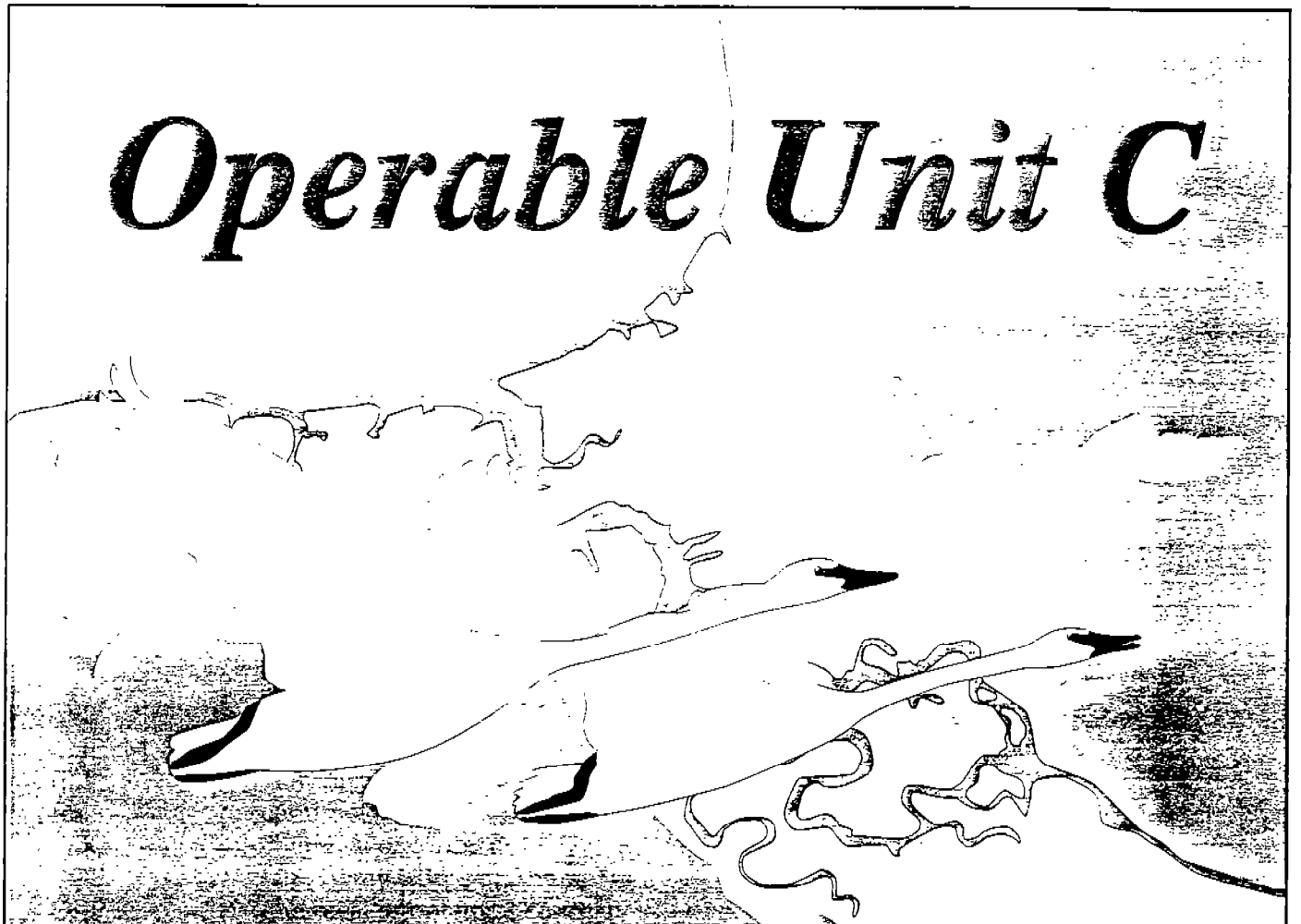
Operable Unit C



Final Remedial Investigation Report

Fort Richardson, Alaska
May 1997
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Delivery Order 1
Modification 3

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This report has been prepared under the
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Abbreviations

AAC	*Alaska Administrative Code*
ADEC	Alaska Department of Environmental Conservation
ADFG	Alaska Department of Fish and Game
AEHA	Army Environmental Hygiene Agency
AEIDC	Alaska Environmental Information and Data Center
AFB	Air Force Base
AOC	area of concern
AOPEC	area of potential concern
ARAR	applicable or relevant and appropriate requirement
AWQC	ambient water quality criteria
bw	body weight
CER	*Eagle River Flats Comprehensive Evaluation Report*
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund)
CFR	*Code of Federal Regulations*
CHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
CLP	Contract Laboratory Program
cm	centimeter
COC	chemical of concern
COE	U.S. Army Corps of Engineers
COPEC	chemical of potential concern
CRREL	U.S. Army Cold Regions Research and Engineering Laboratory
CSM	conceptual site model
CTV	critical toxicity value
CWA	Clean Water Act
DNT	dinitrotoluene
DQO	data quality objective
DWRC	Denver Wildlife Research Center
EcoRA	ecological risk assessment
Eh	measure of redox potential
EMCON	EMCON Alaska, Inc.
EOD	explosive ordnance disposal
ERF	Eagle River Flats
ESE	Environmental Science and Engineering, Inc.
FFA	Federal Facility Agreement
FR	*Federal Register*
FS	feasibility study
g/cm^3	grams per cubic centimeter
GIS	geographical information system
H_3PO_4	phosphoric acid
H_3PO_3	phosphorus acid
ha	hectare
HC	hexachloroethane-zinc mixture

HE	high explosive
HHRA	human health risk assessment
HMX	cyclotetramethylenetetranitramine
kg	kilogram
km	kilometer
L	liter
LC_{50}	acute toxicity
LD_{50}	lethal dose for 50 percent of a sample population
LOEL	lowest observed effects level
MCC	maximum contaminant concentration
MCL	maximum contaminant level
m	meter
µg	microgram
µg/g	micrograms per gram
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µL	microliter
µm	micrometer
mg	milligram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mL	milliliter
mm	millimeter
m/sec	meters per second
m^3/sec	cubic meters per second
msl	mean sea level
mV	millivolt
MOA	Municipality of Anchorage
NCP	National Contingency Plan
NEILE	New England Institute of Landscape Ecology
NOEC	no observed effect concentration
NOEL	no observed effect level
NPL	National Priorities List
NRDA	Natural Resource Damage Assessment
NTU	nephelometric turbidity unit
NWHL	National Wildlife Health Laboratory
NWHRC	National Wildlife Health Research Center
OB	open burning
OD	open detonation
OUC	Operable Unit C
P_4	molecular formula specifically for the white allotrope of elemental phosphorus
P_4O_{10}	phosphorus (V) oxide
P_4O_6	phosphorus (III) oxide
PCB	polychlorinated biphenyl
ppm	parts per million
ppt	parts per thousand
PRG	preliminary remediation goal

PWRC	Patuxent Wildlife Research Center
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act of 1976
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RI	remedial investigation
RPM	remedial project manager
SARA	Superfund Amendments and Reauthorization Act
SWMU	solid waste management unit
TBC	to be considered
TCLP	toxicity-characteristic leaching procedure
TNT	trinitrotoluene
TSS	total suspended sediment
UCI	Upper Cook Inlet
USAEC	U.S. Army Environmental Center
USAEHA	U.S. Army Environmental Hygiene Agency
USARAK	U.S. Army, Alaska
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UXO	unexploded ordnance
WP	white phosphorus
ww	wet weight

Executive Summary

This report presents the results of the remedial investigation (RI) of Operable Unit C on Fort Richardson, Alaska. The U.S. Army Corps of Engineers, Alaska District, on behalf of the U.S. Army, Alaska (USARAK), contracted with CH2M HILL to prepare the RI report under Delivery Order Number 1, Modification 3, of Contract Number DACA85-95-D-0015.

This report documents results of the remedial investigation of Operable Unit C on Fort Richardson, Alaska.

Fort Richardson is an active U.S. Army installation near Anchorage, Alaska. It encompasses 22,260 hectares along the Knik Arm of the Cook Inlet, immediately east of Elmendorf Air Force Base and the Municipality of Anchorage. In June 1994, Fort Richardson was listed by the U.S. Environmental Protection Agency (USEPA) on the National Priorities List (NPL). This listing designated the post as a federal Superfund site subject to the remedial response requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986.

As a result of the listing of Fort Richardson on the NPL, the USARAK, USEPA, and the Alaska Department of Environmental Conservation negotiated the Federal Facility Agreement for Fort Richardson, which all three parties signed on December 5, 1994. Under the terms of the FFA, all remedial response activities will be conducted to protect public health and welfare, and the environment, in accordance with CERCLA, the National Contingency Plan, the Resource Conservation and Recovery Act, and applicable state law.

Fort Richardson was divided into four Operable Units (OUs), labeled A through D, as part of the FFA. Each OU encompasses a series of potentially contaminated sites identified during an inventory that was completed before the FFA was signed. This report documents RI results for OUC, which includes the primary ordnance impact area on Fort Richardson (Eagle River Flats [ERF]) and an adjacent gravel pad that was used for the open burning (OB) and open detonation (OD) of unwanted ordnance (OB/OD Pad).

A productive wetland, ERF serves as an important staging ground for migrating waterfowl during the spring and fall migrations

Eagle River Flats

ERF is an 876-hectare estuarine salt marsh at the mouth of Eagle River. Approximately 25 targets placed in ERF have been used for artillery training since 1949, creating thousands of craters in the wetlands and associated mud flats and leaving an estimated 100,000 unexploded mortar and artillery shells buried in the shallow subsurface. Although ERF is an active impact area, it remains a productive wetland, serving

as an important staging ground for migrating waterfowl during the spring and fall migrations. ERF also supports local populations of fish, birds, mammals, and macroinvertebrates. A series of ponds distributed throughout ERF provide excellent habitat for dabbling waterfowl.

Previous sampling results and detailed observation of various populations within ERF have identified WP as the primary contaminant and waterfowl as the primary receptors.

Since the initial reports of elevated waterfowl mortality in the early 1980s, a multidisciplinary investigation has been conducted to identify the cause of the mortality (shown in 1990 to be white phosphorus [WP]), the extent of the WP contamination, and the potential effects of WP and other munitions on the biota in ERF. WP was released into ERF by ordnance used to create smoke for ground troop cover. WP that did not fully oxidize can remain as particles in the sediment. Ingestion of WP particles by feeding waterfowl has created high levels of mortality. Birds have been observed to die within minutes to hours of ingesting WP in a number of ponds in ERF.

Sampling results have focused primarily on a relatively small number of areas in ERF where the greatest levels of mortality were observed. The results of this sampling have demonstrated that elevated levels of WP exist in most ponds where the highest mortality levels occur; however, in some ponds where high mortality has been observed, WP has not been extensively detected in the sediment. This finding suggests that some birds may ingest WP in a contaminated area but fly away from the point of exposure before succumbing. The potential for birds to move following exposure, coupled with limitations on sampling efforts because of the hazard posed to site workers by the unexploded ordnance (UXO), has complicated delineation of the lateral and vertical extent of WP contamination.

The primary preliminary remediation goal for ERF is the reduction of mortality in dabbling ducks and swans.

Previous sampling results and detailed observation of various populations within ERF have identified waterfowl as the primary receptors of WP contamination. Although low levels of WP have been found in plants, macroinvertebrates, and fish, existing data do not show that these populations have been significantly affected by the presence of WP in ERF. There is some evidence indicating that scavengers that feed on waterfowl carcasses in ERF, particularly bald eagles, may have been affected by WP. It is believed, however, that reducing the acute effect in dabbling waterfowl (mortality) to acceptable levels also will reduce potential effects (acute or chronic) in the predators and scavengers that have been identified as secondary receptors because of the reduction in their exposure concentrations. Therefore, the primary preliminary remediation goal for ERF is the reduction of mortality in dabbling ducks and swans.

Observations of carcass locations, areas preferred by waterfowl, and crater densities were used by researchers to define areas most likely to contain WP. The sediments in these areas were extensively sampled for WP, with the use of radial transects in open ponds. The distribution of ponds and analytical results of WP in sediment were

compiled and used in conjunction with landcovers (combination of landform and vegetation) and bird usage data to identify hot ponds that are likely the areas presenting the highest risk. The UXO hazard in ERF, in combination with the high sampling frequency, makes extensive future sampling efforts infeasible.

The findings documented in this report are based primarily on data collected before implementing the CERCLA process at OUC. However, the analytical process for the identification of WP concentrations was first developed during this phase and has since been adopted by the USEPA as Method 7580 in SW 846 Update III. Compilation and review of these data have led to the following conclusions:

This RI report is based largely on data collected before the CERCLA process was implemented at OUC.

1. **WP is the primary cause of waterfowl mortality.** Symptoms exhibited by exposed ducks in ERF are similar to those observed in ducks dosed with WP in the laboratory. WP also was detected in tissue samples collected from duck carcasses found in ERF.

2. **WP was deposited in the sediment primarily during range firing activities.** WP smoke munitions were used during training activities in ERF for several decades. Rounds were fired onto the flats and detonated, dispersing WP particles over large areas. Further distribution of the particles likely occurred when high-explosive rounds exploded in WP-contaminated soil and sediment.

3. **Craters in ERF potentially indicate the level of range firing activity.** Detonation of HE munitions generally creates a crater at the point of impact. Although WP munitions do not form craters upon detonation, they typically have been used in conjunction with HE training activities. By applying a cause-and-effect approach, it can be deduced that the more craters in an area, the more munitions that have likely been fired there, and thus the higher probability of WP contamination.

4. **WP particles are not homogeneous throughout ERF.** WP particles are dispersed after munitions containing WP are detonated. Particle sizes vary because of the nature of an explosive release. Particle size, dispersion pattern, and ultimate resting location also depend on whether the munitions were detonated on land or over water. Even within small areas, the particle density can vary substantially.

The detection frequencies and concentrations for WP in sediment are highest in Area C, Bread Truck, and Racine Island.

5. **The detection frequencies and concentrations for WP in sediment are highest in Area C, Bread Truck, and Racine Island.** Sixty-three percent of the overall ERF sampling locations had nondetectable concentrations, but at least 45 percent of the locations in each of these three areas had detectable

concentrations. The highest concentration, 3,071 micrograms per gram, was found on Racine Island.

Predation and human exposure to WP by consumption are not high-level concerns at present.

6. **WP particles can break down (sublimate) when exposed to air, but are long lasting in water-saturated media.** WP particles are readily oxidized when exposed to air at temperatures exceeding 20°C. Because they dissolve so slowly, particles have an indefinite life when quenched in the water and allowed to settle into pond or marsh bottom sediments.

7. **Waterfowl are exposed to WP from the sediment of ponds and sedge marshes while they are feeding.** Some WP particles match the size of food (such as seeds and macroinvertebrates) sought by dabbling ducks and swans. As the waterfowl forage for food in pond and marsh bottom sediments, it is possible that they cannot differentiate between WP and their normal food source.

8. **Dabbling ducks and swans are the primary receptors of WP.** Dabbling ducks and swans both forage for food in pond and marsh bottom sediments. In addition, mortality rates of dabbling ducks have been observed to be significantly higher than mortality rates of other waterfowl in ERF as well as other Upper Cook Inlet marshes. Telemetry data in 1996 suggest that the mortality rate among mallards was about 35 percent.

9. **Predation and human exposure to WP by consumption are not high-level concerns at present.** There has been no verified mortality resulting from predators feeding on WP-contaminated waterfowl carcasses. Although a dead eagle has been found with WP contamination, current predator mortality appears low. In addition, the results of analyses of tissue collected from dabbling ducks taken by hunters near ERF do not indicate a threat to humans ingesting the meat.

Twenty-two permanent ponds with a total area of 23 hectares already have been identified as the likely areas of most significant exposure.

10. **Permanent ponds and associated sedge with confirmed presence of WP and/or moderate to high crater density and observed moderate to high dabbling duck and/or swan use are the most significant exposure areas (such ponds are referred to as hot ponds).** According to the conceptual site model, areas of greatest concern are where there is a source (WP-contaminated sediment), a receptor (dabbling duck or swan), and a potential for exposure (foraging for food). Twenty-two hot ponds, which include a total area of 23 hectares, have been identified in these areas: A, C, C/D, Bread Truck, and Racine Island.

11. **The movement of WP through Eagle River to Knik Arm appears to be minimal.** WP has been detected in the sediments traveling through the gullies, but there is no evidence to suggest that WP would be detected in Knik Arm.

An integrated process of evaluating remedial success for ERF should be implemented once remedial action is initiated. Data specific to the remedial technology applied at a hot pond should be used as a preliminary indication that a hot pond has been eliminated. The future monitoring activities should become a primary mechanism for evaluating the main remedial goal of reducing waterfowl mortality over the entire ERF.

OB/OD Pad

OB/OD Pad is about 4 hectares in size and consists of a gravel pad placed as fill on the edge of ERF. Opening burning and open detonation of explosive materials historically have occurred on this pad. Materials have included fuses, high-explosive projectiles, smoke pots, mortar rounds, star clusters, flares, mines, rocket motors, shape charges, detonation cord, dynamite, and some flammable solids. Existing records indicate that no liquids were disposed there. Disposal was either on the surface or in an excavated pit.

A site investigation of the soil and groundwater at OB/OD Pad was completed in 1996. Surface and subsurface soils were sampled. Nine monitoring wells were installed and developed, and groundwater samples were taken. Soil and groundwater samples were analyzed for an extensive list of volatile and semivolatile organic chemicals and metals. Very few chemicals were detected in either the soil or the groundwater. All detected chemicals had concentrations considerably below their action levels for clean closure. In addition, the ecological and human health risk assessments indicate that the risks are very low.

The site investigation of soil and groundwater at OB/OD Pad in 1996 found no detected chemicals in concentrations above action levels for clean closure.

The following are major findings for OB/OD Pad:

1. **The groundwater is at a depth of 6 to 11 m below the surface, and the gradient is shallow, with groundwater moving toward the southwest, toward ERF.** Groundwater movement patterns are likely influenced by the tides and the river.
2. **The site investigation detected only a limited number of organic chemicals and metals in the soil and groundwater.** In many cases, observed soil concentrations were similar to reference area values.
3. **The OB/OD Pad will meet clean closure requirements.** The detected chemicals were all considerably below their clean closure action levels.
4. **The ecological and human health risk assessments found very low risks associated with exposures to these chemicals at the measured concentrations.**

At OB/OD Pad, the USARAK should proceed with clean closure in accordance with the requirements in the closure guidance from

Title 40 of the *Code of Federal Regulations*, Part 264. The USARAK may consider the use of the ERF dredge spoils as cap material.

SECTION 1

Introduction

This report on the OUC RI has been prepared to satisfy CERCLA requirements.

