the steam injection rate. There would also be minimal risk to workers, the community, and the environment during sampling events. Although there is active treatment being performed for both chlorinated and fuel contaminants in soil and groundwater, it is limited to the source area. Because no active treatment is being utilized outside the source area, RAOs would not be achieved for a very long time for the entire site. The actual time required to achieve preliminary chemical-specific ARARs would not be determined until groundwater modeling is performed.	2
Technical and administrative implementability	The technology is generally proven. Steam stripping would require significant operation and maintenance. Trained operators would be present at all times during the 6-month operation period. The effectiveness of this alternative could be reliably monitored through groundwater, surface water, soil, and sediment sampling. Agency approval would be required. Site access would need to be coordinated for both active treatment and sampling events.	1
Cost of implementation	$3,920,000	$3,920,000
State acceptance	NE	NE
Community acceptance	NE	NE

* Land use controls are included under the Basewide Land Use Control Management Action Plan for Elmendorf AFB
AAC – Alaska Administrative Code
CFR – Code of Federal Regulations
EPA – .S. Environmental Protection Agency
GAC – Granular activated carbon
MNA – Monitored natural attenuation
NE – Not evaluated at this time, but will be evaluated once public and agency comments are received.
NPDES – National Pollutant Discharge Elimination System
OSWER – Office of Solid Waste and Emergency Response
RAOs – Remedial action objectives
SVE – Soil vapor extraction

Table 13-7

Detailed Analysis of Alternative 4: Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal and MNA

Evaluation Criterion	Evaluation	Numerical Rating
Overall protection of human health and the environment	Land use controls* and environmental monitoring contained in Alternative 4 would render the alternative protective of human health and the environment. Human receptors would be protected from exposure to contaminants in soil and groundwater until contaminants in these media degrade to acceptable levels. The progress of natural attenuation and the accompanying reduction in risk would be monitored to determine long-term effectiveness, and soil and water use would be restricted. There would be limited active treatment of contaminants in the source area under this alternative, including excavation and off-site treatment. Therefore, rapid reduction of risk would occur in the active treatment area. Since no active treatment would be performed for the rest of the site, however, unacceptable environmental risks from both chlorinated and fuel contaminants would be present at the site until MNA is complete and RAOs are achieved.	4
Compliance with remediation goals	Chemical-specific remediation goals for contaminants would be met in approximately 1 year for the approximately 360 cubic yards of soil that would be excavated. In all other areas, chemical-specific RAOs for contaminants in all environmental media would be met after natural attenuation is complete. Off-site shipment, treatment, and disposal would invoke action-specific ARARs. Outside the excavation area, natural attenuation would be utilized for soil/sediment and MNA for groundwater/surface water. EPA guidance applicable to MNA would apply (EPA OSWER Directive 9200-4.17p). Land use controls* would be in place to prevent exposure.	5
Long-term effectiveness	Chemical-specific RAOs would be met within the excavation area in approximately 1 year. Therefore, once excavation has been completed, residual risks would be acceptable in the source area. Natural attenuation and MNA would be utilized for the remainder of the site. Natural attenuation and land use controls are effective, reliable methods of protecting human health and the environment. Although risks would decline with time because contaminants would be slowly degraded by naturally occurring microorganisms, the time for MNA to reduce the contamination to residential cleanup levels would not be determined until groundwater modeling is performed.	3

Table 13-7 (Continued)

Evaluation Criterion	Evaluation	Numerical Rating
Reduction of toxicity, mobility, and volume of contaminants through treatment	The volume of contaminated soil in the excavation area would be reduced through off-site thermal treatment and disposal. However, Alternative 4 only provides for minimal active treatment. Most of the contamination in soil and water would be reduced through natural attenuation and MNA only.	3
Short-term effectiveness	There are some limited risks associated with excavation, handling, and transportation of hazardous materials. There would also be minimal risk to workers, the community, and the environment during sampling events. Active treatment being performed for contaminants in the soil is limited to the source area at the end of the drain tile from Building 18224. Since the estimated MNA cleanup timeframe is longer at other portions of the site and no active treatment is being utilized in these areas, RAOs would not be achieved for a very long time for the entire site. The time for natural attenuation to reduce the contaminants to residential cleanup levels would not be determined until groundwater modeling is performed.	3
Technical and administrative implementability	The technology is generally proven. The effectiveness of this alternative could be reliably monitored through groundwater, surface water, soil, and sediment sampling. Excavation, transport, treatment, and backfilling would require manifesting and approvals, which should be readily obtained. However, soils would be required to be shipped to an approved disposal facility. Site access would need to be coordinated for both active treatment and sampling events.	3
Cost of implementation	$2,660,000	$2,660,000
State acceptance	NE	NE
Community acceptance	NE	NE

* Land use controls are included under the Basewide Land Use Control Management Action Plan for Elmendorf AFB
ARARs – Applicable or relevant and appropriate requirement
EPA – U.S. Environmental Protection Agency
MNA – Monitored natural attenuation
NE – Not evaluated at this time, but will be evaluated once public and agency comments are received.
OSWER – Office of Solid Waste and Emergency Response
RAOs – Remedial action objectives

Table 13-8

Detailed Analysis of Alternative 5: Limited Source Removal of Chlorinated Contaminated Soils, On-Site Treatment and Disposal and Natural Attenuation

Evaluation Criterion	Evaluation	Numerical Rating
Overall protection of human health and the environment	Land use controls* and environmental monitoring contained in Alternative 5 would render the alternative protective of human health and the environment. Human receptors would be protected from exposure to contaminants in soil and groundwater until contaminants in these media degrade to acceptable levels. The progress of natural attenuation and the accompanying reduction in risk would be monitored to determine long-term effectiveness, and soil and water use would be restricted. During treatment, engineering controls would be in place to ensure air emissions from the mobile soil treatment unit would be maintained below regulatory limits to protect air quality. Treated soils would be sampled to confirm treatment to ensure effectiveness prior to disposal. There would be limited active treatment of chlorinated contaminants in the source area under this alternative, including excavation and on-site treatment. Therefore, rapid reduction of risk would occur in the active treatment area. Since no active treatment would be performed for the rest of the site, however, unacceptable environmental risks from both chlorinated and fuel contaminants would be present until natural attenuation is complete and RAOs are achieved.	4
Compliance with remediation goals	Chemical-specific remediation goals for contaminants would be met in approximately 1 year for the approximately 360 yards of soil that would be excavated. In all other areas, chemical-specific RAOs for contaminants in soil/sediment and groundwater/surface water would be met when natural attenuation is complete. On-site treatment and disposal would invoke action-specific ARARs. Specifically, air emissions from the on-site treatment system must meet regulatory requirements of the Alaska Clean Air Act (18 AAC 50). Outside the excavation area, natural attenuation would be utilized, including groundwater MNA. Land use controls* would be in place to prevent exposure.	5
Long-term effectiveness	Chemical-specific remediation goals would be met within the excavation area in approximately 1 year. Therefore, once excavation has been completed, residual risks would be acceptable in the source area. Natural attenuation of soil and groundwater MNA would be utilized for the remainder of the site. Monitoring and land use controls are effective, reliable methods of protecting human health and the environment. Although risks would decline with time because contaminants would be slowly degraded by natural attenuation, the time required to reduce the contamination to residential cleanup levels would not be determined until groundwater modeling is performed.	3

Table 13-8 (Continued)

Evaluation Criterion	Evaluation	Numerical Rating
Reduction of toxicity, mobility, and volume of contaminants through treatment	The volume of contaminated soil in the excavation area would be reduced through on-site thermal treatment and disposal. However, Alternative 5 only provides for minimal active treatment. Most of the contamination in soil and water would be reduced through natural attenuation and MNA only.	3
Short-term effectiveness	There are some limited risks associated with excavation, handling, and treatment of hazardous materials. Human and ecological exposures could increase if the emissions from the treatment unit caused the spread of contamination to air. These risks could be controlled through proper design and operation of the system, including the use of air emission scrubbers. There would also be minimal risk to workers, the community, and the environment during sampling events. Active treatment being performed for contaminants in the soil, is limited to the source area. Since the estimated natural attenuation cleanup timeframe is longer than other portions of the site and no active treatment is being utilized in these areas, RAOs would not be achieved for a very long time for the entire site. The time for natural attenuation to reduce the contaminants to residential cleanup levels would not be determined until groundwater modeling is performed.	2
Technical and administrative implementability	The technology is generally proven. The effectiveness of this alternative could be reliably monitored through groundwater, surface water, soil, and sediment sampling. Excavation, treatment, and backfilling would require permitting and approvals, which should be readily obtained. However, coordination and mobilization of a treatment unit to the site would be required.	3
Cost of implementation	$2,650,000	$2,650,000
State acceptance	NE	NE
Community acceptance	NE	NE

* Land use controls are included under the Basewide Land Use Control Management Action Plan for Elmendorf AFB
AAC – Alaska Administrative Code
ARARs – Applicable or relevant and appropriate requirement
MNA – Monitored natural attenuation
NE – Not evaluated at this time, but will be evaluated once public and agency comments are received.
RAOs – Remedial action objectives

Table 13-9

Detailed Analysis of Alternative 6: SVE for Soil and GW MNA

Evaluation Criterion	Evaluation	Numerical Rating
Overall protection of human health and the environment	Land use controls* and environmental monitoring contained in Alternative 5 would render the alternative protective of human health and the environment. Human receptors would be protected from exposure to contaminants in soil and groundwater until contaminants in these media degrade to acceptable levels. The progress of natural attenuation and the accompanying reduction in risk would be monitored to determine long-term effectiveness, and soil and water use would be restricted. Active treatment would be limited to soils containing contaminants at concentrations greater than preliminary chemical-specific ARARs. Therefore, rapid reduction of risk would occur within the active treatment area. Since no active treatment would be performed for the rest of the site, however, unacceptable environmental risks from both chlorinated and fuel contaminants would be present at the site until natural attenuation is complete and RAOs are achieved.	4
Compliance with remediation goals	Alternative 5 would require approximately 5 years to treat the soils via SVE. Therefore, chemical-specific RAOs are expected to be met in 5 years for chlorinated contaminants in soil. RAOs for contaminants in groundwater/surface water, and soil/sediments would be met after natural attenuation and MNA are complete. Wells would be installed in accordance with regulatory requirements (18 AAC 75.345(j) and Recommended Practices for Monitoring Well Design, Installation, and Decommissioning). Air emissions must meet the substantive regulatory requirements of the Alaska Clean Air Act regulations (18 AAC 50). Outside the treatment area, natural attenuation and groundwater monitoring would be utilized. EPA guidance applicable to MNA would apply (EPA OSWER Directive 9200-4.17p). Land use controls* would be in place to prevent exposure.	5
Long-term effectiveness	Active remediation would continue until contaminant concentrations in soil are below RAOs. Therefore, once active treatment has been completed, residual risks would be acceptable for the treated areas. However, the operation of SVE may turn the site aerobic and thereby limit anaerobic degradation of chlorinated contaminants for the duration of SVE operation. Natural attenuation and groundwater monitoring would be utilized for the remainder of the site. Natural attenuation and land use controls are effective, reliable methods of protecting human health and the environment. Risks would decline with time because contaminants would be slowly degraded by natural attenuation. Pumps, compressors, and wells used in SVE may require periodic maintenance and possible replacement.	3

Table 13-9 (Continued)

Evaluation Criterion	Evaluation	Numerical Rating
Reduction of toxicity, mobility, and volume of contaminants through treatment	SVE would be used to physically remove contaminants. VOCs stripped from soil would be captured in a carbon adsorption bed. The contaminants would then be disposed with the GAC or sent to a permitted TSD facility for regeneration of the carbon, at which time the contaminants would be destroyed. However, Alternative 5 only provides for minimal active treatment. Some of the contamination in soil and all of the contamination in water would be reduced through natural attenuation and MNA only.	3
Short-term effectiveness	Off-gas treatment would be used to control emissions from SVE, leaving minimal short-term risk; however, treatment would occur for 5 years. There would also be minimal risk to workers, the community, and the environment during sampling events. No active treatment is performed for groundwater, and no active treatment of fuel-contaminated soils is proposed. The time for MNA to reduce the contamination to residential cleanup levels would not be determined until groundwater modeling is performed.	3
Technical and administrative implementability	The technology is generally proven. SVE requires moderate operation and maintenance efforts. The effectiveness of this alternative could be reliably monitored through groundwater, surface water, soil, and sediment sampling. Agency approval would be required. Site access would need to be coordinated for both active treatment and sampling events. Five years of operation and maintenance is expected to be required.	2
Cost of implementation	$2,760,000	$2,760,000
State acceptance	NE	NE
Community acceptance	NE	NE