In June 1994, Fort Richardson, Alaska, was listed by the U.S. Environmental Protection Agency (USEPA) on the National Priorities List (NPL). This listing designated the post as a federal Superfund site subject to the remedial response requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986.

Following inclusion of Fort Richardson on the NPL, the U.S. Army, Alaska (USARAK), USEPA, and the Alaska Department of Environmental Conservation (ADEC) negotiated the Federal Facility Agreement (FFA) for Fort Richardson, which all three parties signed on December 5, 1994. Under the terms of the FFA, all remedial response activities will be conducted to protect public health and welfare, and the environment, in accordance with CERCLA, the National Contingency Plan (NCP), the Resource Conservation and Recovery Act (RCRA), and applicable state law.

This report presents the results of the remedial investigation (RI) of Operable Unit C (OUC) on Fort Richardson. The U.S. Army Corps of Engineers (COE), Alaska District, on behalf of the USARAK, contracted with CH2M HILL to prepare the RI report under Delivery Order No. 1, Modification 3, of Contract Number DACA85-95-D-0015.

The data on which this RI report is based were collected as part of an extended, multidisciplinary investigation conducted primarily by a variety of federal research laboratories under contract to USARAK. The results of this effort, reported in technical memoranda, meeting minutes, and reports, were reviewed along with the contents of an existing geographical information system (GIS) database. This RI report has been compiled by using the review results to satisfy CERCLA requirements for OUC.

1.1 Purpose and Objectives of the Remedial Investigation

The OUC RI is intended to characterize the nature and extent of contamination; to evaluate the associated risks to human health and the environment posed by the contamination; and to obtain information needed to evaluate and select appropriate remedial action.

The approach and methodologies used to conduct the RI are documented in a previously prepared management plan (CH2M HILL, 1996). The results of the RI will be used to develop remedial alternatives in the subsequent feasibility study (FS). The FS will then be used to develop a proposed plan and record of decision to achieve site remediation of OUC.

Results of the RI will be used to develop remedial alternatives in the FS.

Compliance with federal and state environmental standards is evaluated as part of the FS through consideration of the applicable or relevant and appropriate requirements (ARARs). Applicable requirements are those remediation standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or circumstance at a particular CERCLA site.

Studies completed at Eagle River Flats (ERF) before initiation of the OUC RI identified white phosphorus (WP) as the primary chemical of concern (COC). Only limited sampling of surface soils had been completed at the OB/OD (Open Burning/Open Detonation) Pad during past assessments of that portion of OUC. The past data for ERF and OB/OD Pad were evaluated to determine remaining data gaps for the RI.

The following were objectives of the OUC RI:

- Collect remaining data to assess the nature and extent of contamination, and evaluate the potential for offsite migration of the contamination for both ERF and OB/OD Pad
- Collect remaining data and fill data gaps to assess the risks to human health and the environment
- Compile the data to develop source-specific conceptual models and provide a basis for the FS
- Document the results of the field investigations in a format suitable for public review and comment

The OUC RI/FS is part of the Fort Richardson Administrative Record and will be incorporated into the Fort Richardson Community Relations Plan.

Studies completed at ERF before initiation of the OUC RI identified WP as the primary chemical of concern.

1.2 Site Background

Fort Richardson is an active U.S. Army installation near Anchorage, Alaska. Its 22,260 hectares (ha) include a central cantonment area surrounded by ranges, impact, and maneuver areas to the north, east, and south. The Municipality of Anchorage and Elmendorf Air Force Base lie west of Fort Richardson. The entire post is listed as a

Superfund site on the NPL. OUC consists of two main areas: Eagle River Flats (ERF) and the adjacent OB/OD Pad.

OUC contains the ERF estuarine salt marsh and the OB/OD Pad, a former EOD site.

1.2.1 Eagle River Flats

ERF is an 876-ha estuarine salt marsh in the northwest sector of Fort Richardson, Alaska. Located at the mouth of the Eagle River and adjacent to Upper Cook Inlet, ERF is a productive wetland area. It serves as an important staging ground for several species of waterfowl, including ducks, geese, and swans, during spring and fall migrations. The Eagle River, which winds through ERF, maintains spawning runs of chinook, coho, and pink salmon.

ERF has been used as the primary ordnance impact area for Fort Richardson since 1949. It is the only impact area for heavy artillery and mortars on Fort Richardson. The USARAK personnel practice firing at the targets from more than 25 points, at distances of up to 10 kilometers (km) (Racine *et al.*, 1992a). Ordnance fired into ERF since 1949 include machine gun and rifle rounds, grenades, rockets, mortars, and incendiary missiles.

1.2.2 OB/OD Pad

OB/OD Pad, which is located along the eastern edge of ERF, consists of approximately 4 ha formerly used as an explosive ordnance disposal (EOD) site.

The gravel pad at OB/OD Pad covers approximately half of the 4-ha clearing along the eastern edge of ERF. It was constructed at least 20 years ago. OB/OD Pad was used by the USARAK for OB/OD activities, and currently contains the remains of destroyed surplus and outdated munitions, along with assorted objects such as junked vehicles and rocket motor casings. Demolition of propellants on this pad apparently contaminated an area of the salt marsh in the adjacent ERF (Racine *et al.*, 1992a).

The OB/OD Pad has been identified as a solid waste management unit (SWMU) under RCRA. Limited surface soil sampling was conducted at OB/OD Pad in 1992 by the Army Environmental Hygiene Agency (AEHA). A site investigation was completed in 1996. Results of the investigation are included in this RI report.

1.3 Organization of Report

The organization and content of this RI report are described as follows:

- **Section 1, Introduction**, briefly describes where the RI fits in the CERCLA process and summarizes the purpose and objectives of

the RI. Included are a brief history of OUC source areas and other relevant background information.

- **Section 2, Environmental Setting,** describes the physical and ecological features of OUC, including location, climate, geology, soils, hydrology, aquatic and terrestrial ecology, and military and civilian land use.

- **Section 3, Review of Studies,** provides a chronological summary of investigations at ERF, including a discussion of sampling logic; location, number, and type of samples; laboratory analytical methods; and quality assurance (QA)/quality control (QC) measures.

- **Section 4, Nature and Extent of Contamination,** presents the results of the sampling and analysis for WP in ERF (water, soil, and sediment).

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

- **Section 6, OB/OD Pad,** presents information on historical use of OB/OD Pad and a discussion of the 1996 site investigation, including sampling logic, locations, sample collection, laboratory analytical methods, QA/QC procedures and results of the sampling and analysis of soil and groundwater. A conceptual site model based on results of the site investigation is also presented for the OB/OD Pad.

- **Section 7, Comparison of ARARs,** summarizes chemical- and location-specific ARARs pertinent to ERF and OB/OD Pad.

- **Section 8, Baseline Risk Assessment,** presents a summary of the evaluation of the threat to human health and the environment as a result of the contamination identified at OUC. The detailed evaluation, included in Appendices A and B, is based on data obtained from the RI and is consistent with the conceptual site models (CSMs) presented in Sections 5 and 6 and current USEPA guidance on baseline risk assessments.

- **Section 9, Conclusions and Recommendations,** summarizes the findings presented in Sections 4 through 8 including the nature and extent of contamination, contaminant fate and transport, and the risk assessment. Contaminants of concern are identified and recommendations for further monitoring or remediation are presented.

- **Section 10, Preliminary Remediation Goals**, outlines the general and specific objectives for OUC remediation. Discussions of contamination hot spot identification and verification of remedial success also are presented. These discussions will form the basis for the subsequent FS.
- **Section 11, Works Cited**, lists all references cited in the RI report.
- **Appendices** contain the following reports and supporting data:

– Appendix A, Ecological Risk Assessment

– Appendix B, Human Health Risk Assessment

– Appendix C, Site Studies for Chemicals Other Than White Phosphorus

– Appendix D, Quality Assurance Audits

– Appendix E, OB/OD Pad Site Investigation Data

– Appendix F, Responses to Comments

SECTION 2

Environmental Setting

2.1 Location and Climate

2.1.1 Location

A roughly triangular lowland, the Anchorage area lies between Turnagain Arm and Knik Arm, at the head of Cook Inlet. Fort Richardson and OUC are located in the northern third of the Anchorage lowland (Figure 2-1). ERF comprises most of OUC; OB/OD Pad is on the eastern edge of ERF (Figure 2-2).

ERF is an 876-hectare estuarine salt marsh; OB/OD Pad covers about 4 hectares.

ERF is a cornucopia-shaped estuarine salt marsh surrounded by forested uplands on the west, south, and east sides, and bounded by the Knik Arm on the north. The Eagle River flows through ERF from the southeast to the northwest, ultimately discharging into Knik Arm. Two creeks, Clunie and Otter, also drain into ERF (Figure 2-2).

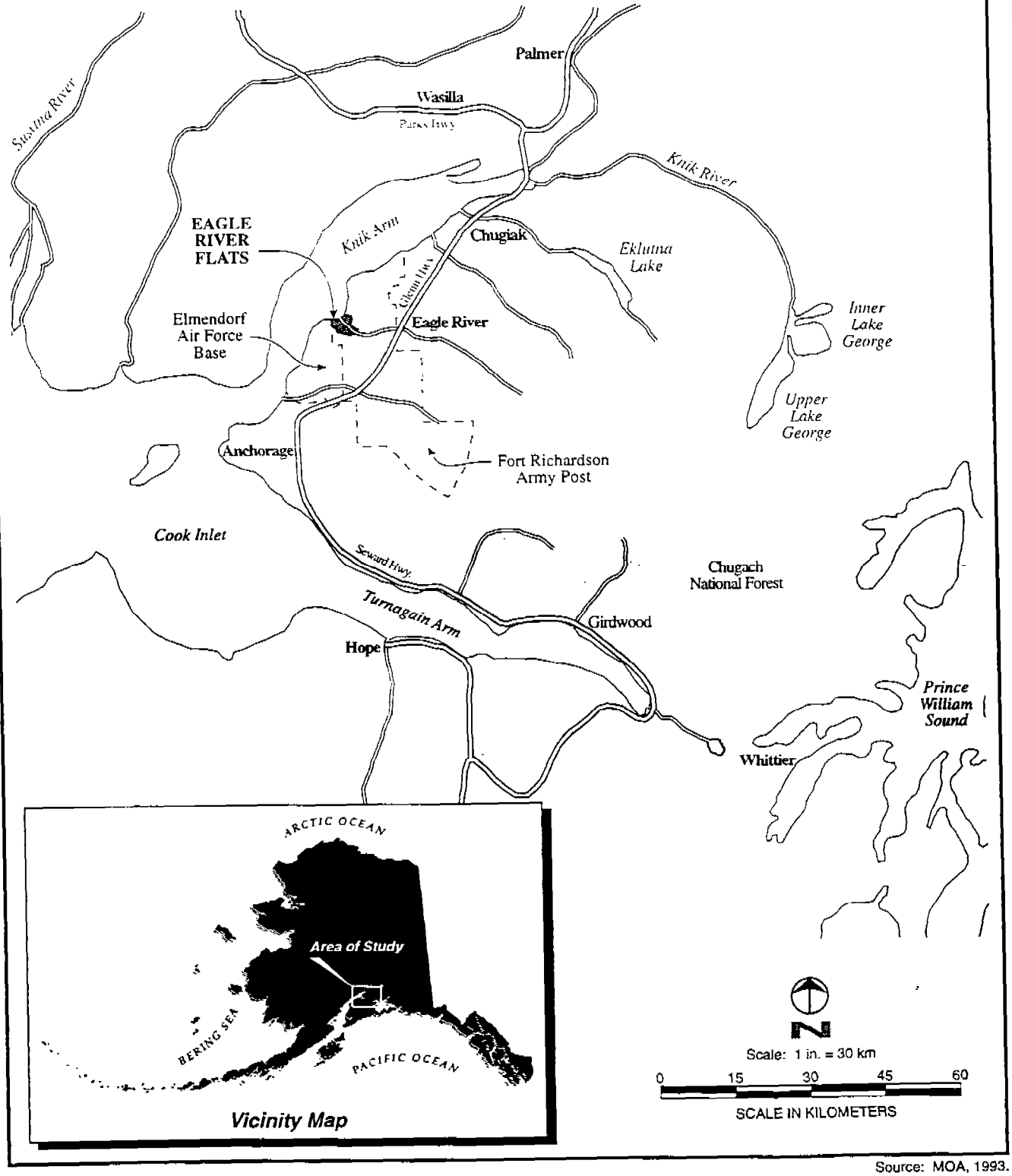
2.1.2 Climate

A transitional climate zone provides a relatively moderate climate for the Anchorage area. The Alaska Range, north and northwest of Anchorage, prevents the influx of very cold air from the Interior, and the waters of Cook Inlet, including Turnagain Arm and Knik Arm to the northwest and southwest, help warm the area. Average temperatures recorded for the period 1952 to 1987 ranged from -2°C to 7°C, with an annual mean of 3°C. The average minimum and maximum extreme temperatures are -18°C to 33°C, respectively (Alaska Environmental Information and Data Center [AEIDC], 1989).

Climate is mild with heaviest rains in the summer.

Air masses from the Gulf of Alaska (to the south) produce relatively heavy rainfall along the Chugach Mountains and can contribute to high runoff events in the rivers draining the mountains, including Eagle River. The heaviest precipitation occurs between July and September, with an average rainfall of almost 18 centimeters (cm) falling during the 3-month period. Annual average rainfall is between 33 and 51 cm (AEIDC, 1989).

In 1994, a meteorological data collection station was installed at ERF to provide baseline data for ongoing investigations. Comparisons between ERF and the Anchorage climatic record showed that daily maximum temperatures were about 1°C cooler and minimum temperatures about 2°C cooler at ERF. A comparison of mean daily air temperatures between the main meteorological station on OB/OD Pad and at an ERF coastal research site showed a 5.3°C difference,



Source: MOA, 1993.

Figure 2-1

Location Map

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

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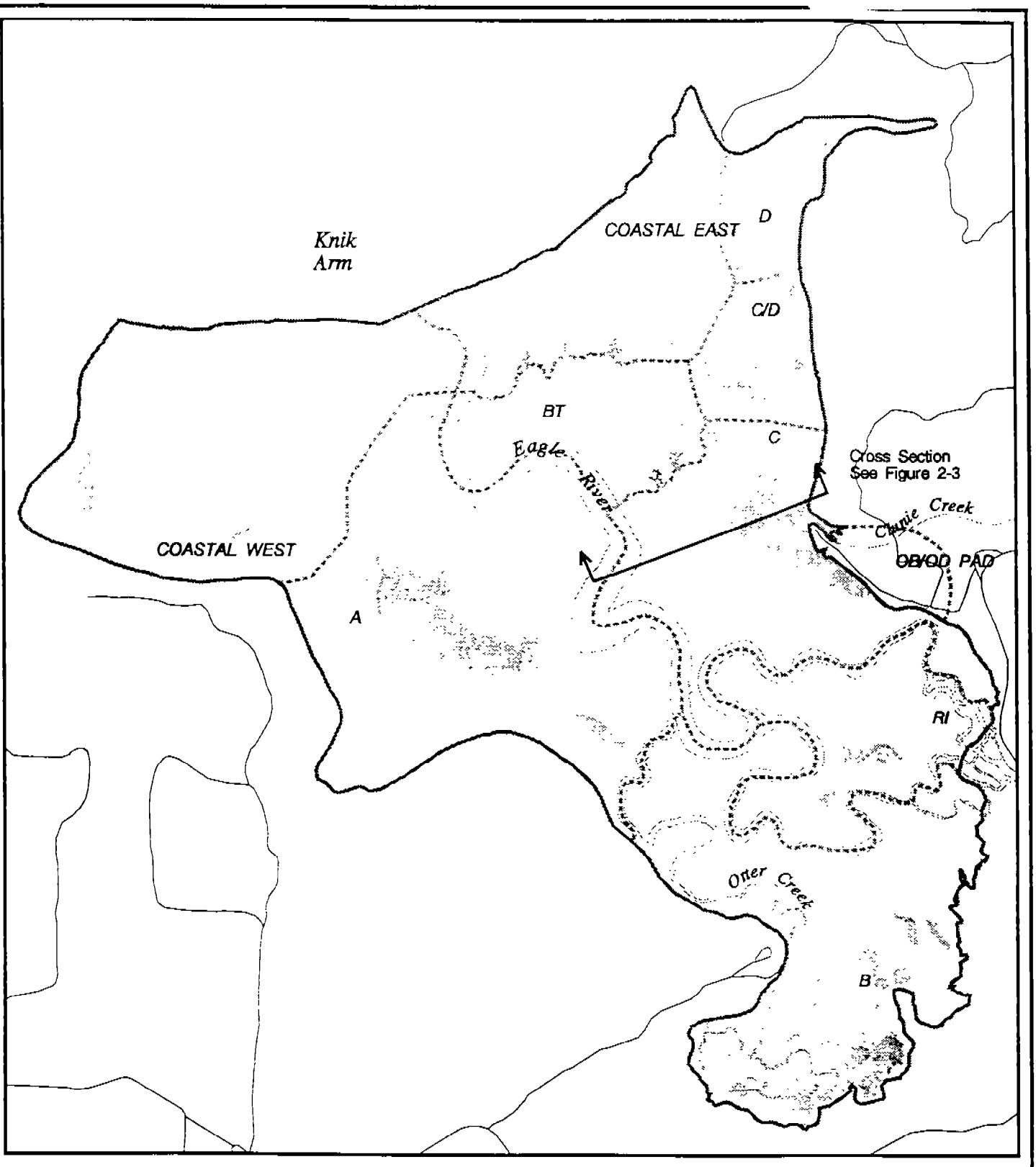


Figure 2-2

Site Map

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

February 13, 1997 AML: /proj2/arf/fig2-21.aml PLOT FILE: /proj2/arf/fig2-21.eps

indicating that air temperature variances within ERF are greater than the ERF/Anchorage differences (Haugen, in Racine *et al.*, 1995).

2.2 Environmental Setting

2.2.1 Topography

ERF was formed as the Eagle River eroded through the alluvial deposits of the Anchorage lowland to create a deep valley that subsequently filled with sediment. ERF is characterized as a roughly triangular estuarine salt marsh surrounded by forested uplands and the Knik Arm portion of Cook Inlet. The topography of ERF is relatively flat, with landform changes occurring with subtle changes in elevation. Measured elevations in ERF range from 1 meter (m) above mean sea level (msl) at the river bottom of the Eagle River to 5.5 m above msl on top of the highest levees along the river.

2.2.2 Geology

Steep bluffs, broken only by principal streams such as Eagle River, mark the edge of the lowland as it drops abruptly to the sea.

Fort Richardson straddles both the alluvial fan gravels of the Anchorage plain and the moraine and glacial alluvium complex near the shore of Knik Arm. The gravel alluvium of the Anchorage plain underlies the main cantonment.