* Land use controls are included under the Basewide Land Use Control Management Action Plan for Elmendorf AFB
AAC – Alaska Administrative Code
ARARs – Applicable or relevant and appropriate requirement
EPA – U.S. Environmental Protection Agency
GAC – granular-activated carbon
MNA – Monitored natural attenuation
NE – Not evaluated at this time, but will be evaluated once public and agency comments are received.
OSWER – Office of Solid Waste and Emergency Response
RAOs – Remedial action objectives
SVE – Soil vapor extraction
TSD – Treatment, Storage, and Disposal
VOCs – Volatile organic compounds

Table 13-10

Comparative Analysis of Remedial Alternatives[a]

Criterion	Alternative 1 No Action	Alternative 2 Monitored Natural Attenuation	Alternative 3 Limited Steam Stripping of Chlorinated Contaminated Soils and Groundwater and GW MNA	Alternative 4 Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal, and GW MNA	Alternative 5 Limited Source Removal of Chlorinated Contaminated Soils, On-Site Treatment and Disposal, and GW MNA	Alternative 6 SVE for Soil and GW MNA
Overall protection of human health and the environment	0	3	4	4	4	4
Compliance with remediation goals	0	4	5	5	5	5
Long-term effectiveness	0	2	4	3	3	3
Reduction of toxicity, mobility, and volume of contaminants through treatment	0	2	4	3	3	3
Short-term effectiveness	3	3	2	3	3	3
Technical and administrative implementability	5	4	1	3	3	2
Cost of Implementation	$0	$1,790,000	$3,920,000	$2,660,000	$2,650,000	$2,760,000
State acceptance	NE	NE	NE	NE	NE	NE
Community acceptance	NE	NE	NE	NE	NE	NE
Total effectiveness score[b]	4	14	19	17	17	18
Total score	9	18	20	21	21	20

[a] Alternatives scored from lowest to highest (0 to 5) for each criterion.

[b] Total of all criterion except technical and administrative implementability and cost of implementation.

ARARs - Applicable or relevant and appropriate requirement
GW – Groundwater
MNA – Monitored natural attenuation
NE – Not evaluated at this time, but will be evaluated once public and agency comments are received
SVE – Soil vapor extraction

Table 13-11

Summary of Costs for Candidate Remedial Alternatives

Cost	**Alternative 1 No Action**	**Alternative 2 Monitored Natural Attenuation**	**Alternative 3 Limited Steam Stripping of Chlorinated Contaminated Soils and Groundwater and GW MNA**	**Alternative 4 Limited Source Removal of Chlorinated Contaminated Soils, Off-Site Treatment and Disposal, and GW MNA**	**Alternative 5 Limited Source Removal of Chlorinated Contaminated Soils, On-Site Thermal Treatment and Disposal, and GW MNA**	**Alternative 6 SVE for Soil and GW MNA**
Capital Cost	$0	$370,000	$1,790,000	$1,240,000	$1,170,000	$800,000
Present Worth O&M Cost (75 yrs, 7%)	$0	$1,420,000	$2,130,000	$1,420,000	$1,480,000	$1,960,000
Total Present Worth (75 yrs, 7%)	$0	$1,790,000	$3,920,000	$2,660,000	$2,650,000	$2,760,000
Total Effectiveness Score	4	14	19	17	17	18
Effectiveness-to-Cost Quotient	NA	7.8	4.8	6.4	6.4	6.5

[a] The effectiveness-to-cost quotient is calculated by dividing the total effectiveness score by the total present worth (in millions of dollars).
GW - Groundwater
MNA -Monitored natural attenuation
NA - Not analyzed (can't divide by a zero cost)
O&M - Operation and maintenance
SVE - Soil vapor extraction

Section 14.0
REFERENCES

Subsection 15.1 contains all references cited in the RI/FS document for Sections 1 through 7 and 10 through 14. Subsections 15.2 and 15.3 contain the references cited in the Human Health Risk Assessment (Section 8) and Ecological Risk Assessment (Section 9), respectively.

14.1 Sections 1–6 and 9–13

Air Force Center for Environmental Excellence (AFCEE). *Handbook for the Installation Restoration Program Remedial Investigations and Feasibility Studies.* September 1993.

Alaska Department of Environmental Conservation (ADEC). *18 AAC 75 Oil and Hazardous Substances Pollution Control Regulations.* 30 January 2003.

Alaska Department of Environmental Conservation (ADEC). *18 AAC 80 Drinking Water Regulations.* 21 September 2002.

Alaska Department of Environmental Conservation (ADEC). *Guidance on Calculating Cumulative Risk.* 2000a.

Alaska Department of Environmental Conservation (ADEC). *18 AAC 70 Water Quality Standards.* 27 May 1999.

American Society of Testing and Materials (ASTM). *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites,* ASTM E-1739-95, Philadelphia, PA. 1995.

Cederstrom, D.J., Trainer, F.W., and Waller, R.M. *Geology and Groundwater Resources of the Anchorage Area, Alaska,* U.S. Geological Survey Water Supply Paper 1773. 1964.

Domenico, P.A. and F.W. Schwartz. *Physical and Chemical Hydrogeology.* Hamilton Printing Company. 1990

Fetter, C.W. *Applied Hydrogeology.* Third Edition. Macmillian Publishing Company. 1993

Fetter, C.W. *Applied Hydrogeology.* Second Edition. Macmillan Publishing Company. 1988.

Gilber, R.O. *Statistical Methods for Environmental Pollution Monitoring.* Van Nostrand Reinhold*,* 320 p. 1987.

MacKay, D. et al. *Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals,* Lewis Publisher, Volume I and III. 1993.

Miller, R.D. and Dobrovolny, E. *Surficial Geology of Anchorage and Vicinity Alaska,* U.S. Geological Survey Bulletin 1093. 1959.

Ministère de l'Environnement du Québec (MDEQ). Critères de qualité de l'eau de surface au Québec. Quebec City, Quebec, Canada. 2001.

National Oceanic and Atmospheric Administration. *Screening Quick Reference Tables, Hamat Report 99-1.* September 1999.

Schmoll, H.R. and Dobrovolny, E. *Generalized Geologic Map of Anchorage and Vicinity, Alaska,* U.S. Geological Survey Miscellaneous Investigations Map I-787-A. 1972.

Shiu, et al. *Water Solubility of Crude Oils and Petroleum Products. Oil and Chemical Pollution 7.* 1999.

Ullery, C.A. and Updike, R.G. *Subsurface Structure of the Cohesive Facies of the Bootlegger Cove Formation, Southwest Anchorage, Alaska,* Alaska Division of Geological and Geophysical Surveys Professional Report 81. 1983.

Updike, R.G. and Carpenter, B.A. *Engineering Geology of the Government Hill Area, Anchorage, Alaska,* U.S. Geological Survey Bulletin 1588. 1986.

United States Air Force (USAF). *Addendum to Site Characterization Investigation at DP98, Final Workplan. Elmendorf Air Force Base, Alaska.* 1 August 2002.

United States Air Force (USAF). *Engineering Evaluation/Cost Analysis for Site DP98, Volume 1. Elmendorf Air Force Base, Alaska.* September 2001.

USAF November 2001. *U.S. Air Force Environmental Restoration Program Guide for Addressing Natural Resource Injury, Initial Draft.* November 2001a.

United States Air Force (USAF). *SERA Phase VIII Release Investigation Report ST423/6/7/8, 381st IS, UST AFID 755, Elmendorf Air Force Base, Alaska.* February 2000a.

United States Air Force (USAF). *Site Characterization Investigation at DP98: Final Workplan.* August 2000b.

United States Environmental Protection Agency (USEPA). *Draft Equilibrium Partitioning Sediment Guidelines (ESGs) for the Protection of Benthic Organisms: PAH Mixtures*. Office of Science and Technology and Office of Research and Development. November 10, 1999.

United States Air Force (USAF). *Year One Summary Report for Site Evaluations and Bioventing Studies at SERA VI Sites, Elmendorf Air force Base, Alaska.* May 1998.

United States Air Force (USAF). *SERA Phase IV UST Closure Investigation Report, Elmendorf Air Force Base, Alaska.* December 1996a

United States Air Force (USAF). *Final Remedial Investigation/Feasibility Study. Operable Unit 6. Volume I. Elmendorf Air Force base, Alaska.* January 1996b.

United States Air Force (USAF). *UST Decommissioning and Site Assessment-AFID 755, 381st IS Site, Elmendorf Air Force Base, Alaska, Draft.* November 1995.

United States Air Force (USAF). *Basewide Background Sampling Report, Elmendorf Air Force Base, Alaska.* 1993.

United States Department of Agriculture (USDA), Natural Resources Conservation Service. *Soil Survey of Elmendorf Air Force Base, Alaska (An Interim Report).* December 1997.

United States Environmental Protection Agency (EPA). *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites.* Office of Solid and Waste and Emergency Response Directive 9200.4-17. 1997

United States Environmental Protection Agency (USEPA). *Water Quality Criteria Summary.* Office of Science and Technology, Washington, D.C., USA. 1991.

United States Environmental Protection Agency (EPA). *Risk Assessment Guidance for Superfund: Human Health Evaluation Manual.* Vol. 1. 1991

United States Environmental Protection Agency (EPA). *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final.* Office of Emergency and Remedial Response. October 1988.

United States Fish and Wildlife Service (USFWS). *National Wetlands Inventory Map. Anchorage, Alaska.* 1:63, 000 scale. 1979.

Xu, M. and Y. Eckstein. "Use of Weighted Least-Square Method in Evaluation of the Relationship Between Dispersivity and Scale," *Journal of Association of Ground Water*, 33(6): 905-908. 1995.

14.2 <u>Section 7, Human Health Risk Assessment</u>

Alaska Department of Environmental Conservation (ADEC). *Risk Assessment Procedures Manual.* June 8, 2000a.

Alaska Department of Environmental Conservation (ADEC). *Guidance for Cleanup of Petroleum Contaminated Sites.* September 2000b.

United States Environmental Protection Agency (USEPA). *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual.* Part A. Interim Final. EPA 540/1-89/002. U.S. EPA Office of Emergency and Remedial Response. Washington, D.C. 1989.

United States Environmental Protection Agency (USEPA). *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual.* Supplemental Guidance: Standard Default Exposure Factors. Interim Final. OSWER Directive: 9285.6-03. March 25, 1991a.

United States Environmental Protection Agency (USEPA). "Guidelines for Exposure Assessment." Notice. *Federal Register* 57(104):22888-22938. 1992b.

United States Environmental Protection Agency (USEPA). *Supplemental Guidance to RAGS: Calculating the Concentration Term.* Publication: 9285.7-081. Office of Solid Waste and Emergency Response. Washington, D.C. May 1992.

United States Environmental Protection Agency (USEPA). *Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual - Supplemental Guidance, Standard Default Exposure Factors for Central Tendency and Reasonable Maximum Exposure*. Draft. 1993.

United States Environmental Protection Agency (USEPA). *Guidance for Risk Characterization*. Science Policy Council. February 1995.

United States Environmental Protection Agency (USEPA). *Health Effects Assessment Summary Tables.* EPA 540/R-97-036. Office of Research and Development, Office of Emergency and Remedial Response. July 1997.

United States Environmental Protection Agency (USEPA). *National Center for Environmental Assessment (NCEA) Risk Assessment Issue Papers on PCE and TCE*. Superfund Technical Support Center. November 1998.

United States Environmental Protection Agency (USEPA). Risk assessment issue paper for: Derivation of an Inhalation Unit Risk for Ethylbenzene. Superfund Technical Support Center, NCEA. 1999.

United States Environmental Protection Agency (USEPA). Supplemental Guidance for Developing Soil Screening Levels for Superfund *Sites*. Peer Review Draft. OSWER 9355.4-24. March 2001a.

United States Environmental Protection Agency (USEPA). *Trichloroethylene Health Risk Assessment: Synthesis And Characterization* External Review Preliminary Draft. August 2001b.

United States Environmental Protection Agency (USEPA). Integrated Risk Information System (IRIS) Online Database (http://www.epa.gov/iris/index.html). September 2002a.

United States Environmental Protection Agency (USEPA). *U.S. EPA Region 9 Preliminary Remedial Goal (PRG) Table and Supplemental Information*. October 2002b.