The confined gravel aquifer is from 60 to 120 m below the surface in this area of the installation (Selkregg, 1972). Groundwater flow in this confined aquifer is in a generally western to northwestern direction (COE, 1996).

Just north of the main cantonment is the southern edge of the Elmendorf Moraine, a hummocky, long series of ridges running east-west across Fort Richardson and Elmendorf Air Force Base (AFB), roughly parallel to Knik Arm. The moraine is chiefly till, including poorly sorted gravel.

Alluvial and glacial surface deposits lie over sedimentary rock.

Surfical deposits in ERF consist of a complex of glacially deposited materials. These materials include morainal deposits of the Elmendorf Moraine, the southern extent of which mark the farthest extent of the latest glacier to occupy Knik Arm. Other glacial deposits consist of unsorted or poorly sorted till material and glacial alluvium, including glacial outwash gravels, kames, and kame terraces deposited at the edge of the former glacier.

North of the Elmendorf Moraine is a complex of moraine and glacial alluvium deposits in the form of irregularly shaped hills. The complex of hills just south of the south end of ERF is part of this glacial alluvium deposit. Evidence of the glacial alluvium can be seen as poorly sorted gravels in the steep bluffs surrounding ERF. Farther north, on either side of ERF, are more moraine deposits. These

deposits are more subdued in topography than the Elmendorf Moraine.

2.2.3 Landforms and Vegetation

Marshes are the predominant habitat.

Landforms, vegetation, and expected tidal flooding frequencies change with elevation (Racine *et al.*, 1993). A generalized pattern of decreasing elevation creates a series of zones or landforms from levees to mud flats to brackish ponds and marshes (Figure 2-3). Measured elevations vary from less than 1 m above msl at the river bottom of Eagle River to 5.5 m on top of the highest levees near Eagle River. Distributary channels (or gullies) cut deeply through the mud flats and connect ponds with Eagle River.

Subtle changes in elevation of the channel floors dictate whether tidal flooding occurs daily, occasionally, or rarely. Where bottom elevations of the gullies are 2.2 to 3.75 m, flooding occurs daily during high tides. Between 3.75 and 4.0 m above msl, flooding occurs only with the highest tide of each month; only extreme high tides, in combination with high river discharge levels, flood areas between 4.4 and 5.0 m above msl (Racine *et al.*, 1993).

ERF can be divided into five generalized geomorphic and vegetation zones on the basis of features described above (Racine, in Racine *et al.*, 1994). These zones, which are summarized in Table 2-1, include the following:

1. A mud flat/distributary zone covering about 30 percent of the marsh
2. A sedge meadow zone (10 percent)
3. A pond/marsh zone (20 percent)
4. An inner edge meadow zone (30 percent)
5. A bordering shrub/tree zone (5 percent)

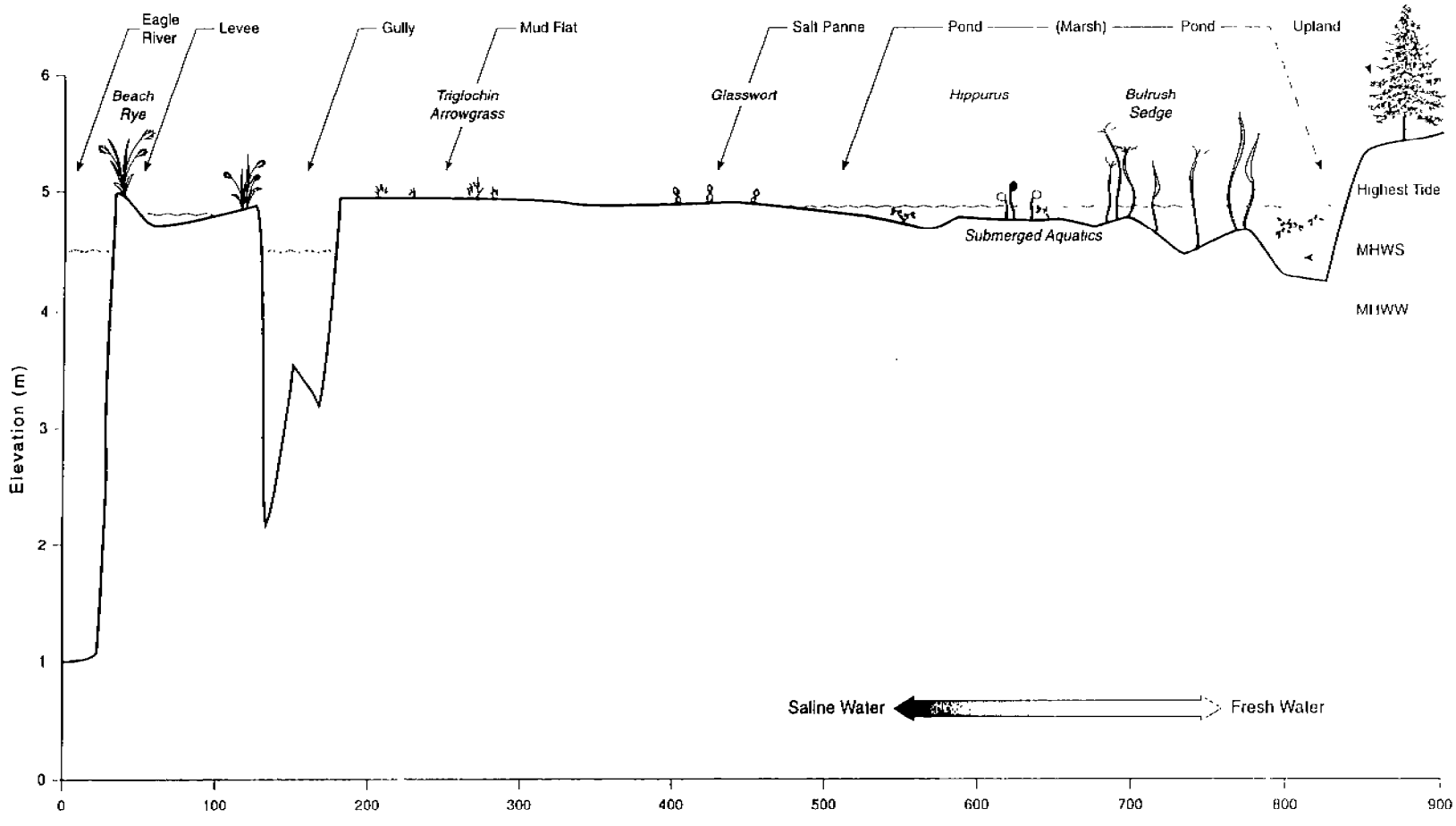
Different types of vegetation are associated with each landform.

The broad channel of Eagle River covers the remaining 5 percent. The five land types or zones within ERF can be further divided into 18 general habitat types, as shown in Figure 2-4.

Photographs of various habitats and portions of ERF can be found in CRREL reports, including *Remedial Investigation Report: White Phosphorus Contamination of Salt Marsh Sediments at Eagle River Flats, Alaska* (Racine *et al.*, 1992a) and *Interagency Expanded Site Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska* (Racine *et al.*, 1994).

2.2.3.1 Mud Flat/Distributary Zone

ERF mud flats and distributaries occupy a zone closest to the coastal inlet and extend inland along Eagle River. The mud flats grade from



Notes: Features other than surface profile are not drawn to scale.
Vertical exaggeration is 78x.
See Figure 2-2 for approximate location of cross section.
Source: Racine et al., 1993

MHWS = Mean high water summer
MHWW = Mean high water winter

Figure 2-3

Eagle River Flats
Cross Section from Area C to Upland

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

OUC 0029306

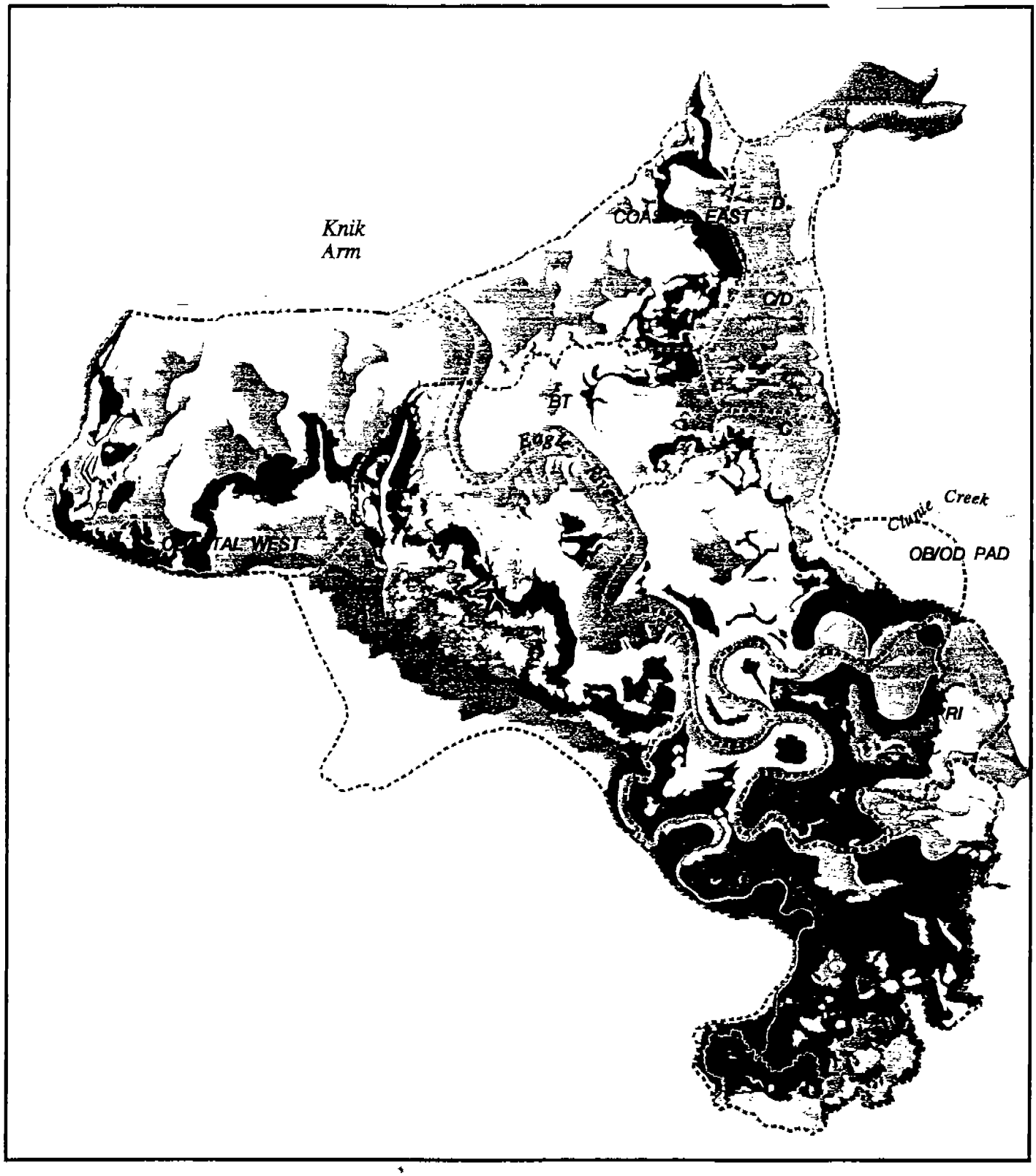


Figure 2-4

Land Cover

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

N

Scale 1:24000
1 cm = 240 m

0 meters 720

Mapping and database source:
Racine et al., 1996.

- OUTSIDE SITE
- UNCLASSIFIED
- MUD FLAT BARREN
- BORDER LOW SHRUB
- BORDER SPRUCE WOODLAND
- CREEK
- GULLEY
- HALOPHYTIC HERB MEADOW
- INTERIOR SEDGE MEADOW
- INTERMITTENT POND
- LEVEE GRASS MEADOW
- MARINE ALGAE
- PERMANENT POND
- RIVER
- RIVER MEANDER MEADOW
- RELICT RIDGE
- RAMENSKI'S SEDGE MEADOW
- SEDGE BOG
- SEDGE MARSH
- WET SWALE

CH2MHILL

February 13, 1997 AML: /proj2/ert/fig.aml PLOT FILE: /proj2/ert/fig2-41.eps

TABLE 2-1
Hierarchical Landcover Classification ERF

I.	Mud flat/distributary zone		
	1.	Sparsely vegetated mud flat	
		(*Puccinellia nutkaensis, Salicornia europaea, Atriplex patula*)	
	2.	Vegetated mud flat	
		a.	Arrowgrass (*Triglochin maritima*)
		b.	Plantain (*Plantago maritima*)
	3.	Tidal creek banks/natural levees (*Elymus arenarius*)	
		a.	Beach rye (*Elymus arenarius, Potentialla egedii*)
II.	Sedge meadow zone (old levees, pond borders)		
	1.	Ramenski's sedge (*Carex ramenskii, Triglochin maritima*)	
III.	Pond/marsh zone		
	1.	Permanent ponds (>10 cm deep)	
		a.	Submerged aquatics (*Zannichellia palustris, Potamogeton sp., Ruppia spiralis*)
		b.	Emergent *Hippurus tetragona*
	2.	Intermittent ponds (<10 cm)	
		a.	No aquatic vegetation
		b.	*Salicornia europaea, Triglochin maritima* (during drying cycle)
	3.	Sedge marsh	
		a.	Tall bulrush (*Scirpus validus*)
		b.	Low bulrush (*Scirpus paludosus*)
		c.	Lyngbye's sedge *(Carex lyngbyei)*
IV.	Interior lowland		
	1.	Sedge meadow (*Carex lyngbyei; C. ramenskii*)	
	2.	Deep ponds	
	3.	Bulrush marsh	
V.	Bordering shrub/spruce zone		
	1.	Shrub-grass (*Myrica gale, Calamagrostis spp., Carex spp.)*	
	2.	Black spruce-sedge	
	3.	Floating sedge mat (*Carex pluriflora, C. mackenziei. C. lyngbyei*)	
VI.	Coastal zone		
	1.	Marine algae (*Ulva* sp.)	
VII.	Riverine zone		

Source: Racine, in Racine *et al.*, 1994.

barren to vegetated, with sparsely vegetated mud flats occurring closer to the shallow ponds, and usually along their edges.

Tidal creek channels comprise an important drainage system for ERF and connect ERF ponds to the main channel of Eagle River. These distributaries are probably formed by the movement of tidal water and runoff. While the distributaries near Eagle River have eroded deeply into the sediments to form gullies, farther away they form shallow, vegetated depressions that frequently reach back into ponds.

Natural levees occur along the edge of Eagle River and the larger distributary streams near Eagle River. Tall stands of beach rye grow on levees that are higher than 4 m above msl.

2.2.3.2 Sedge Meadow Zone

Old levees, set back from Eagle River, support dense stands of sedge lawn in a narrow band between the mud flat/distributary and pond/marsh zones.

2.2.3.3 Pond/Marsh Zone

Ponds and marshes receive upland freshwater and salt water from tidal flooding.

Behind the sedge meadow zone, there is a complex pattern of brackish ponds and marshes fed partly by fresh water from the uplands and partly by salt water from occasional tidal flooding. Shallow mud flat ponds (3 to 15 cm deep) frequently become dry during certain times of the summer; deeper, permanent ponds vary in depth from 20 cm to more than 50 cm. Salinity in the permanent ponds varies from as much as 20 parts per thousand (ppt) on the shallow outer edge to less than 5 ppt near freshwater streams or springs. The permanent ponds support a variety of submerged aquatic vegetation as well as emergent vegetation. Dense stands of grasses, sedges, and shrubs grow on pond banks.

Marsh vegetation generally borders the ponds on the inland edge. Two types of marsh dominate ERF: the tall, coarse sedge marsh and the bulrush marsh.

2.2.3.4 Inner Sedge Meadow Zone

The upriver end of ERF, where Eagle River and Otter Creek enter ERF, is covered in a nearly continuous sedge meadow. The vegetation forms an almost impenetrable root/rhizome mat and the surface is only flooded during the spring tides.

Isolated ponds occur at a few locations in this zone and are always surrounded by a broad border of bulrush marsh inside the sedge marsh. Salinities in these ponds are only 2 to 4 ppt.

2.2.3.5 Bordering Shrub/Spruce Zone

Fresh water enters ERF around the edge from streams and springs, supporting vegetation radically different from the more salt-tolerant systems. The vegetation of this zone is diverse, ranging from floating sedge mats to low shrub vegetation and open spruce woodland.

2.2.4 Hydrology

Eagle River bisects the flats with its discharge, which can vary substantially from spring meltwater and rainstorms. With an average flow rate of 15 cubic meters per second (m^3/sec), Eagle River drains approximately 500 square km of mountains and lowlands. Glaciers cover 13 percent of the drainage basin. The river reaches peak discharges of more than 70 m^3/sec in July and August, but a particularly heavy rainfall or high runoff from glaciers can generate a discharge greater than 103 m^3/sec (Racine *et al.*, 1993). Sediment concentration apparently does not depend on the discharge rate of the river, and results of previous studies of ERF physical dynamics suggest that the tides have a greater suspended sediment concentration than the river (Racine *et al.*, 1993, 1994, 1995).

Aerial photographs available from the past 40 years have demonstrated the large-scale dynamics of hydrology and sedimentology at ERF.

Aerial photographs available from the past 40 years have demonstrated the large-scale dynamics of hydrology and sedimentology at ERF, a complex and physically active area. For example, the primary river channel entering the flats was abandoned some time between 1950 and 1967. The channel meanders have changed their positions substantially over the past four decades. The drainage pattern on the flats suggests that an active system and a relic system are present, perhaps affected by earthquakes. In September 1995, the flow in the western channel of Eagle River was reduced when flooding caused channel scour and migration, shifting the eastern channel farther northeast.

Hydrology is governed by tidal fluctuations and discharges from Eagle River. All of ERF floods during the highest tides.

The tides have a maximum height of approximately 11 m and are an important source of sediment. Tidal flooding begins at the coast, moving progressively up the Eagle River channel and gullies. It then spills across the inner mud flats into the ponds. The water level drops first at the coastal mud flats during the ebb, and then progresses into the gullies. Water level changes from tidal inundation show a 20- to 40-minute delay in peak tidal flood height across ERF, in Eagle River, and at the coast relative to that predicted at Anchorage. The flooding height of the delayed tide is also generally 0.5 m or more greater than the Anchorage datum, reflecting at least in part the funneling of water out of Cook Inlet into the narrower Knik Arm (Lawson *et al.*, 1996).

The combination of tides and river discharge cause variable levels of flooding across the flats. The levees flood less frequently than the ponds because of their higher elevations. High river discharges will

produce a higher flood than one predicted by using high-tide elevations listed in the tide tables.

In summer, there may be long periods between flooding tides, and parts of the flats can become relatively dry. During winter, Eagle River continues to flow, but ice thickens over the flats with succeeding flood events during cold temperatures. Ice breakup typically occurs in April or early May. It appears that the hydrology and sedimentology of the upper third of the flats is dominated by the river, with the remainder dominated by the tides. This dynamic environment is extremely complex, making predictions difficult and uncertain.

In addition to Eagle River, several small tributary streams enter the ERF. Otter Creek, a small perennial stream, drains Otter Lake and enters ERF near its southern end (Figure 2-2). Clunie Creek drains several small lakes east and northeast of ERF and enters ERF just north of OB/OD Pad (Racine *et al.*, 1993).

Tidal inundations deposit suspended sediment.

2.2.5 Sedimentation and Erosion

During summer, Eagle River carries a moderate suspended-sediment load derived from glacial melt and runoff. U.S. Geological Survey (USGS) data collected in the early 1970s indicate that a summer mean daily load of suspended sediment for Eagle River ranges between 100 and 300 milligrams per liter (mg/L) but increases to 400 to 700 mg/L during high discharge periods. The maximum recorded sediment load is 1,810 mg/L (USGS, 1990). These sediment loads are fairly low for glacially fed rivers in Alaska. In comparison, the Knik River has a mean daily concentration during the summer of 1,400 mg/L, concentrations near 4,000 mg/L during high discharge periods, and a maximum recorded sediment concentration of 6,290 mg/L.

The waters of Knik Arm also contain a moderate suspended-sediment load derived from the glacially fed rivers emptying into it, such as the Matanuska and Knik rivers. Each time the ERF is inundated, by water from both the Eagle River and by high tides within the Knik Arm, silts and clays settle out of the water (during slack and early ebb tide) or ice covering the flats and are deposited, both on the mud flats and in the shallow ponds. Thus, sedimentation will tend to bury WP particles progressively deeper within the sediments of ERF over time.

Spring thaws, tidal events, and river flows cause erosion in ERF.

Although the sediment thickness is increasing throughout ERF, erosion is taking place simultaneously at a number of locations. Erosion occurs as a natural process during spring thaws, tidal events, and river flows. Tidal current measurements indicate that velocities are higher during ebb than during flood, resulting in potentially greater sediment transport and channel erosion during ebb. The distributary gullies are being incised into the mud flats at a rate that may be measured by monitoring the rate of headwall migration into

ERF. The gully headwall areas are typically characterized by a headwall with a near vertical face of 1.2 to more than 2 m, adjacent to a plunge pool 0.5 to more than 2 m deep. The bed gradient becomes progressively shallower downstream of the plunge pool, but then steepens again near the river. The gradient steepens sharply along short segments of the gully channel (thalweg), indicating the existing gully slope is not in equilibrium with current hydrologic conditions. Processes that are deepening the channel and reducing the thalweg gradient and extending the headwall into the mud flats are attempting to restore that equilibrium.

The erosion of gully headwalls has been monitored at a number of locations throughout ERF for several years. The rates of headwall migration were highly variable, both within and between gullies. The variability relates to the erosional process. The uppermost 20 to 30 cm of consolidated, root-bound soil is undermined by current erosion, and fails after a 0.5-m or deeper cut is made below it. Lateral walls of gullies fail mostly by retrogression-slump flow. Net headwall recession rates varied from 0.1 to about 33 m between 1992 and 1995 (Lawson *et al.*, 1996).

Several methods have been used to measure the rate of sedimentation and resedimentation from naturally resuspended sediments at a number of sites within the ponds around ERF. Resuspension occurs because of wind currents and waves, bottom-feeding waterfowl, and other disturbances (Racine *et al.*, 1993).

Gully headwall erosion eventually may drain some ponds.

Net sedimentation rates in Area C were found to vary with an overall trend of an increasing rate eastward from the levees (several millimeters [mm] each season), across the mud flats (10 to 15 mm each season with one area reaching 30 mm), and into the ponds (20 to 40 mm each season). The differences are believed to be largely related to the number of flooding events, which is a function of their elevation. During the period of record (1992 to 1994), approximately 186 tides exceeded the height required to inundate most ponds, but only 25 tides extended high enough to flood the levee. In the ponds, approximately an equal amount of resuspended and new sediments were deposited.

WP has become integrated into the ERF sediments as a result of incomplete oxidation of the chemical following its release into the environment (U.S. Army Environmental Hygiene Agency [USAEHA], 1993). The fate and transport of WP in sediment is discussed in Section 5.

2.2.6 Water Quality

The salinity of the surface water varies seasonally within ERF, particularly in relation to the distance from freshwater inlet streams along the edge of ERF. Salinity measurements were made at

20 locations throughout ERF. Salinity values at these locations ranged from less than 1 to 46 ppt. The majority of the values were 10 ppt or less, with all but one of the rest being between 20 and 40 ppt. Measurements were made in ponds, gullies, and Eagle River. These data indicate the influence of both saltwater and freshwater inputs and reflect the complexity of the surface water hydrology in ERF.

Suspended sediment concentrations measured in 1994 in Eagle River, tidal gullies draining the ponds and mud flats, and Knik Arm indicate that most of the sediment is derived from Knik Arm tidal waters. The total suspended solids (TSS) in waters of ERF vary with tidal stage, location, source, and season. Eagle River is fed by glaciers and varies seasonally from peak TSS values of 100 to 700 mg/L between breakup in May and freeze-up in October. Two seasonal highs apparently occur annually, the first during snowmelt runoff and the second during the peak glacial melt season. In contrast, TSS of Knik Arm water ranges from about 1,000 to 2,800 mg/L from May to October. During a tidal cycle, TSS measurements at gully sites increase steadily through the flooding tide and decrease at a slower rate during the ebb. Seasonally, TSS values in gully and Knik Arm waters increased from spring to fall; the cause of this increase is unknown (Lawson *et al.*, in Racine *et al.*, 1995).

ERF supports diverse and abundant populations of waterfowl, shorebirds, other birds, and mammals.

The results of November 1996 groundwater sampling for OB/OD Pad are included in Section 6.5.

2.2.7 Fish and Wildlife Use of ERF

The interspersion and zonation of bulrush and sedge marsh, open water ponds, and mud flats within ERF provide ideal habitat for large numbers of waterfowl, shorebirds, gulls and terns, raptors, and other birds and mammals. Studies have documented diversified avian species (Table 2-2), but because the field sessions were limited, a complete species list was not developed. Waterfowl censuses have been estimated in ERF for the period from April to October since 1988.

Fish and aquatic macroinvertebrate populations have been characterized, but in less detail than waterfowl, because the results of past studies did not indicate that these populations were adversely affected by the presence of WP.

Although peregrine falcons are occasionally observed as migrants, resident threatened or endangered species are not known to occur on Fort Richardson (Garrett, 1991; Quirk, 1991). The probability of occurrence of threatened or endangered species is considered low because of the lack of prime habitat and nesting sites.

Birds migrating in spring and fall use ERF as a feeding and resting point.

2.2.7.1 Waterfowl

Table 2-2 lists the species of waterfowl that have been seen using ERF. The area is a feeding and resting point for birds migrating in the

TABLE 2-2
Bird Species Observed During Field Studies in May and August 1991-1992

Common Name	Species Name
Waterfowl	
Common loon	*Gavia immer*
Red-necked grebe	*Podiceps grisegena*
Horned grebe	*Podiceps auritus*
Eared grebe	*Podiceps nigricollis*
Tundra swan	*Cygnus columbianus*
Trumpeter swan	*Cygnus buccinator*
Greater white-fronted goose	*Anser albifrons*
Snow goose	*Chen caerulescens*
Canada goose	*Branta canadensis*
Mallard	*Anas platyrhynchos*
Green-winged teal	*Anas crecca*
American wigeon	*Anas americana*
Eurasian wigeon	*Anas penelope*
Northern pintail	*Anas acuta*
Northern shoveler	*Anas clypeata*
Blue-winged teal	*Anas discors*
Cinnamon teal	*Anas cyanoptera*
Canvasback	*Aythya valisineria*
Ring-necked duck	*Aythya collaris*
Greater scaup	*Aythya marila*
Lesser scaup	*Aythya affinis*
Barrow's goldeneye	*Bucephala islandica*
Common goldeneye	*Bucephala clangula*
Bufflehead	*Bucephala albeola*
Oldsquaw	*Clangula hyemalis*
Common merganser	*Mergus merganser*
Gulls and Terns	
Herring gull	*Larus argentatus*
Mew gull	*Larus canus*
Glaucous-winged gull	*Larus glaucescens*
Bonaparte's gull	*Larus philadelphia*
Arctic tern	*Sterna paradisaea*
Raptors	
Golden eagle	*Aquila chrysaetos*
Bald eagle	*Haliaeetus leucocephalus*
Northern harrier	*Circus cyaneus*
Merlin	*Falco columbarius*
Peregrine falcon	*Falco peregrinus*
Red-tailed hawk	*Buteo jamaicensis*
Rough-legged hawk	*Buteo lagopus*
Sharp-shinned hawk	*Accipiter striatus*

TABLE 2-2
Bird Species Observed During Field Studies in May and August 1991-1992

Common Name	Species Name
Northern goshawk	*Accipiter gentilis*
American kestrel	*Falco sparverius*
Short-eared owl	*Asio flammeus*
Shorebirds	
Sandhill crane	*Grus canadensis*
Semipalmated plover	*Charadrius semipalmatus*
Killdeer	*Charadruis vociferus*
Black-bellied plover	*Pluvialus squatarola*
Lesser golden-plover	*Pluvialis dominica*
Hudsonian godwit	*Limosa haemastica*
Whimbrel	*Numenius phaeopus*
Greater yellowlegs	*Tringa melanoleuca*
Lesser yellowlegs	*Tringa flavipes*
Solitary sandpiper	*Tringa solitaria*
Spotted sandpiper	*Actitis macularia*
Wilson's phalarope	*Phalaropus tricolor*
Red-necked phalarope	*Phalaropus lobatus*
Short-billed dowitcher	*Limnodromus griseus*
Long-billed dowitcher	*Limnodromus scolopaceus*
Common snipe	*Gallinago gallinago*
Ruddy turnstone	*Arenaria interpres*
Surfbird	*Aphriza virgata*
Semipalmated sandpiper	*Calidris pusilla*
Western sandpiper	*Calidris mauri*
Least sandpiper	*Calidris minutilla*
Baird's sandpiper	*Calidris bairdii*
Pectoral sandpiper	*Calidris melanotos*
Dunlin	*Calidris alpina*
Other Birds	
Belted kingfisher	*Ceryle alcyon*
Tree swallow	*Tachycineta bicolor*
Violet-green swallow	*Tachycineta thalassina*
Bank swallow	*Riparia riparia*
Rough-winged swallow	*Stelgidopteryx serripennis*
Cliff swallow	*Hirundo pyrrhonota*
Black-billed magpie	*Pica pica*
Common raven	*Corvus corax*
Common northern raven	*Corvus corax*
American robin	*Turdus migratorius*
Bohemian waxwing	*Bombycilla garrulus*
Northern shrike	*Lanius excubitor*
Savannah sparrow	*Passerculus sandwichensis*
Fox sparrow	*Passerella iliaca*

TABLE 2-2
Bird Species Observed During Field Studies in May and August 1991-1992

Common Name	Species Name
Lincoln's sparrow	*Melospiza lincolnii*
Song sparrow	*Melospiza melodia*
Lapland longspur	*Calcarius lapponicus*
Rusty blackbird	*Euphagus carolinus*

Source: Racine *et al.*, 1993.

spring and fall. Mallards, American wigeons, northern pintails, green-winged teals, and sandhill cranes use ERF as a breeding and nesting area as well (Racine *et al.*, 1993; Eldridge, in Racine *et al.*, 1994).

The U.S. Fish and Wildlife Service (USFWS) has conducted aerial waterfowl surveys of ERF annually since 1988 (Tweten, 1989; Eldridge, 1990, 1991, 1992, 1994; in Racine *et al.*, 1994, 1996; in Walsh *et al.*, 1997). Census data indicate that most waterfowl use ERF predominantly during late April to early June and mid-August to mid-October (Racine *et al.*, 1993; Eldridge, in Racine *et al.*, 1994). During most years there are more waterfowl at ERF in fall than in spring. A small population of ducks, cranes, and shorebirds remain to breed in ERF throughout the summer. Male American wigeons also stage in ERF in small numbers before molt migration in late June (Eldridge, 1994).

The number and species of waterfowl using each area within ERF also varies. Table 2-3 summarizes the observations of the 1995 ERF aerial surveys. For convenience, only the 1995 results are presented. Review of past data indicate that the 1995 censuses are indicative of historical waterfowl use of ERF.

In general, more waterfowl use ERF in fall than in spring.

Swans have been observed mainly in Areas B and D in recent years. Hazing and human activity designed to keep swans away from more highly contaminated areas, such as Areas A and C, apparently have been effective. It is also likely that Areas B and D are preferred habitat for swans because of deeper water and associated food (Steele and Reitsma, 1996). Use of ERF by tundra and trumpeter swans was minimal during spring 1995, similar to 1994 (Eldridge and Robertson, in Racine *et al.*, 1996). Swan use of ERF during fall was similar to other years. Swan numbers in 1995 began building during the last 2 weeks of September, peaked in late September and early October, then declined during the first week of October.

Canada geese used more inland areas in spring 1995 than in previous years. In the past, Canada geese have been numerous in Areas A and D; whereas snow geese used Areas A and B more. The most heavily used zone within ERF in 1995, measured by density of all species of geese, was Coastal East. In general, numbers of geese using ERF in 1995 were lower than in the late 1980s and early 1990s, probably as a result of hazing and other disturbances.

Dabbling ducks prefer shallower ponds; swans prefer the deeper ponded areas for foraging.

Observations of duck species using ERF in 1995 were similar to aerial survey observations in previous years. Summer 1995 numbers were similar to those of 1994, and higher than for earlier years, possibly because of favorable water conditions and cessation of firing in ERF. Fall numbers were generally higher than in recent years. Use of Areas A, B, C, and D by ducks depends on water levels, ice conditions, and human disturbance; however, Areas A and D are consistently important to ducks.

TABLE 2-3
Percent of Total 1995 Aerial Survey Observations of Waterfowl Groups and Species in Study Zones of ERF by Season

Waterfowl Group	Coastal West	A	B	Racine Island	C	C/D	Bread Truck Pond	Coastal East	D	(n)[a]
Spring										
Swans	0	13	5	0	14	3	0	0	65	130
Geese	7	20	1	0	31	0	8	28	4	1,216
Lesser Snow	0	11	0	0	24	0	16	48	0	620
Canada	15	32	2	1	41	0	0	8	2	532
Ducks	8	26	17	1	17	8	4	2	18	2,302
Summer										
Swans	0	0	0	0	0	0	0	0	0	0
Geese	68	10	9	0	7	0	0	0	6	353
Lesser Snow										
Canada	72	8	10	0	7	0	0	0	3	335
Ducks	3	31	7	0	17	12	4	4	21	2,584
Fall										
Swans	0	0	45	0	0	0	0	10	45	793
Geese	32	14	11	0	4	0	0	38	0	2,659
Lesser Snow										
Canada	34	14	10	0	2	0	0	40	0	2,659
Ducks	12	18	12	0	7	11	5	14	21	15,031

[a]Total number of birds observed

Source: Eldridge and Robertson, in Racine *et al.*, 1996.

2.2.7.2 Shorebirds

As many shorebird species as waterfowl are represented in ERF. Table 2-2 details this variety. Shorebirds inhabit the mud flats and shallow water at ERF and occur in abundance. Field observations documented that phalaropes, yellowlegs, pectoral sandpipers, and common snipe exhibit mating behaviors or appear to use ERF for breeding (Racine *et al.*, 1993). Many shorebirds migrate south before the last 2 weeks in August. As with waterfowl, species abundance of shorebirds was dependent on migration habits, but the abundance of mating birds and the overall diversity of species show that ERF is important habitat for shorebirds.

2.2.7.3 Gulls and Terns

Shorebirds inhabit the mud flats and shallow water at ERF.

Racine *et al.* (1993) reports that 5 to 10 herring gull nests and 10 mew gull nests have been seen in ERF, mostly in Area D, on hummocks of bulrush; but some herring gull pairs use the artillery targets as nesting platforms. Non-breeding herring gulls are abundant in ERF, where they feed on salmon in Eagle River and on duck carcasses and aquatic organisms in the small ponds. Gull species were combined for the USFWS aerial surveys (Eldridge and Robertson, in Racine *et al.*, 1996). They include glaucous-winged gulls, in addition to mew and herring gulls. In 1995, numbers increased from 50 in mid-April to about 100 to 200 gulls in early May. Numbers decreased after mid-June, with less than 50 gulls in mid-July.

Arctic terns feed on small fish in the open water of ERF. Racine *et al.* (1993) notes that Arctic terns are most common in May, when they can be seen displaying courtship behavior. Usually 5 to 15 terns were counted during June and July (Eldridge and Robertson, in Racine *et al.*, 1996).

2.2.7.4 Raptors

ERF supports a small resident population of bald eagles, with larger transient populations feeding there in spring and fall.

Although a few bald eagles use ERF year round, they are most abundant in May (as many as 58 have been seen), before salmon become a major food source. In mid- to late-May, eulachon (*Thaleichthys pacificus*) migrate to Upper Cook Inlet (UCI) streams and provide a food source for eagles before the salmon runs (Rosenberg, 1994). The eagles often perch on artillery targets and driftwood and on trees along the margins of ERF. Racine *et al.* (1993) points out that during 1991 and 1992 field observations, an unusually high number of bald eagles were attracted to ERF, probably because of the dead and dying ducks there. However, numbers of bald eagles in 1995 were the lowest recorded since aerial surveys began in 1988 (Eldridge and Robertson, in Racine *et al.*, 1996).

Northern harriers use ERF during spring and fall. Harriers feed primarily on rodents in wet grassy areas, but Racine *et al.* (1993) states that the birds have been seen feeding on dead ducks at ERF. During

1991 and 1992 field observations, merlins were seen regularly, feeding on dragonflies. Peregrine falcons were seen during fall migration, presumably attracted by the abundant shorebirds (Racine *et al.*, 1993). Other raptor species are listed in Table 2-2.

2.2.7.5 Other Birds

Other bird species that use ERF are listed in Table 2-2. Racine *et al.* (1993) notes that several species of swallows were observed in ERF during 1991 and 1992 field observations. Such species include violet-green, rough-winged, tree, bank, and cliff swallows, in abundance. Observers saw belted kingfishers fishing in the pools on the margins of ERF and rusty blackbirds in the bulrushes in May and August. According to Racine *et al.* (1993), the blackbirds may also breed in ERF. During the studies, savannah sparrows were common throughout the summer, and flocks of Lapland longspurs were common in August.

Common northern ravens also occur in abundance (Racine *et al.*, 1993). Six to eight ravens use ERF regularly. Ravens use dead ducks as their primary food resource, although they are subordinate to the eagles and are often chased away from carcasses.