United States Environmental Protection Agency (USEPA).Toxicological Review of Xylenes (and IRIS Summary). External Review Draft. NCEA S-1203. January 2002c.

14.3 Section 8, Ecological Risk Assessment

Abernathy, S., A.M. Bobra, W.Y. Shiu, P.G. Wells, and D. Mackay. "Acute Lethal Toxicity of Hydrocarbons and Chlorinated Hydrocarbons to Two Planktonic Crustaceans: The Key Role of Organism-Water Partitioning." *Aquatic Toxicology* 8(3):163-174. 1986.

Air Force Center for Environmental Excellence (AFCEE). *Guidance for Contract Deliverables: Appendix D – Risk Assessment Methods.* HQ Air Force Center for Environmental Excellence, Technical Services Quality Assurance Program, Brooks AFB, Texas. 1997.

Alaska Department of Environmental Conservation (ADEC). *Risk Assessment Procedures Manual.* Contaminated Sites Remediation Program, Juneau, AK. June 8, 2000.

Alaska Department of Environmental Conservation. *Petroleum Cleanup Guidance: Background on Development of Regulations for Soil and Groundwater Cleanup Levels at Sites Contaminated with Petroleum Products.* Public Review Draft, Division of Spill Prevention and Response, Juneau, AK. 23 pp. 1996.

Alberta Environmental Protection. *Alberta Ambient Surface Water Quality – Interim Guidelines.* Alberta Environmental Assessment Division, Edmonton, Alberta. 7 pp. 1997.

Bobra, A.M., W.Y Shiu, and D. Mackay. "A Predictive Correlation for the Acute Toxicity of Hydrocarbons and Chlorinated Hydrocarbons to the Water Flea *(Daphnia magna)."* *Chemosphere* 12(9-10):1121-1129. 1983.

Boehm, P.D. and J.G. Quinn. "The effect of dissolved organic matter in sea water on the uptake of mixed individual hydrocarbons and number 2 fuel oil by a marine filter-feeding bivalve *(Mercenaria mercenaria)."* Estuar. Coast. Mar. Sci. 4:93-105. 1976.

Boudreau, B.P. "Is burial velocity a master parameter for bioturbation?" *Geochim. Cosmochim.* Acta 58:1243-1249. 1994.

Bridges, T.S. and C.H. Lutz. *Interpreting Bioaccumulation Data with the Environmental Residue-Effects Database*. Dredging Research Technical Note EEDP-04-30, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, USA. 1999.

Bringmann, G. and R. Kuhn. "Results of Toxic Action of Water Pollutants on *Daphnia magna* Straus Tested by an Improved Standardized Procedure." *Z. Wasser-Abwasser-Forsch.* 15(1):1-6. 1982.

Bringmann, G. and R. Kuhn. “Results of the Damaging Effect of Water Pollutants on *Daphnia magna.” Z. Wasser-Abwasser-Forsch.* 10(5):161-166. 1977.

Brooks, J.M., G.A. Fryxell, D.F. Reid, and W.M. Sackett. “Gulf Underwater Flare Experiment (GUFEX): Effects of Hydrocarbons on Phytoplankton.” In *Proc. Pollution Effects Marine Organisms,* C.S. Giam (Ed.). pp.45-75. 1977.

Buchman, M. *Screening Quick Reference Tables.* Hazmat Report 99-1, National Oceanic and Atmospheric Administration, Seattle, WA. 1999.

Chapman, H.F. and D.W. Connell. “Uptake and clearance of diesel alkanes from sediments by the Great Barrier Reef gastropod *Strombus luhuanus*.” *Mar. Biol.* 92:15-19. 1986.

Chapman, J.A. and G.E. Feldhamer, eds. *Wild Mammals of North America, Biology, Management, Economics.* The Johns Hopkins University Press, Baltimore, MD. 1982.

Cravedi, J.P. and J. Tulliez. “Accumulation, distribution and depuration in trout of naphthenic and isoprenoid hydrocarbons (dodecylcyclohexane and pristane).” *Bull. Environ. Contam. Toxicol.* 28:154-161. 1982.

Das, P.K.M.K. and S.K. Konar. “Acute Toxicity of Petroleum Products, Crude Oil and Oil Refinery Effluent on Plankton, Benthic Invertebrates and Fish.” *Environ. Ecol.* 6(4):885-891. 1988.

Deneer, J.W., T.L. Sinnige, W. Seinen and J.L.M. Hermens. “The joint acute toxicity to Daphnia magna of industrial organic chemicals at low concentrations.” *Aquat. Toxicol.* 12:33-38. 1988.

Donkin, P., J. Widdows, S.V. Evans and M.D. Brinsley. “QSARs for the sublethal responses of marine mussels *(Mytilus edulis).” Sci. Total Environ*. 109/110:461-476. 1991.

Donkin, P., J. Widdows, S.V. Evans, C.M. Worrall and M. Carr. “Quantitative structure-activity relationships for the effect of hydrophobic organic chemicals on rate of feeding by mussels *(Mytilus edulis).” Aquat. Toxicol.* 14:277-294. 1989.

Dyer, S.D., C.E. White-Hull and B.K. Shephard. “Assessments of chemical mixtures via toxicity reference values overpredict hazard to Ohio fish communities.” *Environ. Sci. Technol*. 34:2518-2524. 2000.

Efroymson, R.A., M.E. Will, G.W. Suter II and A.C. Wooten. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision.* ES/ER/TM-85/R3, Oak Ridge National Laboratory, Oak Ridge, TN. 1997.

Eisler, R.M. *Handbook of Chemical Risk Assessment, Health Hazards to Humans, Plants, and Animals. Volume 2, Organics.* Lewis Publishers, Boca Raton, FL. 2000.

Ferrando, M.D., and E. Andreu-Molinar. “Acute Toxicity of Toluene, Hexane, Xylene, and Benzene to the Rotifers *Brachionus calyciflorus* and *Brachionus plicatilis.” Bull. Environ. Contam. Toxicol.* 49(2):266-271. 1992.

Foster, G.D. and R.E. Tullis. Quantitative Structure-Toxicity Relationships with Osmotically Stressed *Artemia salina* Nauplii. *Environ. Pollut. Ser. A Ecol. Biol.* 38:273-281. 1985.