The Eagle River is an anadromous stream used by king and red salmon.

2.2.7.6 Fish and Aquatic Invertebrates

About 300 to 500 naturally occurring king and red salmon pass through ERF annually on their way to spawn in small clear tributaries of the north and south forks of Eagle River. In 1990, the Alaska Department of Fish and Game (ADFG) released 100,000 king salmon fingerlings into the upper stretches of Eagle River in the hopes of establishing a king salmon sport fishery in Eagle River. This release is likely to produce about 3,000 returning salmon each year, which will also travel through ERF to return to Eagle River spawning grounds. The new sport fishery is currently restricted to sections of Eagle River east of the Glenn Highway (Quirk, 1991).

Dolly Varden trout also occur in Eagle River. Although the lower portion of Eagle River that passes through ERF supports limited rearing activity for salmon and Dolly Varden, it serves primarily as a migration corridor for adult salmon moving upstream (June to September) and juvenile salmon running to the ocean (mid-April to June) (Quirk, 1991).

Fish were sampled for WP analysis during 1993, but species were not identified in the report by Sparling (in Racine *et al.*, 1994). However, sticklebacks and sculpins were shown as potential food-chain components for fish-eating birds such as terns and kingfishers that feed in ERF. Two types of stacklebacks have been identified by Bouwkamp. Overall, information on the distribution and abundance of fish in ERF is limited.

Benthic macroinvertebrates (bottom-dwelling aquatic insects, crustaceans, and other invertebrates) were collected during 1993 and 1994 at 20 to 30 pond and tidal creek locations in ERF and at two reference locations in Goose Bay (Bouwkamp, in Racine *et al.*, 1994). Macroinvertebrates also were collected from ERF distributaries where ponding occurred at low tide. The organisms were sorted, identified to species when possible, and counted to determine diversity (H), species richness, percent contribution of dominant species, and similarity between samples. The benthic macroinvertebrate populations included six or fewer species at each sample site. Typical benthic macroinvertebrates found at the various sampling locations included annelid worms (Oligochaeta), amphipods, and insects, including mainly dipterans (Chironomidae, Ceratopogonidae, Ephydridae, and Muscidae).

The *Chironami's salinarius* was the most abundant invertebrate found in sediment. Other sampling for macroinvertebrates to be analyzed above ground (that is, not in sediments) for WP during 1993 and 1994 included collection of dragonflies and damselflies (Odonata), midges, and brineflies (Diptera), beetles (Coleoptera), snails (Gastropoda), and amphipods (Amphipoda) that were sufficiently abundant for analysis. Odonates were more frequently caught, followed by midge larvae and snails.

Beluga whales feed on salmon in Eagle Bay and in the Eagle River.

2.2.7.7 Other Wildlife

In addition to birds, moose and coyotes frequent ERF. Black bears are occasionally observed in ERF in summer. Smaller mammals that use the flats also include beaver, muskrat, mink, weasel, wolverine, red fox, lynx, and numerous rodents (Quirk, 1991). In August, wood frogs thrive in ERF, where they comprise a major food source for sandhill cranes (Racine *et al.*, 1993).

Beluga whales have been observed entering the mouth of a drainage slough in the northwest corner of ERF, near the mouth of both Eagle River and a large drainage slough to the north, as well as close to the shoreline throughout Eagle Bay and approximately 1-1/4 mile up Eagle River. Sightings have occurred from June to the end of October. Whales have been observed vigorously chasing salmon up drainages along the river bank (Gossweiler, undated).

ERF is the only ordnance impact area for Fort Richardson; OB/OD Pad was formerly used as an explosive ordnance disposal site

2.3 Land Use

2.3.1 Military Land Uses at ERF

ERF is the only impact area for heavy artillery and mortars on Fort Richardson. Approximately 40 derelict cars and trucks have been placed individually or in groups as targets around ERF, as shown in Figure 2-5. U.S. Army personnel practice firing at the targets from

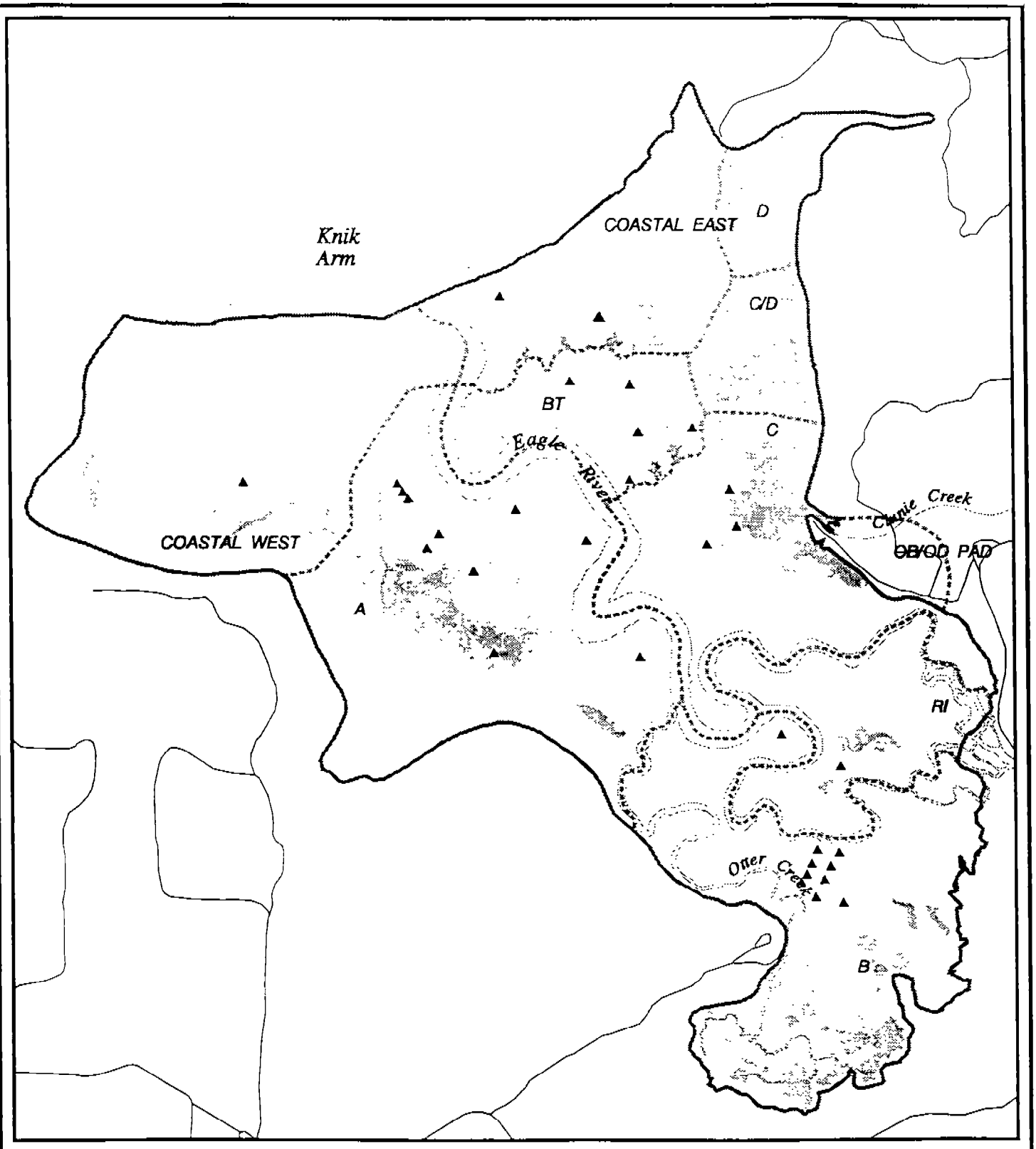


Figure 2-5

Targets

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

N

Scale 1:24000
1 cm = 240 m

0 meters 720

Mapping and database source:
Racine et al., 1996.

- Intermittent Pond
- Permanent Pond
- Road
- Area Boundary
- OUC Site Boundary
- ▲ Target

CH2MHILL

February 13, 1997 AML: /proj2/arf/fig.aml PLOT FILE: /proj2/arf/fig2-51.eps

more than 25 points, located at distances of up to 10 km (Racine *et al.*, 1992b).

OB/OD Pad is a 4-ha clearing with a 2-ha gravel pad constructed at least 20 years ago along the east side of ERF. Although no longer used to detonate outdated munitions, demolition of propellants on this pad apparently contaminated an area of the salt marsh in ERF (Racine *et al.*, 1992b). Three general types of munitions have been fired into ERF. These include high explosives (HEs), WP smokes, and illumination flares (Racine *et al.*, 1992b). Table 2-4 lists the munitions and corresponding

TABLE 2-4
Military Munitions Potentially Fired into ERF

Munitions Category	Munitions Description	Filler Material(s)[b]
High explosives	105mm howitzer, 60mm mortar, 81mm mortar, 107mm mortar, 90mm recoilless rifle, 66mm Light Anti-tank Weapon (LAW), 40mm grenades, 155mm HE artillery[a], Shillelagh missiles[a], 3.5-inch rockets[a]	TNT, RDX, HMX, Comp A3, Comp A5, Comp B, Comp B Grade A, Comp C-4, or Octol
Smokes	105mm howitzer, 60mm mortar, 81mm mortar, 107mm mortar, 40mm grenades	WP (not used since 1990), FS (not used since 1985), and HC
Illumination rounds	Flares	Mg
Small arms ammunition	7.62mm, 5.56mm, and .50 caliber	None

[a]Munitions discovered on an adjacent impact area.
[b]Filler material components
TNT = Trinitrotoluene
RDX = Cyclotrimethylenetetranitramine
HMX = Cyclotetramethylenetetranitramine
Comp A3 = 90% RDX, 10% wax
Comp A5 = 98.5% RDX, 1.5% stearic acid
Comp B = 60% RDX, 40% TNT with 1% wax added
Comp C-4 = RDX, wax
Octol = HMX, TNT
WP = White phosphorus
FS = Sulfur trioxide, chlorosulfonic acid
HC = Hexachloroethane-zinc mixture
Mg = Magnesium
Sources: Tweten, 1989; Racine *et al.*, 1992b.

Unexploded ordnance is still widespread.

component filler materials potentially fired into ERF. When an HE projectile (such as a missile, mortar, or rocket) is fired at a target in ERF, it hits the ground, explodes, creates a crater, and spreads fragments of steel (shrapnel) near the impact zone.

WP smokes are used to obscure or screen the movement of troops and vehicles. Smokes have critical defensive importance in neutralizing enemy sensors and hiding friendly forces and materials. Smoke screens also can be used offensively for immobilizing enemy troops by obscuring their vision (Muhly, 1983; Yon *et al.*, 1983).

Smoke rounds deposited white phosphorus in sediment.

White phosphorus and hexachloroethane-zinc-mixture (HC) smokes are the two most common agents used by the military to produce white smokes in the visible spectrum (Cichowicz, 1983). White phosphorus, consisting primarily of elemental phosphorus (P_4) has been used as a smoke-producing material in munitions since World War I (Yon *et al.*, 1983). WP smoke projectiles contain a very small HE bursting charge and do not form craters upon impact. When munitions containing WP are detonated, the phosphorus breaks up into minute particles that disperse over a large area; WP reacts spontaneously with air, forming a pillar of rising smoke. The tendency for the smoke to rise, rather than linger, was considered by the U.S. Army to be a serious inadequacy. In 1944, the problem was solved by plasticizing the WP, and coating the granules with a viscous solution of synthetic rubber in a solvent (Yon *et al.*, 1983). Another development in WP smoke munitions was to impregnate felt wedges with WP. Upon deployment, a central burster charge separated the wedges. Both modifications produced larger fragments, with a decrease in total surface area, resulting in slower oxidation rates of WP in the fragments.

The HC is a pyrotechnic smoke-producing composition of aluminum, zinc oxide, and hexachloroethane. It is also used in smoke pots, which produce large volumes of smoke for extended periods of time on land or water.

High-explosive projectiles were fired after WP smokes. These HE projectiles made the craters, which are generally concentrated around the firing targets in ERF. Thousands of craters occur in ERF as 1- to 2-m-diameter depressions that are 20- to 40-cm deep (Racine *et al.*, 1993). Depending on the tidal cycle and season, the craters may or may not be filled with water. However, numerous examples of underwater and "off-target" craters can be found almost anywhere in ERF.

An estimated 17,000 kg of white phosphorus was released to ERF.

In 1978, a fire destroyed the ERF range control building. Also lost in the fire were records of munitions fired into ERF before 1978. In 1990, the U.S. Army banned the firing of smokes containing WP onto the ERF. Additional restrictions were placed on training activities at the ERF as follows:

- A minimum of 15 cm of ice must cover the ERF before it can be used for firing
- Firing is allowed only between November 1 and March 31
- Only point-contact detonators may be used

Tables 2-5 and 2-6 summarize the only available documentation of use of WP munitions at ERF. Table 2-5 lists the rounds fired into ERF between April and December 1989. Table 2-6 lists the number of WP rounds fired into ERF between January 1987 and February 1990.

The data in Table 2-6, extrapolated to provide an estimate of WP fired into ERF between 1950 and 1990, indicate that approximately 17,000 kilograms (kg) may have been fired into ERF. This estimate is considered conservative for the following reasons:

- Current U.S. Army policy is to discontinue use of munitions if there is higher than a 10 percent dud rate. (Past practices may not have been so stringent.)

TABLE 2-5
Summary of WP Rounds Fired into ERF Between April and December 1989

Projectile	Type	Number of Rounds
60mm mortar	HE	1,983
	WP	106
	Illumination	146
81mm mortar	HE	1,520
	WP	105
	Illumination	94
105mm howitzer	HE	2,173
	WP	27
	Illumination	459
	HC	132
107mm mortar	HE	96
	WP	36
	Illumination	27
Total rounds		**6,904**

Source: Racine *et al.*, 1992b.

TABLE 2-6
Number of WP Rounds Fired into ERF Between January 1987 and February 1990

	Number of Rounds per Calendar Year						
Projectile	1987	1988	1989	1990	Average Rounds per Year	Average WP Weight per Round (kg)	Average WP Weight per Year (kg)
60mm mortar	187	57	135	29	136	0.35	48
81mm mortar	287	210	120	29	215	1.30	280
105mm howitzer	72	35	38	18	54	1.77	96
Total							**424**

Source: Racine *et al.*, 1992b.

- Dud rates tend to be lower when firing onto a hard target such as ice. (In the past, training exercises also occurred during the warmer months when the marshes had soft bottom-muds.)

Although there are no plans to resume warm-weather firing onto the ERF, future changes to the mission of Fort Richardson could necessitate the use of the training area during the summer months.

Because the quantities and locations of unexploded ordnance (UXO) in ERF are unknown and may never be fully neutralized, future land uses there likely will be tied to continued restricted access by the U.S. Army.

2.3.2 Civilian Land Uses Near ERF

There are no civilian land uses within or downstream of ERF.

The community of Eagle River lies within the boundaries of the Municipality of Anchorage (MOA), about 4 miles upstream of the nearest point of ERF (Figure 2-1). At the time of the 1990 census, the Eagle River community had a population of about 6,000 and an average of 3.1 persons per residence (MOA, 1993). Most residential and commercial development in the Eagle River community is on the east side of the Glenn Highway (Figure 2-1) (MOA, 1993). No one resides, works, or attends school within or immediately downstream of ERF.

The primary source of drinking water for the residents of the Eagle River community is surface water from Eklutna Lake, 15 miles to the northeast. Most residents of the urban/suburban Eagle River area are served by the MOA water system (MOA, 1993). Residences and businesses outside the MOA water system service area use private wells for a water supply. Only one water supply well has been identified within a 6.4-km radius of the nearest point of ERF (USGS, 1993). The well is at Otter Lake Lodge on the west shore of Otter Lake, west of Area B (Figure 2-2) and is either upgradient of or cross-gradient to ERF contamination. Therefore, no current threat to human health as a result of groundwater contamination from ERF is known to exist.

SECTION 3

Historical Summary of ERF Remedial Investigation

OUC, and particularly ERF, received considerable investigation before the site was placed on the NPL.

Many sites on the NPL have an extensive investigative history. Most, however, receive significantly more attention once they are included on the NPL and the CERCLA process is initiated. In contrast, OUC, and particularly ERF, received considerable investigation before being placed on the NPL. Most of the data reported in this RI were collected before Fort Richardson was added to the NPL, and therefore before implementation of the CERCLA process at OUC. These preliminary data, as well as data collected after Fort Richardson was placed on the NPL, are summarized in this section. During both periods, data have been collected and evaluated as part of an unusually broad investigation by a interdisciplinary project team with considerable expertise.

This historical summary was prepared to provide a concise compilation of the studies that have been completed on OUC since unusually high levels of waterfowl mortality were first documented in the early 1980s. It includes a review of these studies in chronological order to provide the context in which the studies were planned and conducted. It concludes with a section discussing the QA/QC programs that have been implemented to evaluate the quality of the data.

3.1 Review of Studies

Biological, chemical, and physical investigations have been ongoing at ERF since the early 1980s. The focus of the investigations varied, depending on current site knowledge, and questions that needed to be addressed.

This section provides an overview of the studies that have led to the current understanding of WP contamination at ERF. The influence of these investigations on the current understanding is presented in Figure 3-1.

A chronological list of all investigations is presented in Table 3-1. Although descriptions of remedial technologies are not within the scope of this remedial investigation report, as a convenience to the reader, previous treatability studies have been summarized in Table 3-1.