Franks, N. and W. Lieb. “Where do general anaesthetics act?” *Nature* 274:339-342. 1978.

Freitag, D., L. Ballhorn, H. Geyer and F. Korte. "Environmental hazard profile of organic chemicals: An experimental method for the assessment of the behaviour of organic chemicals in the ecosphere by means of laboratory tests with ^{14}C labelled chemicals." *Chemosphere* 14:1589-1616. 1985.

Geiger, D.L., L.T. Brooke, and D.J. Call. *Acute Toxicities of Organic Chemicals to Fathead Minnows (Pimephales promelas), Vol. 5.* Center for Lake Superior Environmental Studies, University of Wisconsin, Superior, WI. 332 pp. 1990.

Ghatak, D.B., M.M. Hossain, and S.K. Konar. "Acute Toxicity of n-Heptane and n-Hexane on Worm and Fish." *Environ. Ecol.* 6(4):943-947. 1988.

Golder Associates Ltd. *Recommendations to B.C. Environment for Development of Remediation Criteria for Petroleum Hydrocarbons in Soil and Groundwater. Volume 1, Text.* Submitted to Industrial Wastes and Hazardous Contaminants Branch, British Columbia Ministry of Environment, Lands and Parks, Victoria, B.C. June 16, 1995.

Guarino, A.M. and S.T. Arnold. Xenobiotic Transport Mechanisms and Pharmacokinetics in the Dogfish Shark. p. 233-258 in Khan, M.A.Q., J.J. Lech and J.J. Menn, eds. Pesticide and Xenobiotic Metabolism in Aquatic Organisms. American Chemical Society, ACS Symposium Series 99, Washington, D.C. 1979.

Guarino, A.M., G. Rieck, S. Arnold, P. Fenstermacher, J. Bend, M.J. Knutson, and J.B. Anderson. "Distribution and Toxicity of Selected Water Pollutants in the Spiny Dogfish, *Squalus acanthias." Bull. Mt. Desert Isl. Biol. Lab.* 16:50-53. 1976.

Heitmuller, P.T., T.A. Hollister, and P.R. Parrish. "Acute Toxicity of 54 Industrial Chemicals to Sheepshead Minnows (*Cyprinodon variegatus)." Bull. Environ. Contam. Toxicol.* 27(5):596-604. 1981.

Herman, D.C., C.I. Mayfield and W.E. Inniss. "The relationship between toxicity and bioconcentration of volatile organic hydrocarbons by the alga *Selenastrum capricornutum."* Chemosphere 22:665-676. 1991.

Hermens, J.L.M., H. Canton, P. Janssen and R. de Jong. "Quantitative structure-activity relationships and toxicity studies of mixtures of chemicals with anaesthetic potency: Acute *lethal* and sublethal toxicity to *Daphnia magna*." Aquat. Toxicol. 5:143-154. 1984.

Hill, E.F. and M.B. Camardese. *Lethal Dietary Toxicities of Environmental Contaminants and Pesticides to Coturnix.* U.S. Fish and Wildlife Service Technical Report 2, U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 147 pp. 1986.

Hodson, P.V., D.G. Dixon and K.L.E. Kaiser. "Measurement of median lethal dose as a rapid indication of contaminant toxicity to fish." *Environ. Toxicol. Chem*. 3:243-254. 1984.

Hodson, P.V., D.G. Dixon and K.L.E. Kaiser. "Estimating the acute toxicity of waterborne chemicals in trout from measurements of median lethal dose and the octanol-water partition coefficient." *Environ. Toxicol. Chem.* 7:443-454. 1988.

Huibers, P.D.T. and A.R. Katritzky. "Correlation of the aqueous solubility of hydrocarbons and halogenated hydrocarbons with molecular structure." J. Chem. Inf. Comput. Sci. 38:283-292. 1998.

Hutchinson, T.C., J.A. Hellebust, D. Tam, D. Mackay, R.A. Mascarenhas, and W.Y. Shiu. "The Correlation of the Toxicity to Algae of Hydrocarbons and Halogenated Hydrocarbons with their Physical-Chemical Properties." *Environ. Sci. Res.* 16:577-586.

Idoniboye-Obu, B. “Toxicity of Isolated Water-Soluble C6 Petroleum Hydrocarbons to Lobsters, *Homarus americanus.”* In *Symp. Animals Monitors Environ. Pollut*., S.W. Nielsen, G. Migaki, and D.G. Scarpelli (Eds.). 12:383-384. 1979.

Jenkins, D., S.A. Klein and R.C. Cooper. “Fish toxicity of jet fuels - I. The toxicity of the synthetic fuel JP-9 and its components.” *Water Res*. 11:1059-1067. 1977.

Kaiser, K.L.E., D.G. Dixon and P.V. Hodson. “QSAR Studies on Chlorophenols, Chlorobenzenes and Para-Substituted Phenols.” p. 189-206 in Kaiser, K.L.E., ed. *QSAR in Environmental Toxicology.* D. Reidel Publishing Co., Dordrecht, Holland. 1984.

Krasavage, W.J., J.L. O’Donoghue, G.D. Divencenzo and T. Erhaar. “Relative neurotoxicity of MBK, n-hexane and their metabolites.” Toxicol. Appl. Pharmacol. 52:433-441. 1980.

Kuhnhold, W.W. and F. Busch. “On the Uptake of Three Different Types of Hydrocarbons by Salmon Eggs *(Salmo salar L.)*.” *Meereforschung* 26:50-59. 1978.

LeBlanc, G.A. “Acute Toxicity of Priority Pollutants to Water Flea (Daphnia magna).” *Bull. Environ. Contam. Toxicol.* 24(5):684-691. 1980.

Lee, R.F., R. Sauerheber and A.A. Benson. “Petroleum hydrocarbons: Uptake and discharge by the marine mussel *Mytilus edulis.” Science 177:344-346.* 1972.

Legore, R.S. The Effect of Alaskan Crude Oil and Selected Hydrocarbon Compounds on Embryonic Development of the Pacific Oyster, /*Crassostrea gigas.* Ph.D. Thesis, University of Washington, Seattle, WA. 189 pp. 1974.

MacDonald, D.D., T. Berger, K. Wood, J. Brown, T. Johnsen, M.L. Haynes, T. Brydges, M.J. MacDonald, S.L. Smith and D.P. Shaw. *A Compendium of Environmental Quality Benchmarks*. Georgia Basin Ecosystem Initiative Report GBEI 99-01, Environment Canada, Vancouver, BC. 1999.