TABLE 3-1
Summary of Previous Investigations at Eagle River Flats

Investigation/Report	Investigators	Field Date(s)
Draft Physical System Analyses of Natural Attenuation and Intrinsic Remediation of White Phosphorus Contamination, ERF, Fort Richardson, Alaska	CRREL	1995
Waterbird Utilization of ERF and Upper Cook Inlet: April - October 1995	USFWS	1995
Movement, Distribution and Relative Risk of Waterfowl and Bald Eagles Using ERF	DWRC	1995
Evaluation of AquaBlok™ on Contaminated Sediment to Reduce Mortality of Foraging Waterfowl	DWRC	1995
Waterfowl Use and Mortality at ERF	NEILE	1995
Site Conditions, Ecological Inventory	CRREL	1994
Physical System Dynamics, WP Fate and Transport, Remediation and Restoration, Eagle River Flats, Fort Richardson, Alaska	CRREL	1994
Climate and Tides	CRREL	1994
WP Evaluation and Characterization, White Phosphorus Toxicity and Bioindicators of Exposure in Waterfowl and Raptors.	PWRC	1994
Toxicological Properties of White Phosphorus: Comparison of Particle Sizes on Acute Toxicity and the Biotransfer of White Phosphorus from Hen to Eggs	Dartmouth	1994
Analysis of the Eagle River Flats White Phosphorus Concentration Database	CRREL	1994
Waterbird Utilization of Eagle River Flats: April-October 1994	USFWS	1994
Waterfowl Use and Mortality at Eagle River Flats	NEILE	1994
Movement, Distribution and Relative Risk of Waterfowl, Bald Eagles and Dowitchers Using Eagle River Flats	DWRC	1994
Evaluation of White Phosphorus Effects on the Aquatic Ecosystem, Eagle River Flats, Fort Richardson, Alaska	AEHA	1994
Integrated Risk Assessment Model (IRAM) for Determining White Phosphorus Encounter Rate by Waterfowl	DWRC/ CRREL/ NEILE	1994
Treatability Studies; Chemical Hazing of Free-Ranging Ducks in Eagle River Flats: Field Evaluation of ReJex-iT™ WL-05	DWRC	1994
Hazing at Eagle River Flats	ADC	1994
Evaluation of AquaBlok™ on Contaminated Sediments to Reduce Mortality of Foraging Waterfowl	DWRC	1994
Screening Study of Barriers to Prevent Poisoning of Waterfowl in Eagle River Flats, Alaska	CRREL	1994
Investigation of Natural Size Reduction of White Phosphorus Particles in Eagle River Flats Sediments	CRREL	1994
Pond Draining Treatability Study	CRREL	1994
Dredging as a Remediation Strategy for White Phosphorus-Contaminated Sediments at Eagle River Flats, Alaska	CRREL	1994
Appendix A. Eagle River Flats Map Atlas	CRREL	1994
Mapped Craters	CRREL	1993
Contaminant Inventory	AEHA	12-23 Jul 1993

TABLE 3-1
Summary of Previous Investigations at Eagle River Flats

Investigation/Report	Investigators	Field Date(s)
Treatability Study–Hazing Waterfowl in ERF	ADC	May, Sep-Oct 1993
Treatability Study–Laboratory Evaluation of a Methyl Anthranilate Bead Formulation	DWRC	1993
Treatability Study–Field Behavioral Response and Bead Formulations for Methyl Anthranilate	DWRC	Jun, Aug 1993
Treatability Study–Field Evaluation: Mortality of Mallards Feeding in Areas Treated with Methyl Anthranilate	DWRC	Jun 1993
Waterfowl Mortality at ERF	NEILE	Apr-May, Aug-Oct 1993
Distribution and Concentrations of White Phosphorus in ERF	CRREL	1991–1993
Waterfowl Distribution and Movements in ERF	DWRC	Apr-Jun, Aug-Oct 1993
White Phosphorus Poisoning of Water birds in ERF	PWRC	May-Sep 1993
Toxicological Studies of White Phosphorus in Waterfowl	PWRC	1993
Physical System Dynamics (Sedimentation and Erosion at ERF)	CRREL	May 1992- Sep 1993
Food Chain Invertebrates and Fish: Sediment Bioassay	AEHA	July 12-23 1993
White Phosphorus in Invertebrates and Fish	PWRC	Jun 1993
Habitat and Vegetation in ERF	CRREL	1993
White Phosphorus in Plants at ERF	CRREL	Jun 1993
Water bird Utilization of ERF	USFWS	Apr-Oct 1993
Treatability Study–Pond Draining	CRREL	Jun-Aug 1993
Treatability Study–Air Drying Contaminated Sediments	CRREL	Jun-Aug 1993
Treatability Study–Geosynthetic Covering of Contaminated Sediment	CRREL	Jul 1993
Treatability Study–Evaluation of Concover and BentoBalls on Contaminated Sediments to Reduce Mortality of Foraging Waterfowl	DWRC	Jun 1993
U.S. Army Eagle River Flats: Protecting Waterfowl from Ingesting White Phosphorus	DWRC	1992
Rapid Uptake and Disappearance of White Phosphorus in American Kestrels	CRREL and Dartmouth Medical School	1992
Draft Report–Preliminary Assessment of Sedimentation and Erosion in the Eagle River Tidal Flats, Fort Richardson, Alaska	CRREL	May-Sep 1992
Hazardous Waste Consultation No. 37-66-JR11-92, Soil Sampling Results. Fort Richardson, Alaska, July 6-7, 1992	AEHA	July 6-7 1992
Draft Report–Water bird Utilization of Eagle River Flats, April - October 1992	USFWS	Apr-Oct 1992
Draft Report–White Phosphorus Contamination of Salt Marsh Sediments at Eagle River Flats, Alaska, February 1993	CRREL	1991-1992
Waterbird Utilization of Eagle River Flats, April–October 1991. December 1991	USFWS	Apr-Oct 1991

TABLE 3-1
Summary of Previous Investigations at Eagle River Flats

Investigation/Report	Investigators	Field Date(s)
Waterfowl Mortality in Eagle River Flats, Alaska. The Role of Munitions Residues. May 1992	CRREL	1990
Waterbird Utilization of Eagle River Flats, April - October 1990. December 1990.	USFWS	Apr-Oct 1990
Eagle River Flats Expanded Site Investigation, Fort Richardson, Alaska. Final Technical Report, June 1990	ESE	Jul-Oct 1989
Eagle River Flats Waterfowl Mortality Progress Report, August 1989	As noted below	
Laboratory Investigations	ADEC	Sep 15, 1988
Laboratory Investigations	USEPA	Jul 11, 1988
Laboratory Investigations	USEPA	Jul 22, 1988
Bird Utilization of ERF During Spring, Summer, and Fall, and Associated Mortality	USFWS	Apr-Oct, 1988
Investigations of Waterfowl Mortality, ERF	USFWS	1983-88
Laboratory Investigations	AEHA	1985
Field Investigations	USFWS	1982-85

Notes:
ADC = Animal Damage Control
CRREL = U.S. Army Cold Regions Research and Engineering Laboratory
DWRC = Denver Wildlife Research Center
ER = Eagle River
ESE = Environmental Science and Engineering, Inc.
NEILE = New England Institute of Landscape Ecology

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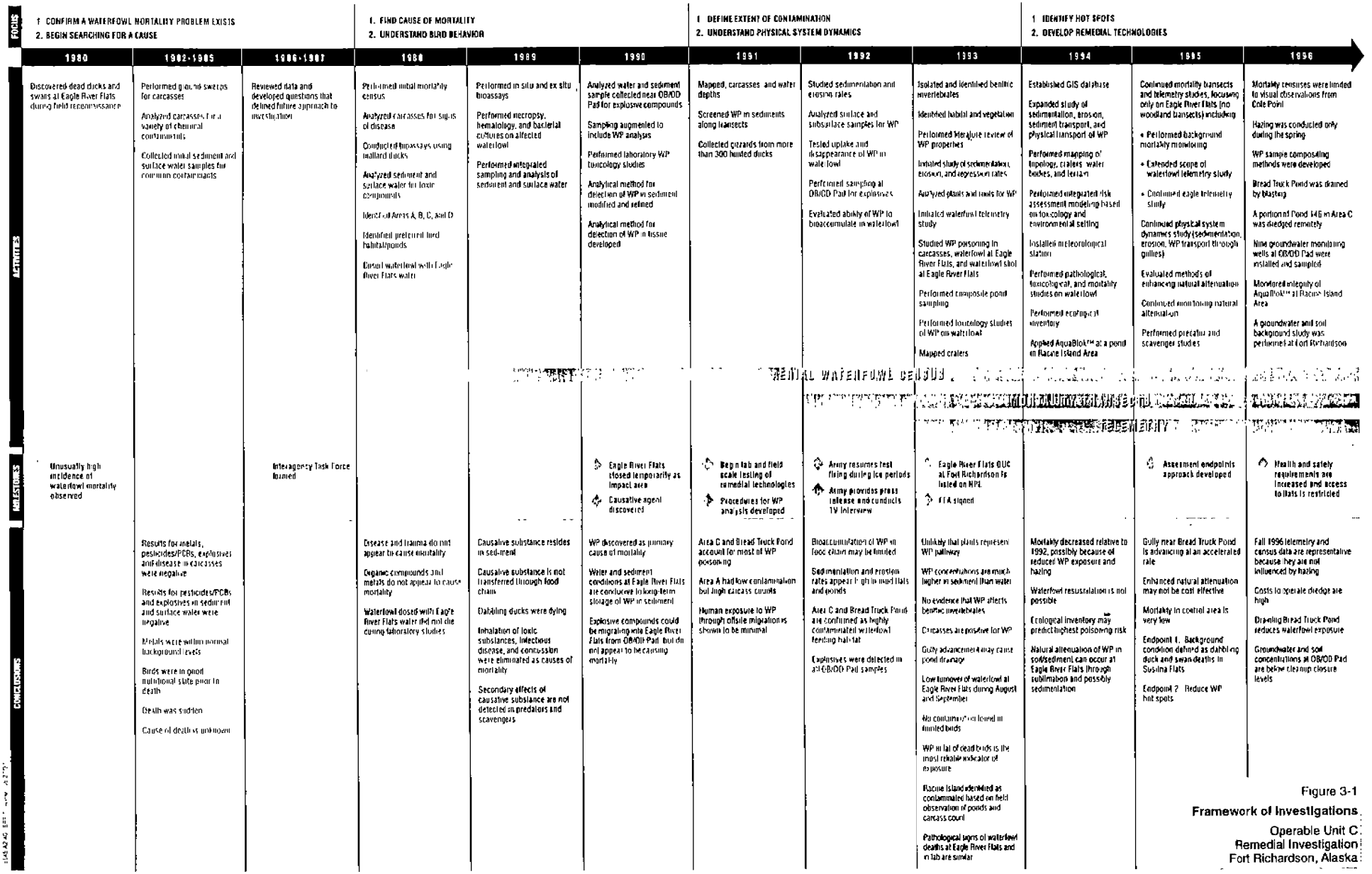


Figure 3-1

Framework of Investigations

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

3.1.1 Overview

In 1980, an unusually high number of waterfowl carcasses were found in the ERF marshes.

In 1980, U.S. Army biologists noticed an unusually high number of waterfowl carcasses, including several dead swans, in the ERF marshes. Subsequent, random searches by the U.S. Army, USFWS, and ADFG discovered abnormally high numbers of dead waterfowl, indicating a serious problem.

Several preliminary studies were conducted between 1982 and 1987 that focused on finding the cause of the mortality. While the results of these studies eliminated a number of possible causes from consideration, the actual cause of the mortality was not identified. An interagency task force was formed in 1987 for the purpose of developing a comprehensive approach to the investigation. The ERF Task Force was composed of representatives from the following federal and state agencies:

- USARAK
- USEPA
- USFWS
- ADFG
- ADEC

The ERF Task Force was assembled to identify the cause of the waterfowl die-offs and recommend remedial alternatives.

The primary objective of the ERF Task Force was to identify the cause of the waterfowl die-offs and recommend remedial alternatives. Since the formation of the ERF Task Force, several studies and investigations have been conducted to identify contaminants of concern, characterize the nature and extent of contamination, and evaluate potential remedial alternatives.

In addition to the ERF Task Force member agencies, other agencies that have been involved in the investigations in ERF include the following:

- COE, Alaska District
- U.S. Army Cold Regions Research and Engineering Laboratory (CRREL)
- U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) (formerly U.S. Army Environmental Hygiene Agency [USAEHA])
- U.S. Army Environmental Center (USAEC) (formerly U.S. Army Toxic and Hazardous Materials Agency [USATHAMA])
- U.S. Department of Agriculture (USDA)

The task force directed investigation efforts from 1987 to 1989. During this time, the scope of the field and laboratory investigations expanded significantly. The results of a 1989 investigation indicated that chemicals from explosive ordnance were the probable cause for

the waterfowl mortality in ERF. In February 1990, on the basis of conclusions reached in the 1989 study, the U.S. Army temporarily suspended the use of ERF for live firing until the causative agent of waterfowl mortality was identified. Field and laboratory studies conducted by CRREL in 1990 provided evidence that WP was the likely cause of the mortality. On the basis of these findings, the Army initiated a public review process that evaluated alternatives for the resumption of live firing. ERF was reopened for training uses in January 1992, following a series of test firings, under several restrictions that essentially eliminated firing during the summer months and permanently eliminated use of WP.

Studies of waterfowl in ERF have included feeding behaviors, movement, and mortality.

Since that time, the feeding behaviors, movement in ERF, and mortality of waterfowl have been extensively studied, as have other physical characteristics and other organisms within this intertidal ecosystem. A series of potentially applicable remediation technologies also have been studied.

3.1.2 Discovery of Unusually High Waterfowl Mortality, 1980 to 1986

In October 1980, a U.S. Army wildlife biologist discovered an unusually high number of duck carcasses, including several dead swans, at ERF. Subsequent ground searches conducted in September 1983 found 368 waterfowl carcasses, including about 35 fresh carcasses. In August and September 1984, about 175 carcasses were discovered. At that time, the U.S. Army estimated the number of waterfowl deaths to be between 1,500 and 2,000 per year (Tweten, 1989).

This discovery of unusually high mortality prompted the questions:

- Does a mortality problem exist?
- Why are the waterfowl dying? Is contamination the cause, or are the deaths natural?

The waterfowl carcasses were analyzed for common waterfowl diseases.

Carcasses from the 1983 and 1984 ground searches were sent to National Wildlife Health Laboratory (NWHL) for analysis. The waterfowl carcasses sent to the NWHL were analyzed for three common waterfowl diseases and metals. Brain tissue samples were sent to the Patuxent Wildlife Research Center (PWRC) and analyzed for cholinesterase inhibition. The following are results of these analyses:

- Analyses for common waterfowl diseases–avian botulism, bacterial pathogens, and viral pathogens–were negative.
- Concentrations of zinc, mercury, and magnesium were within normal limits. Lead concentrations in one bird were elevated. Phosphorus results were inconclusive.

- Brain cholinesterase inhibition, an indicator of the presence of organic esters of phosphoric acid derivatives, was not detected in brain tissue.

The condition of most carcasses indicated that the birds were in a good nutritional state, and that death was relatively sudden.

The condition of most carcasses indicated that the birds were in a good nutritional state, and that death was relatively sudden. Lesions, such as hemorrhages or ruptured organs, were not evident, indicating that death by concussion was unlikely.

In 1985, a study was conducted under a cooperative agreement between the Army and the USFWS. More than 70 carcasses were collected in May. Three days before the carcass search, munitions containing WP had been fired into ERF.

Also during 1985, sediment and surface water samples were collected from seven locations in ERF and from two control sites at Goose Bay, across Knik Arm from ERF. The results of analyses for pesticides, polychlorinated biphenyls (PCBs), and explosives were negative, and concentrations of metals detected were within normal background ranges. No other samples were collected or analyses conducted until 1988.

These results suggested that the observed waterfowl mortality was not caused by the types of contaminants found at many other sites in Alaska. Thus, it became clear that finding the cause of waterfowl mortality would require a more detailed and comprehensive effort than had been attempted.

3.1.3 Searching for a Cause, 1987 to 1989

An interagency task force, made up of representatives from USARAK, USEPA, USFWS, ADFG, and ADEC was formed to identify the cause of waterfowl deaths.

In late 1987, an interagency task force was formed to identify the cause of waterfowl deaths. The ERF Task Force consisted of representatives from USARAK, USEPA, USFWS, ADFG, and ADEC. With the formation of this task force, a more organized interagency approach to studying waterfowl mortality was implemented.

Previous studies had shown that the birds were healthy at death and the death was sudden. Further sampling of carcasses, sediment, and water failed to determine the cause of death. This finding prompted the following questions:

- What causes the sudden death of healthy waterfowl, when the environment is not contaminated with metals, PCBs, and volatile organic compounds?

- What clues can be gleaned from bird behavior?

Through review of existing data and developing these questions, the task force was to focus the project team on an approach that would establish the cause of waterfowl mortality. This approach included a search for the cause of mortality based on physical and chemical data,

and an evaluation of waterfowl behavior based on biological data. These biological studies would aid in understanding how waterfowl behavior might affect mortality.

Dabbling duck species comprised most of the affected waterfowl.

3.1.3.1 Waterfowl Behavior

The studies initiated to assess waterfowl behavior include bird utilization and mortality studies. These efforts encompass a variety of activities, which are summarized below.

Bird Utilization. Field observations provided information on the seasonal distribution of waterfowl in ERF, the locations of dead and dying birds, and the behavior of wild birds. The results indicated that dabbling duck species comprised most of the affected waterfowl, and that the causative substance did not appear to produce secondary effects in predators or scavengers that fed on the affected waterfowl (Environmental Science and Engineering, Inc. [ESE], 1990).

The following areas of potential concern have been identified: A, B, C/D, D, Bread Truck Pond, Pond Beyond, and the Mud flats.

Mortality. On the basis of where most waterfowl mortality had been concentrated, ERF was initially divided into four Areas: A, B, C and D. Over time, four other areas of potential concern also have been identified: Area C/D (between Areas C and D), Bread Truck Pond, Pond Beyond, and the mud flats.

Mortality studies were initiated in 1988 and have continued. Earlier studies were conducted on a single day over limited areas of ERF during the fall or spring. These ground searches confirmed that an unusually high number of bird deaths was continuing. Feather/bone piles and carcasses in various states of decomposition were counted. An intensive survey of dead birds was conducted in 1988, where foot searches by 34 searchers in Area C (and part of D) found nearly 1,000 dead waterfowl. After several years, transects were established (and are still used) to count dead birds and feather/bone piles, and to mark carcasses to monitor decomposition and removal rates.

3.1.3.2 Finding the Cause of Mortality

Chemical analyses of sediment and water samples, clinical analyses, and bioassays were performed on live waterfowl and carcasses in an effort to establish the cause of waterfowl mortality. Each is summarized below.

Transects were established to count dead birds and feather/bone piles, and to mark carcasses to monitor decomposition and removal rates.

Clinical Studies. Twenty-five bird carcasses were collected for analysis at NWHL. The results of analyses ruled out the probability of bacterial, viral, and parasitic diseases; predation; and trauma as the primary cause of death (Tweten, 1989). The results of analyses conducted at PWRC indicated that the cause of waterfowl death also could not be linked to the organic compounds (organochlorine and aromatic hydrocarbons) or trace and heavy metal analytes.

Necropsy, hematology, histopathology, and bacterial culture studies of affected waterfowl were conducted. These clinical studies eliminated

the possibility of infectious disease, concussion, and inhalation of toxic substances as causes of waterfowl mortality. The results of laboratory analyses also indicated that algae toxins were probably not the cause of the waterfowl mortality (ESE, 1990).

Bioassays. As part of the 1988 fieldwork, USEPA conducted bioassays with mallard ducklings, dosing the ducklings with water samples collected from three locations in ERF. No deaths occurred during the bioassay period; however, some birds did develop diarrhea.

In situ and ex situ bioassays were conducted to investigate the causes of death. The results of the laboratory bioassay studies indicated that contaminants in water and possibly sediments from some locations in ERF were the cause of the waterfowl mortality, and that the causative substance was not transferred through plants in the food chain (ESE, 1990). This result was further substantiated by subsequent in situ sentinel bird experiments, which produced similar results.

Clinical studies eliminated the possibility of infectious disease, concussion, and inhalation of toxic substances as causes of waterfowl mortality.

Sediment and Surface Water Sampling. During the 1988 field season, ADEC personnel collected surface water and sediment samples from three locations in ERF and one control site in Potter Marsh, south of Anchorage. Toxic compounds were not detected in the water or sediment samples in concentrations expected to cause waterfowl deaths, and chemicals from explosive ordnance were not detected.

Although specific chemicals were not identified by ESE during the 1989 investigation, the results of the integrated sampling program indicated a relationship between chemicals from explosive ordnance and the waterfowl mortality at ERF (ESE, 1990). As a result, the U.S. Army temporarily closed ERF as an impact area in February 1990. Despite the closure, large numbers of waterfowl continued to die at ERF during the spring and fall migrations.

3.1.4 Discovery of Cause of Waterfowl Death, 1990

Census data for 1988 to 1989 indicated that dabbling ducks comprised the majority of the affected waterfowl. Only a relatively small percentage of the ducks that entered and fed in ERF died. In addition, despite the closure of the ERF impact area, the ducks continued to die.

In May 1990, CRREL initiated a sediment and surface water sampling program at ERF. The strategy of the 1990 field season was based on the following assumptions:

- Contaminants reside in sediments.
- Distribution of the contaminants is heterogeneous.
- Contaminant degradation rate is slow.

Therefore, the focus of the 1990 field season was to find the cause of mortality that remained stable in sediment, but was heterogeneously distributed.

3.1.4.1 Sediment and Water Samples

The 1990 field studies sought a cause of mortality that remained stable in sediment, but was heterogeneously distributed.

Water and sediment samples were collected primarily from craters. The locations of the sampling sites and selected surface features in the salt marsh were surveyed, and the data were entered into a GIS database (Racine *et al.*, 1992a).

Samples were field-screened for hexahydro-1,3,5-trinito-1,3,5-triazine (RDX) and 1,3,5-trinitrotoluene (1,3,5-TNT). Neither RDX nor TNT was detected in any of the 93 sediment and water samples collected in May 1990. However, 2,4-dinitrotoluene (2,4-DNT) was detected in three sediment samples collected from a sedge marsh adjacent to OB/OD Pad. To reconfirm the presence of 2,4-DNT near OB/OD Pad, three more samples were collected for analysis in late June 1990; but only trace amounts were detected.

One sediment sample, however, emitted a very small vapor cloud when opened and stirred (Racine *et al.*, 1991). The behavior was recognized as a characteristic of smoke-producing chemical, such as WP, used in munitions. A portion of the sample was air-dried and analyzed for orthophosphate, an oxidation product of WP. The concentration of phosphate exceeded the range for the procedure (greater than 225 milligrams per kilogram [mg/kg]). The analytical program for the fall 1990 sampling was augmented to include testing for WP in sediment using a newly modified and refined analytical method.

A sedge marsh sediment sample emitted a very small vapor cloud when opened and stirred.

Because the analytical results for the samples collected in May 1990 indicated the presence of munitions compounds only near OB/OD Pad, the second round of samples, collected in August 1990, was concentrated along the interface between Area C and OB/OD Pad. Only sediment samples were collected because the contaminant source appeared to be in the sediments. Of the 172 sediment samples collected, 62 contained 2,4-DNT. Most samples that contained at least 1 mg/kg of 2,4-DNT also had detectable concentrations of TNT (Racine *et al.*, 1992a). Aqueous soluble phosphate was detected in 42 of the sediment samples. Of the 17 samples analyzed for WP, 8 contained detectable concentrations.

3.1.4.2 Field Observations

Field observations of ERF waterfowl were conducted by CRREL personnel from an observation tower in Area C in mid-September 1990. The symptoms associated with the death of six ducks were observed during a 5-day period. The general progression of symptoms included the following (Racine *et al.*, 1992a; Coburn *et al.*, 1950):

- Lethargy
- Hiding in dense vegetation
- Head rolling back and forth across the back
- Swimming in tight circles
- Violent convulsions followed by death

Dartmouth Medical School personnel also conducted laboratory WP toxicity studies. The behavior of the dying ducks observed at ERF was consistent with the observations of the ducks dosed with WP in the laboratory. Concentrations of WP in tissues were also similar.

The results of the 1990 CRREL investigations provided strong evidence that WP was the primary cause of the waterfowl mortality at ERF. Further, it was suggested that the water and sediment conditions at ERF were conducive to long-term storage of the WP in the sediments (Racine *et al.*, 1992a).

WP in sediment was identified as the primary cause of the waterfowl mortality at ERF.

3.1.5 Dynamics of ERF, 1991 to 1993

With the discovery of WP as the causative agent, the questions asked about ERF shifted to the following:

- Where is the WP contamination located?
- What are the risks of WP exposure on waterfowl and humans?
- What are the physical dynamics of the flats that might affect the fate and transport of WP in sediment?

Therefore, ERF investigations performed in the following 3 years focused on defining the extent of contamination, determining the factors that contribute to risk, and understanding the physical dynamics of ERF. This information became a high priority, with the initiation of laboratory and field-scale testing of remedial technologies in 1991.

In March 1991, the U.S. Army conducted test firing to determine if it could resume using ERF as an impact range. Routine use of ERF as an impact range began again in January 1992, with the restriction that ice cover must be sufficient to prevent disturbance to sediments upon munitions impact and detonation.

Field investigations conducted in 1993 focused primarily on the east side of ERF near Area C and Bread Truck Pond

Laboratory and field-scale testing of remedial technologies began in 1991.

3.1.5.1 Estimate Extent of Contamination

In 1991, CRREL developed the procedures to analyze soil, sediment, and bird tissue for WP. Previously, no standard method of analysis for WP was available. The method developed as part of this effort has since become a standard method of WP analysis (Method 7580) referenced in SW 846 Update III.

Sediment. More than 400 sediment samples and 60 carcasses were collected for analysis. The results of the 1991 fieldwork indicated that two ponded areas in ERF, Area C and Bread Truck Pond, accounted for most of the WP poisoning of dabbling ducks (Racine *et al.*, 1991). WP was detected in pond sediments to depths of 20 cm. The aerial extent of WP contamination in non-ponded areas was not determined because only ponded areas were sampled.

In 1992, pond sediment surface and subsurface sampling and analysis were performed to further characterize aerial and vertical distribution of WP contamination.

Two ponded areas in ERF, Area C and Bread Truck Pond, accounted for most of the WP poisoning of dabbling ducks.

During the 1992 field season, USAEHA collected 48 soil samples at OB/OD Pad to analyze for explosives, including cyclotetramethylenetetranitramine (HMX), RDX, 2,6-DNT, 2,4-DNT, and TNT. All the analytes were detected in at least one sample, with 2,4-DNT and 2,6-DNT detected most frequently. The maximum concentration of 2,4-DNT was 76 mg/kg; maximum of 2,6-DNT was 2.6 mg/kg.

Many investigations in 1993 focused on WP. USAEHA performed a contaminant inventory. It collected sediment and surface water samples and analyzed for WP, explosives, nutrients, target analytes, and target compound. The only COC detected was WP. CRREL performed a literature review of the chemical and physical properties of WP. This review was used to evaluate the factors that influence the persistence of WP in the environment, and the results suggested that WP persistence is inversely related to temperature. CRREL collected sediment and surface water samples and analyzed them for WP. Results from the 1991 and 1992 field season were included to develop a further understanding of the distribution and concentrations of WP in ERF. CRREL concluded that WP concentrations were 1,000 times less in water than in sediment.

Racine Island was first sampled by CRREL in August 1993. During the first visit, numerous waterfowl carcasses were found, and subsequent searches between August and October revealed carcasses of 112 ducks and 1 swan. WP was detected in several samples collected from Racine Island. The concentration in one sediment sample was more than 3,000 µg/g, the highest ever detected in sampling along transects in ERF.

Craters. In 1993, CRREL began mapping the location of craters throughout ERF from aerial photographs. It was the examination of aerial photographs for craters, as well as targets and permanent ponds, that led to the sampling of Racine Island in August 1993. The existence of craters was considered to be another measure of the extent of WP contamination. This information was to be used to identify areas of WP contamination where sampling had not been performed. The crater mapping was entered into the ERF GIS.

WP was not detected in any hunter-harvested ducks.

Waterfowl. During the 1991 fall hunting season, ADFG and USFWS staff collected 305 gizzards from hunter-harvested ducks at Goose Bay, Palmer Hay Flats, Susitna Flats, and the Anchorage Coastal Wildlife Refuge (Figure 2-2). The gizzards were analyzed for WP to evaluate the potential for offsite transport of WP by the waterfowl. WP was not detected in any birds (Racine *et al.*, 1991). However, it was observed that waterfowl can fly short distances after ingestion of WP and may be contributing to distribution of the contaminants.

The results of CRREL's sampling program generally confirmed the 1991 findings that the highest concentrations of WP were near Area C and Bread Truck Pond, in a densely cratered area east of Eagle River. Localized areas of concern were suspected in Area A because a high number of carcasses were consistently observed on one Area A pond. However, this hypothesis was not confirmed by the results of the sample analyses.

3.1.5.2 Physical Dynamics

In 1993, CRREL investigations examined the physical system of the flats.

In 1992, sedimentation rates were measured at various locations in ERF. In 1993, CRREL performed several investigations of the physical system of the flats. In one study, five zones and 18 habitat-vegetation types were identified in ERF (Figure 2-4). In another, CRREL measured erosion and sedimentation rates around ERF and concluded that gully advancement may cause pond drainage.

3.1.5.3 Toxicological Studies

CRREL, in conjunction with Dartmouth Medical School, in Hanover, New Hampshire, conducted laboratory experiments in 1992 to evaluate the ability of WP to bioaccumulate in the tissues of waterfowl predators at ERF. American kestrels were used to simulate the predator population. When fed a diet containing WP, rapid uptake of WP into bird tissues was observed. Conversely, rapid disappearance of WP in tissues was observed when exposure to WP was reduced. These results indicated that the ability of WP to bioaccumulate in the food chain is very limited (Nam *et al.*, 1994). Because the kestrel experiments were only accomplished with one level of WP dissolved into the fat content of the food, it cannot be assumed that at other concentrations or longer times of exposure WP would not bioaccumulate (Roebuck, 1994a). In addition, WP exposure to predators/scavengers is in the forms of both WP dissolved into biological material and WP particles. The kestrel experiments only refer to exposure through dissolved particles.

The ability of WP to bioaccumulate in the food chain is very limited.

The impacts of WP on the wildlife at ERF were examined in several laboratory studies. USAEHA collected stickleback fish for WP tissue analysis, collected invertebrates for evaluation of the effects of WP on community integrity, and conducted WP sediment toxicity studies on invertebrates. USFWS collected 35 carcasses and 52 fresh water bird specimens for laboratory analysis for WP to study poisoning of water birds. It concluded that WP concentration in fat is the best indicator of WP exposure. USFWS also collected macroinvertebrates and fish for laboratory analyses, but found that impacts are not great enough for WP cleanup to be driven by macroinvertebrate or fish accumulation. CRREL collected plant samples from areas where WP had previously been detected in sediments for analysis. It was found that the role of plants as a major food-chain pathway for herbivores is unlikely.

In addition to the activities described above, several investigations regarding waterfowl and mortality census were conducted. They are listed below:

- USFWS studied waterfowl utilization of ERF April through October 1993, by conducting 42 aerial surveys during spring, summer, and fall.
- CRREL estimated waterfowl mortality to assess future changes in mortality rates resulting from decreased exposure to WP following remedial activities.
- USDA monitored waterfowl distribution and movements in ERF by tagging 23 ducks and fitting 39 ducks with radio transmitters.

In 1993, USFWS performed toxicological studies of WP in waterfowl by conducting laboratory studies to determine acute lethal doses for adult and juvenile mallards.

The ERF GIS database spatially links the results of previous investigations of ERF into a single geographical framework.

3.1.6 Identifying Areas of Concern, 1994 and 1995

Within the last 3 years, the ERF investigations have focused on finding a feasible remedy. Therefore, the investigations aimed at answering these questions:

- What are the ERF areas of concern?
- What remedial technologies would be effective in reducing exposure?

Determining the areas of highest cleanup priority involved bringing together previous data and collecting additional information. Areas of priority were estimated by using WP data and information regarding telemetry, carcass transects, physical system dynamics, and landcovers.

3.1.6.1 1994 Studies

In 1994, CRREL established the ERF GIS database. This database spatially links the results of previous investigations of the flats into a single geographical framework. Types of data within the ERF GIS include carcass locations, crater counts by hectare, location of targets, telemetry data, and WP sampling locations and concentrations. In addition, physical features of the flats, such as gullies, mud flats, water bodies, and vegetation, are presented. Many graphics in subsequent sections of this report are based on the ERF GIS.

White phosphorus concentrations are highly spatially variable.

CRREL continued its study of physical system dynamics in 1994. Erosion control, as well as transport, deposition, and burial of WP-bearing sediments, were examined. A meteorological site was installed at ERF. Historical Anchorage temperature and precipitation data were prepared, and a tide table program was written to predict tidal inundations. In addition, an ecological inventory was performed.

Vegetation, topography, soil texture, water bodies, and craters were mapped and entered into the ERF GIS.

CRREL conducted a study of the persistence of WP particles in 1994. Results of this study showed that planted WP particles were persistent in saturated sediments, but there was loss of WP in unsaturated sediments in ERF. Therefore, natural attenuation is a viable remedial option for mud flats and intermittent ponds that have the potential to drain and dry.

In 1994, the WP concentrations database was updated and reviewed by CRREL. No new WP-contaminated areas were found. Pond sediments frozen to rafted ice blocks were found to contain WP. In addition, WP concentrations at a single site were found to be highly spatially variable.

Dartmouth assessed the toxicity of dissolved and particulate WP on waterfowl. Results suggest that toxicity and mortality statistics are the same for dissolved and particulate WP. Tests were conducted to determine if it would be possible to resuscitate birds that have ingested WP. It was determined that mortality onset is too fast to treat sick birds, and that antidotes for anti-cholinesterase poisoning would not be effective.

Toxicity and mortality statistics were found to be the same for dissolved and particulate WP.

Several organizations continued tracking bird populations. During spring migration, the Denver Wildlife Research Center (DWRC) studied the distribution, movement, turnover rate, and mortality of waterfowl, eagles, and dowitchers. It recommended that telemetry data be integrated into project activities. USFWS continued aerial waterfowl surveys. The New England Institute of Landscape Ecology (NEILE) continued the waterfowl use and mortality studies.

Studies were performed at PWRC to identify biomarkers of WP in waterfowl, to better understand toxicological effects of WP in mallards, and to examine secondary toxicity effects in raptors. It was found that hematocrit and hemoglobin levels, after further study, may be reliable indicators of WP exposure. Raptors could be at risk of WP intoxication if they consume poisoned waterfowl.

NEILE continued the mortality studies started in 1991. These studies involved counting feather piles and carcasses to estimate the mortality and to detect potential new areas of high mortality. Scavengers of WP-poisoned carcasses were photographed. Mortality rate declined significantly in 1993 and has not reached levels observed in 1992. The decline in mortality may be a result of reduced WP exposure, hazing, differences in sample size, and human disturbance. A more detailed discussion of mortality is presented in Appendix A, Section 3.2.

3.1.6.2 1995 Studies

USFWS continued to conduct aerial surveys to monitor water bird use of ERF during the spring, summer, and fall of 1995, as part of the ongoing mortality studies. UCI marshes were also surveyed for water birds to estimate background populations.

Aerial surveys monitored the use of ERF by water birds.

NEILE continued the mortality transect study. Objectives for 1995 were to monitor waterfowl mortality in ERF, in an uncontaminated section of ERF, and in an uncontaminated reference area. Measurements in reference areas were used to develop a background level of mortality to be used as a mortality endpoint. The mortality rate at ERF during fall 1995 was lower than during fall 1994. This decline continued a trend since 1992. The mortality rate in 1992 was approximately 10 times higher than in 1995. NEILE concluded that this decline is the result of decreased availability of WP. This decrease is due to either natural attenuation of WP, sedimentation on the top of contaminated ponds, or high surface-water levels causing ducks to feed in non-contaminated areas.

In August 1995, DWRC continued monitoring bird movements and utilization. Ducks and eagles were captured and radio transmitters were attached. Generally, waterfowl distribution data from 1995 were similar to those from 1993 and 1994. Mortality during 1995 was about 9 percent, about half the number of ducks that died during the fall migration in 1993. Turnover rates in 1995 were lower than in 1993 or 1994.

The processes of erosion and sedimentation could reduce WP concentrations in surface sediment over a significant portion of ERF.

CRREL conducted analyses of the physical system of ERF. The focus of these investigations was the role of the physical system in the intrinsic remediation of WP contamination in ERF. Through these investigations, it was concluded that the processes of erosion and sedimentation may reduce WP concentrations in surface sediment over a portion of ERF. Gully erosion and headwall recession may drain larger areas of contaminated ponds in about 1 to 10 years. Through historical analyses, field data and process analyses indicate that Bread Truck Pond could begin draining in 1 year and portions of Area C/D, Lawson's Pond, and C-Pond could begin draining in 10 to 15 years. The draining could expose areas to WP degradation. In addition, it was postulated that pond sedimentation rates are high enough to bury WP to a depth sufficient to reduce the exposure risk for feeding in certain ponds and marshes within a similar time frame.

In 1995, CRREL also continued measurements of sediment moisture, sediment temperature, and persistence of WP particles. It was hypothesized that when sediments are exposed and desaturated, the smallest WP particles are the least persistent and are lost relatively rapidly, because small particles have large surface to volume ratios and sublimation occurs from the particle surface. Larger particles are much more persistent, but shrink during periods of desaturation.

CRREL concluded that natural attenuation of WP particles appears to be occurring at two highly contaminated sites (Site 883 and Miller's Hole) in the intermittent pond of Area C.

When samples were taken from Site 883 in fall 1995 at the same locations as samples collected in fall 1992, the number of samples with WP concentrations greater than 10 µg/g declined, and the number of samples below 0.001 µg/g increased. In addition, the number of WP particles counted in samples collected at this site has decreased between 1992 and 1995. Sediments at this site were desaturated during the summers of 1993 and 1994 when weather conditions and the length of time between flooding tides were favorable for pond shrinkage. During 1995, flooding tides occurred monthly and sediments at this site were continually under water.

Samples also were obtained from Miller's Hole, the crater produced by the detonation of WP UXO in the intermittent pond of Area C in 1992. The rim of the crater, which had a WP concentration of nearly 1,000 µg/g when sampled in 1992, had significantly lower concentrations in 1995. Gravel-size (> 2 mm) WP particles also were isolated from a permanently saturated site on Racine Island, but were absent from sites in the intermittently ponded areas.