McCall, P.L. and M.J.S. Tevesz. “The effects of benthos on physical properties of freshwater sediments.” p. 105-176 in McCall, P.L. and M.J.S. Tevesz, eds. *Animal-Sediment Relations*. Plenum Press, New York, NY. 1982.

McCarty, L.S. and D. Mackay. “Enhancing ecotoxicological modeling and assessment: Body residues and modes of toxic action.” *Environ. Sci. Technol.* 27:1719-1728. 1993.

Mackenzie, K.M. and D.M. Angevine. “Infertility in mice exposed in utero to benzo(a)pyrene.” *Biol. Repro*. 24:183-191. 1981.

Massachusetts Department of Environmental Protection (MDEP). Updated Petroleum Hydrocarbon Fraction Toxicity Values for the VPH/EPH/APH Methodology. Draft. Bureau of Waste Site Cleanup, Boston, MA. May 2002.

Massachusetts Department of Environmental Protection (MDEP). *Characterizing Risks Posed by Petroleum Contaminated Sites: Implementation of the MADEP VPH/EPH Approach, Final Draft.* Bureau of Waste Site Cleanup, Boston, MA. June 2001.

Michelsen, T. 1997. MTCA Technical Support Document. *The Narcosis Model for Predicting the Toxicity of Dissolved Petroleum Constituents in Groundwater to Surface Water Receptors.* External Agency Review Draft, Toxics Cleanup Program, Washington Department of Ecology, Bellevue, WA. December 1997.

Morrow, J.E., R.L. Gritz, and M.P. Kirton. "Effects of Some Components of Crude Oil on Young Coho Salmon." *Copeia* 2:326-331. 1975.

Nunes, P. and P.E. Benville, Jr. "Uptake and depuration of petroleum hydrocarbons in the Manila clam, *Tapes semidecussata Reeve".* *Bull. Environ. Contam. Toxicol*. 21:719-726. 1979.

Ogata, M., K. Fujisawa, Y. Ogino and E. Mano. "Partition coefficient as a measure of bioconcentration potential of crude oil compounds in fish and shellfish." *Bull. Environ. Contam. Toxicol*. 33:561-567. 1984.

Passino, D.R.M. and S.B. Smith. "Acute Bioassays and Hazard Evaluation of Representative Contaminants Detected in Great Lakes Fish." *Environ. Toxicol. Chem.* 6(11):901-907. 1987.

Patton, J.F. and M.P. Dieter. "Effects of petroleum hydrocarbons on hepatic function in the duck." *Comp. Biochem. Physiol.* 65C:33-36. 1980.

Pawlisz, A.V. and R.H. Peters. "Effects of sublethal exposure on lethal body burdens of narcotic organic chemicals in *Daphnia magna."* *Environ. Sci. Technol*. 29:613-621. 1995.

Payne, J.F., L.L. Fancey, J. Hellou, M.J. King and G.L. Fletcher. "Aliphatic hydrocarbons in sediments: A chronic toxicity study with inter flounder *(Pleuronectes americanus)* exposed to oil well drill cuttings." *Can. J. Fish. Aquat. Sce.* 52:2724-2735. 1995.

Rogerson, A., W.Y. Shiu, G.L. Huang, D. Mackay, and J. Berger. "Determination and Interpretation of Hydrocarbon Toxicity to *Ciliate Protozoa*." *Aquatic Toxicology* 3(3):215-228. 1983.

Schultz, T.W. Comments on: "Influence of the energy relationships of organic compounds on toxicity to the cladoceran *Daphnia magna* and the fish *Pimephales promelas*." *Ecotoxicol. Environ. Saf.* 38:336-337. 1997.

Shephard, B.K. and J.W. Webb. Ecological toxicity reference values for petroleum alkane mixture toxicity to aquatic biota. Poster PMP060, 19th Annual Meeting, Society of Environmental Toxicology and Chemistry, Charlotte, NC. 1998.

Shephard, B.K. and L.S. McCarty. Tissue residue approaches to deriving numerical sediment quality criteria. Interactive Poster Presentation 590, 18th Annual Meeting, Society of Environmental Toxicology and Chemistry, San Francisco, CA. 1997.

Shephard, B.K. Quantification of Ecological Risks to Aquatic Biota from Bioaccumulated Chemicals. p. 2-31 to 2-52 in National Sediment Bioaccumulation Conference Proceedings, EPA 823-R-98-002, Office of Water, U.S. Environmental Protection Agency, Washington, D.C. 1998.

Snell, T.W., B.D. Moffat, C. Janssen, and G. Persoone. "Acute Toxicity Tests Using Rotifers IV. Effects of Cyst Age, Temperature, and Salinity on the Sensitivity of *Barachionus calyciflorus." Ecotoxicol. Environ. Saf.* 21(3):308-317. 1991.

Snyder, R. *Ethel Browning's Toxicity and Metabolism of Industrial Solvents, 2nd edition, Vol. 1: Hydrocarbons*. Elsevier Sciencie Publishing Company, Amsterdam, The Netherlands. 1987.

Stortelder, P.B., M.A. van der Gaag and L.A. van der Kooij. Perspectives for Water Organisms. An Ecotoxicological Basis for Quality Objectives for Water and Sediment. Part I. Results and Calculations. DBW/RIZA Memorandum N.89.016a. (English version August 1991). Institute for Inland Water Management and Waste Water Treatment. Lelystad, The Netherlands. 1989.

Stratton, G.W. “Toxic Effects of Organic Solvents on the Growth of Blue-Green Algae.” *Bull. Environ. Contam. Toxicol.* 38(6):1012-1019. 1987.

Stratton, G.W. and T.M. Smith. “Interaction of Organic Solvents with the Green Alga *Chlorella pyrenoidosa*.” *Bull. Environ. Contam. Toxicol.* 40(5):736-742. 1988.

Struhsaker, J.W. 1977. *Effects of benzene (a toxic component of petroleum) on spawning Pacific herring, Clupea harengus pallasi.* Fish. Bull. 75:43-49.

Suter, G.W. II and C.L. Tsao. *Toxicological Benchmarks for Screening Potential contaminants of Concern for Effects on Aquatic Biota:* 1996 Revision. ES/ER/TM-96/R2, Oak Ridge National Laboratory, Oak Ridge, TN. 1996.

Suter, G.W. II, R.A. Eftoymson, B.E. Sample and D.S. Jones. *Ecological Risk Assessment for Contaminated Sites.* Lewis Publishers, Boca Raton, FL. 438 pp. 2000.

Swihart, R.K., N.A. Slade and B.J. Bergstrom. “Relating body size to the rate of home range usage in mammals.” *Ecology* 69:393-399. 1988.

Thoms, S.R., G. Matisoff, P.L. McCall and X. Wang. *Models for Alteration of Sediments by Benthic Organisms.* Report D43014, Project 92-NPS-2, Water Environment Research Foundation, Alexandria, VA. 1995.

Travis, C.C. and A.D. Arms. “Bioconcentration of organics in beef, milk, and vegetation*.”* *Environ. Sci. Technol.* 22:271-274. 1988.

Tsuji, S., Y. Tonogai, Y. Ito, and S. Kanoh. “The Influence of Rearing Temperatures on the Toxicity of Various Environmental Pollutants for Killifish *(Oryzias latipes).”* *J. Hyg. Chem.* 32(1):46-53. 1986.

URS Consultants, Inc. Final Preliminary Source Evaluation 2 (PSE-2) Guidance Document, Operable Unit A, *Naval Air Facility (NAF) Adak, Adak Island, Alaska*. CTO-165. Prepared for Engineering Field Activity, Northwest, Southwest Division, Naval Facilities Engineering Command, Poulsbo, WA by URS Consultants, Seattle, WA. 1996a.

URS Consultants, Inc. *Final Remedial Investigation/Feasibility Study Management Plan, Adak Naval Complex, Adak Island, Alaska.* CTO-203. Prepared for Engineering Field Activity, Northwest, Southwest Division, Naval Facilities Engineering Command, Poulsbo, WA by URS Consultants, Seattle, WA. 1996b.

URS Consultants, Inc. *Draft Methodology Report: Tiered Approach to Risk Assessment for Petroleum Site Cleanup. Naval Air Facility Adak, Adak Island, Alaska.* CTO-213. Prepared for Engineering Field Activity, Northwest, Southwest Division, Naval Facilities Engineering Command, Poulsbo, WA by URS Consultants, Seattle, WA. CTO-213. 1996c.

URS Consultants, Inc. *Draft Ecological Risk Assessment Scoping Document, Naval Air Facility (NAF) Adak, Adak Island, Alaska.* CTO-152. Prepared for Engineering Field Activity, Northwest, Southwest Division, Naval Facilities Engineering Command, Poulsbo, WA by URS Consultants, Seattle, WA. 1995.

URS Consultants, Inc. *Draft Literature Review of Habitats and Wildlife, Adak Island, Alaska.* CTO-152. Prepared for engineering Field Activity , Northwest, Southwest Division, Naval Facilities Engineering Command, Paulsbo, WA under Navy CLEAN Contract #N62474-89-D9295 by URS consultants, Seattle, WA. 1994.

U.S. Environmental Protection Agency (EPA). *Guidelines for Ecological Risk Assessment*. EPA/630/R-95/002F, Risk Assessment Forum, Washington, D.C. 1998.

U.S. Environmental Protection Agency (EPA). *Ecological Risk Assessment for Superfund: Process for Designing and Conducting Ecological Risk Assessments – Interim Final.* EPA 540-R-97-006, Office of Solid Waste and Emergency Response, Washington, D.C. 1997a.

U.S. Environmental Protection Agency (EPA). *EPA Region 10 Supplemental Ecological Risk Assessment Guidance for Superfund*. EPA-910-R-97-005, Risk Evaluation Unit, USEPA Region 10, Seattle, WA. 1997b.

U.S. Environmental Protection Agency (EPA). *Wildlife Exposure Factors Handbook.* EPA/600/R-93/187a and b, Office of Research and Development, Washington, D.C. 1994.

U.S. Environmental Protection Agency (EPA). *Technical Basis for Deriving Sediment Quality Criteria for Nonionic Organic Contaminants for the Protection of Benthic Organisms by Using Equilibrium Partitioning.* EPA-822-R-93-011, Office of Water, Washington, D.C. 1993.

U.S. Environmental Protection Agency (EPA). *Health Effects Assessment Summary Tables* (HEAST). EPA/540/1-86-060, Environmental Criteria and Assessment Office, Cincinnati, Ohio. 1992.

U.S. Environmental Protection Agency (EPA). *Ambient Water Quality Criteria for Polynuclear Aromatic Hydrocarbons.* EPA 440/5-80-069, Criteria and Standards Division, Washington, D.C. 1980.

U.S. Environmental Protection Agency (EPA). *In-Depth Studies on Health and Environmental Impacts of Selected Water Pollutants.* U.S. Environmental Protection Agency, Duluth, MN. 1978.

Van Wezel, A.P. and A. Opperhuizen. "Narcosis due to environmental pollutants in aquatic organisms: Residue-based toxicity, mechanisms, and membrane burdens." *Crit. Rev. Toxicol.* 25:255-279. 1995.

Varanasi, U., J.E. Stein and M. Nishimoto. "Biotransformation and disposition of polycyclic aromatic hydrocarbons (PAH) in fish." p. 93-149 in Varanasi, U., ed. Metabolism of Polycyclic Aromatic Hydrocarbons in the Aquatic Environment. CRC Press, Boca Raton, FL. 341 pp. 1989.

Wallen, I.E., W.C. Greer, and R. Lasater. "Toxicity to *Gambusia affinis* of Certain Pure Chemicals in Turbid Waters*." Sewage Ind. Wastes* 29(6):695-711. 1957.

Washington State Department of Ecology. Model Toxics Control Act Cleanup Regulation. Chapter 173-340 WAC. Publication 94-06, Toxics Cleanup Program, Washington Department of Ecology, Olympia, WA. February 12, 2001.

Wentsel, R.S., T.W. LaPoint, M. Simini, R.T. Checkai, D. Ludwig and L.W. Brewer. *Tri-Service Procedural Guidelines for Ecological Risk Assessments, Volume 1.* U.S. Army Edgewood Research, Development and Engineering Center, Aberdeen Proving Ground, MD. 108 pp. 1996.