3.2 Field Investigations and Laboratory Quality Assurance and Quality Control

The investigation team included broadly diverse backgrounds: wildlife biologists, botanists, chemists, hydrologists, geologists, engineers, and toxicologists.

The uniqueness of the ERF setting and the challenge of assessing the cause of the waterfowl mortality was recognized early in the investigative process. In response to the challenge, experts from a number of government agencies and academia have performed the investigations documented in this report. Wildlife biologists, botanists, chemists, hydrologists, geologists, engineers, and toxicologists have participated in this effort over the course of the investigations.

An important component of the field and laboratory procedures are the QA/QC measures used to maintain and enhance the data quality. Much of the data discussed in this report was collected before designation of Fort Richardson as a CERCLA site. During that time, the activities were overseen by the ERF Task Force, formed in 1987 and consisting of federal and state agencies: USARAK, USEPA, USFWS, ADFG, and ADEC. The types of QA/QC procedures used were those employed as common practice within each agency. The Task Force reviewed the results annually and developed new activities based on the previous results.

Investigations were overseen by federal and state agencies. QA/QC procedures that were common practice within each agency were followed.

Table 3-2 summarizes the QA/QC measures employed in the different types of investigations. Typically these included standard procedures, external review of procedures and results by scientists not performing the work, equipment calibration, and controls (for laboratory studies).

Following the designation of Fort Richardson as a CERCLA site, a number of changes were made in the QA/QC program. A set of data quality objectives (DQOs) was developed for the research activities (CH2M HILL, 1996a). Following are additional QA/QC measures implemented since 1994:

- Emphasis on coordination of fieldwork between agencies and researchers and on standardization of procedures
- Standardization of field techniques for sample collection, handling, and documentation among all researchers
- General coordination of individual research projects to reduce interferences between studies, as well as consolidate and maximize data collection efforts
- Weekly meetings between researchers, Fort Richardson Department of Public Works, and range control personnel to coordinate field activities and discuss significant findings and observations
- Implementation of third-party QA field audits (copies of completed audit checklists are included in Appendix D).
- Verification and validation of field and analytical data
- QC review of the ERF GIS by returning the information from the GIS database to the researchers for their review and correction. Required changes are then made in the database.
- Annual meetings of the researchers and agencies, including the remedial project managers (RPMs) and members of the Biological Technical Assistance Group, to discuss the results obtained during the recent field season

Throughout these investigations there has been substantial concern about the human exposure to unexploded ordnance while collecting these data. This factor, and the substantial expense required, has substantially limited the collection of confirmatory data obtained after Fort Richardson was designated a CERCLA site. Existing data, therefore, have been used to the maximum extent possible.

TABLE 3-2
Summary of QA/QC Activities for Data Collection

Data Type	Application	Characteristics	Data Collection Group	QA/QC Procedures
Field Activities				
White phosphorus environmental samples	Nature and extent of contamination	Sampling a variety of environments (sediment, water, and AquaBlok™) and locations for WP.	CRREL DWRC AEHA NEILE	Location: Location summary returned to data collector to confirm location, and some field checks on location. Sample collection: Calibration of field instruments. Duplication of some samples from the same sample jar. Laboratory analysis: Standard WP method developed and implemented. Standard laboratory QA/QC.
Mortality transects	Changes in mortality rate.	Standard belt and edge transects, and quadrates to count carcasses and featherpiles. Includes reference transects. Observed at least once every 6 days during spring and fall migrations.	NEILE	Duplication of transects by two people to check accuracy of counts. Conduct counts along mock transects to check accuracy. Transects areas are maintained from year to year. Transect width designed to allow easy observation in zig-zag pattern.
Water bird utilization of ERF	Exposure group population variability over seasons and years	Spring and fall bird populations in ERF. Observed daily from Cole Point.	NEILE	Duplication of observations by different people. Standard map defined areas. Performed at approximately the same time each day. Training program for new observers.
Bird behavior	Bird activities while in different areas.	Observe waterfowl use of ERF areas and behavior of birds not being hazed.	NEILE	Duplicate observations. Written guidance on identifying behaviors. Radio contact between multiple observers. Ducks located on sketch maps. Area borders located by global positioning system (GPS). Training program for observers.

OUC 0029346

TABLE 3-2
Summary of QA/QC Activities for Data Collection

Data Type	Application	Characteristics	Data Collection Group	QA/QC Procedures
Water bird utilization of ERF and Upper Cook Inlet	Exposure group population variability over seasons and years	Aerial observations of bird populations in ERF and Upper Cook Inlet. Observed twice per week during spring and fall and once per week in summer.	USFWS	Study areas standardized. Same aircraft, speed, and altitude used. Same observer used for most flyovers. Explicit weather criteria for when not to fly.
Movement, distribution and relative risk of waterfowl and bald eagles	Bird movements within and away from ERF	Waterfowl capture, transmitter attached, and then location recorded on daily basis for several weeks.	DWRC	Internal QA unit to audit activities and review reports. Use internal standard operating procedures. Compasses on tower reset daily for correct observation direction.
Physical system dynamics	Movement of water, sediments, and WP	Measure: sedimentation and resuspension; gully erosion and recession; water quality parameters; WP particle transport; tidal hydrology.	CRREL	Sedimentation: multiple measurements of same location. Gully erosion and headwall recession: multiple measurements at same location. Water flow and quality parameters: instruments calibrated to manufacturers' specification at start of season; equipment cleaned at the end of each tidal cycle.
WP effects on the ecosystem	WP aquatic effects and bioaccumulation in ERF	Macroinvertebrate, sediment, and water sampling. WP measurements. Water quality measurements.	AEHA	Used internal standard operating procedures for sample collection, handling, analysis. Collected duplicate samples at frequency of about 10 percent. Standard analytical method Field instruments calibrated according to manufacturer's specifications. Sediment toxicity tests followed ASTM protocol.

OUC 0029347

TABLE 3-2
Summary of QA/QC Activities for Data Collection

Data Type	Application	Characteristics	Data Collection Group	QA/QC Procedures
WP attenuation	Potential for natural WP loss from drying and heating	Place WP particles in the field and measure them later. Laboratory studies also done.	CRREL	Duplicate samples. Standard analytical methods. Latin square design for field test plots. Temperature: replicate measurements. Sediment moisture: replicate measurements and confirmation by an independent method.
WP in plants	Contamination of salt marsh plants by WP in ERF	Marsh plants washed, and then tissues analyzed for WP	CRREL	Standard analytical method.
WP in birds	Contamination of birds by WP in ERF	Collected birds were necropsied and tissues analyzed for WP. Eggs yolk also tested for WP.	PWRC	Experimental conditions: Use control animals; randomize treatment conditions. Laboratory: Split samples; control samples analyzed with treatment samples; duplicates every tenth sample; standard analytical method.
Physical features, habitat and vegetation	Location of activities at ERF	Field inventories of environmental conditions, and then classification and mapping.	CRREL	Field spot checks. Automated classification of digital data. Confirmations by researchers.
Climate and tides	Weather and tides drive physical processes at ERF	Measure surface temperatures, solar radiation, relative humidity, wind speed and direction, and precipitation. Predict tides.	CRREL	Purchased quality equipment used by weather services. Compared results to those obtained by other equipment. Soil thermisters were tested in ice water. Tidal information was supplied by NOAA.

OUC 0029348

TABLE 3-2
Summary of QA/QC Activities for Data Collection

Data Type	Application	Characteristics	Data Collection Group	QA/QC Procedures
Laboratory Activities				
Toxicology studies in waterfowl	Dose-response function for WP in ducks	Measure mortality with increasing doses of WP. Performed with dissolved and pelletized WP.	PWRC	Experimental conditions: Use control animals; randomize treatment conditions. Laboratory: Split samples; control samples analyzed with treatment samples; duplicates every tenth sample; standard analytical method.
Toxicity biomarkers	Identify indicators of WP toxicity other than mortality	Blood chemistry analysis of mallards treated with WP.	PWRC	Experimental conditions: Use control animals; randomize treatment conditions. Laboratory: Split samples; control samples analyzed with treatment samples; duplicates every tenth sample; procedural blanks; all enzyme analysis was duplicated; standard reference sample to measure enzyme activity.
Reproductive effects of WP	Identify reproductive effects in female mallards	Dose females laying eggs and observe hatched eggs.	PWRC	Design study to estimate required sample size. Experimental conditions: Used control animals; randomize treatment conditions. Laboratory: Split samples; control samples analyzed with treatment samples.
Persistence of WP in mallards	Potential for contaminated waterfowl to expose hunters	Measure WP in mallard tissues over time.	PWRC	Experimental conditions: Used control animals; randomized treatment conditions. Laboratory: Split samples; control samples analyzed with treatment samples; duplicates every tenth sample; standard analytical method.

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TABLE 3-2
Summary of QA/QC Activities for Data Collection

Data Type	Application	Characteristics	Data Collection Group	QA/QC Procedures
WP uptake and disappearance in American kestrels	WP toxicity in secondary receptors	Kestrels fed WP-contaminated baby chicks and parts. Mortality and blood chemistry observed.	PWRC	Experimental conditions: Use control animals; randomize treatment conditions. Laboratory: Split samples; control samples analyzed with treatment samples; duplicates every tenth sample; standard analytical method.
WP particle size and toxicity	Effect of different size WP particles on toxicity.	Measure mortality rate with different size WP particles, holding total weight constant.	Dartmouth	Standard method for measuring WP: calipers and calibrated ocular grid in microscope. Three birds treated simultaneously with same WP weight: WP in oil, small particles, large particles. Observer blind to bird treatment. Standard analytical laboratory QA/QC.
Biotransfer of WP from hen to egg	Potential for transfer of WP from female to offspring	Hens dosed with WP, eggs collected at different times. WP was measured in the yolk and white.	Dartmouth	Standard laboratory QA/QC for WP. Included duplicates of isooctane extract.
Database				
ERF GIS	Spatial distribution of results. Identification of hot spots, and linking of ERF areas with remedial technologies.	Query the GIS to obtain areas that meet specified characteristics.	CRREL	Data in the ERF GIS has been returned to researcher that produced it. Researchers have reviewed data and confirmed or modified it as appropriate. The GIS has then been corrected if necessary. Procedures of importing data from researchers are standardized.

Notes:
ASTM = American Society for Testing and Materials
NOAA = National Oceanic and Atmospheric Administration

OUC 0029350

SECTION 4

Nature and Extent of ERF Contamination

This section summarizes the nature and extent of contamination in the physical environment (principally the sediment and water) at ERF. The discussion of contaminants found in the plant and animal life at ERF is discussed in Section 8. The nature and extent of contaminants in the OB/OD Pad is presented in Section 6.

ERF has been sampled extensively for WP, because WP was identified as the causative agent of the acute waterfowl mortality. Principally along the border of ERF with OB/OD Pad, a few other samples have been taken in which laboratory analyses for other contaminants have been made. Chemicals analyzed included munitions residues, other organic compounds, and metals. Some of the these compounds did not have detectable quantities, and the likely source for contaminants other than WP is the munitions disposal activities at OB/OD Pad. The metals concentrations in the sediment were below the upper bounds of concentrations found in sediments from reference areas, and in the water were below ambient freshwater criteria. Detected concentrations of organics were infrequent in all the samples taken. They were low, below 1 µg/g, and typically even lower, only at trace levels. For the above reasons, WP has been chosen as the only potential COC for ERF.

Focus is on white phosphorus because it is the acute toxic agent for waterfowl mortality.

Information on the WP samples was obtained from the ERF GIS coverages provided by CRREL, and the discussion in this section depends on the accuracy of these data. This section first provides an overview of the sampling, laboratory analysis methods, and the ERF GIS database. Discussed next are the results of the WP analysis for each area of ERF and the different landcovers (for example, ponds and sedge marsh). The studies of other chemicals are summarized at the end of the section.

4.1 Overview of Sampling, Analysis, and Data Storage

4.1.1 Sampling Objectives

The sampling objectives, which are described below, changed over time, depending on the focus of each field season. The WP sampling did not begin until 1991, because WP was identified in 1990.

- **Screen for WP across ERF, 1991.** The sediment in large ponds and adjacent marsh was sampled in Areas A, B, C, D, and C/D and Bread Truck. Samples were taken at 25-m intervals along transects through the ponds.

- **Examine small-scale and vertical distribution of WP, and check for WP on the mud flats, 1992.** Close-interval sampling was performed to define the small-scale distribution or specific areas of concern (AOCs) based on WP concentrations. Core samples were taken to assess the vertical distribution of WP, and mud flat sediments were sampled.

- **Sample for WP in areas having new discoveries of high duck mortality, 1992-1993.** Random samples were taken from Lawson Pond (a very small pond on the west side of Area C where considerable mortality has been observed) and Racine Island where high carcass densities had been observed. Samples also were taken from the sediments in the gullies.

- **Determine whether WP was moving through ERF or affecting invertebrate populations and the effectiveness of treatability studies, 1994.** Additional samples were taken from the gully sediment and water. Samples also were taken to characterize WP in pond sediment traps and from material adhering to the bottom of rafted ice blocks. Other samples were taken from areas of known WP contamination to characterize the concentrations and correlate concentrations with invertebrate populations. Samples were taken to support remediation treatability studies involving natural attenuation and lining pond bottoms with AquaBlok™.

Sampling objectives changed each year based on the data collected the previous year.

- **Determine whether WP was moving through ERF and the effectiveness of treatability studies, 1995.** Samples were taken to examine WP in gullies and sediment traps and the effectiveness of several remedial technologies: natural attenuation, enhanced intrinsic remediation, AquaBlok™, and dredging.

During the initial phases of the WP sampling in ponds, crater density in mud flats adjacent to ponds and mortality observations were the main criteria used in selecting ponds to be sampled. Sampling priority was placed on ponds and adjacent mud flat areas that had high density of crater coverage and high numbers of observations of water bird mortality.

4.1.2 Sample Collection

4.1.2.1 Sediment

The basic method of collecting a sediment sample involves using the open, gloved hand to scrape a surface sediment sample from an area as large as perhaps 930 cm^2 to a depth of 2.5 to 5 cm. The sample is

placed in a 500-milliliter (mL) ICHEM jar, capped, and returned to the laboratory.

Two types of coring devices were used in 1991 and 1992 to obtain cores from the soft bottom sediments in the ponds: one designed to collect saturated cores; the other for firmer sediment horizons. Cores were taken to a maximum depth of 60 cm, and were transported to the field laboratory in rigid plastic sleeves. At the laboratory, the cores were sampled in 5-cm increments. Core samples were taken only in 1991 and 1992 before the practice was halted by EOD.

In 1993, CRREL tested a WP composite sampling method to simulate feeding by dabbling ducks in a pond. A large long-handled spoon was used to scoop small "dabs" of sediment at many random locations in each pond. As each dab was collected, it was placed in a No. 30 mesh (0.59-mm) bucket sieve and washed and stirred while the sample collector walked through the sample pond holding the bottom of the bucket underwater. This process removed the fine-grained silt particles, leaving organic materials and particles larger than the 0.59-mm mesh size. Depending on the size of the pond, from 5 to 15 spot sediment samples were collected and washed. The residual material was placed in a 500-mL jar for analysis (Racine and Walsh, in Racine *et al.*, 1994).

In 1994 and 1995, plankton nets with a length of 3 m, an opening of 1 m, and a mesh size of 80 micrometers (µm) were used to sample sediment in suspended and bed load transport in gullies during the ebb tide. The plankton net was tied to stakes in the gully bottom, and the net was extended down channel in the direction of the ebb. A cup at the apex of the net collected trapped sediments (Lawson, Bigl, Hunter, Nadeau, Weyrick, and Bodette, in Racine *et al.*, 1995; Lawson *et al.* in Racine *et al.*, 1996).

Standard methods were developed for collecting sediment and water samples. A standard analytical method for WP was used.

4.1.2.2 Water

Water samples were collected in 0.5-liter (L) containers. To distinguish between dissolved and suspended WP, some samples were filtered through a SamplePro High Capacity Field filter into the collection container. The pore size of the filters was 0.45 µm.

4.1.3 Sample Analysis

Samples of wet soil or sediment were analyzed with USATHAMA Method KN01 (Walsh, in Racine *et al.*, 1994). The method uses gas chromatography following an iso-octane extraction. Concentrations are expressed as wet-weight concentrations. The certified reporting limit is 0.00088 microgram per gram (µg/g).

Sample analysis for WP in water was performed by using a similar gas chromatographic technique. The method detection limit was 0.011 microgram per liter (µg/L) (Walsh, in Racine *et al.*, 1994).

4.1.4 White Phosphorus Sample Database

Field data were maintained in the ERF geographical information system.

The ERF GIS developed by CRREL includes all WP sampling and results as well as other data. It contains information such as the organization that collected the sample, the sample location, type of site, sampled material, sampling method, analytical laboratory, and concentration. The database contains sediment and water data through the 1995 field season. WPSAMP11, the name of the WP coverage used for this assessment, includes 2,578 samples. In the database, a value of "0" has been used to indicate values below the detection limit. This approach has been used in the figures included in this section.

4.2 White Phosphorus in Sediment

Particle-size studies showed that WP in the sediments exists as soft, waxy particles with shapes varying from angular to globular. The particle masses ranged from less than 0.1 to 3.4 milligrams (mg), and the particle lengths ranged from 0.26 to 2.9 mm; however, in 1996 a 150-mg particle was found in Racine Island sediment. The proportion of particles in different size classes varied from sample to sample.

White phosphorus contamination in sediments exists as particles, with substantial local variability in concentrations.

Substantial local variability also was noted in the WP concentrations. For example, three surface sediment samples collected within a 2-m-diameter circle have concentrations that vary by several orders of magnitude (Racine, in Racine *et al.*, 1995). As discussed in Section 2, explosions created the WP particles and distributed them in the environment. This process creates a very heterogeneous presence of WP in both local and wide geographic areas.

Figure 4-1 summarizes the locations and WP concentrations of the surface grab samples. In cases of multiple samples from the same location, the sample with the most recent date and highest concentration (if more than one sample had the same date) is shown in all figures in this section. The landcovers of intermittent and permanent ponds and of sedge marsh also have been included because of their importance in defining potential hot zones of WP concentration and bird usage (discussed in Section 10). The density of sampling is high in some areas, making it difficult to distinguish the analytical results. Other figures in this section provide more geographical detail.

The only areas with detected white phosphorus concentrations greater than 1 µg/g are Area C, Bread Truck, and Racine Island.

Tables 4-1 and 4-2 summarize the WP concentrations for the ERF areas. The only areas with detected WP concentrations greater than 1 µg/g also contain the maximum WP concentrations: Area C, Bread Truck, and Racine Island. Areas B and D and Coastal West have no locations with detectable WP. The ERF areas will be discussed individually in the following subsections.

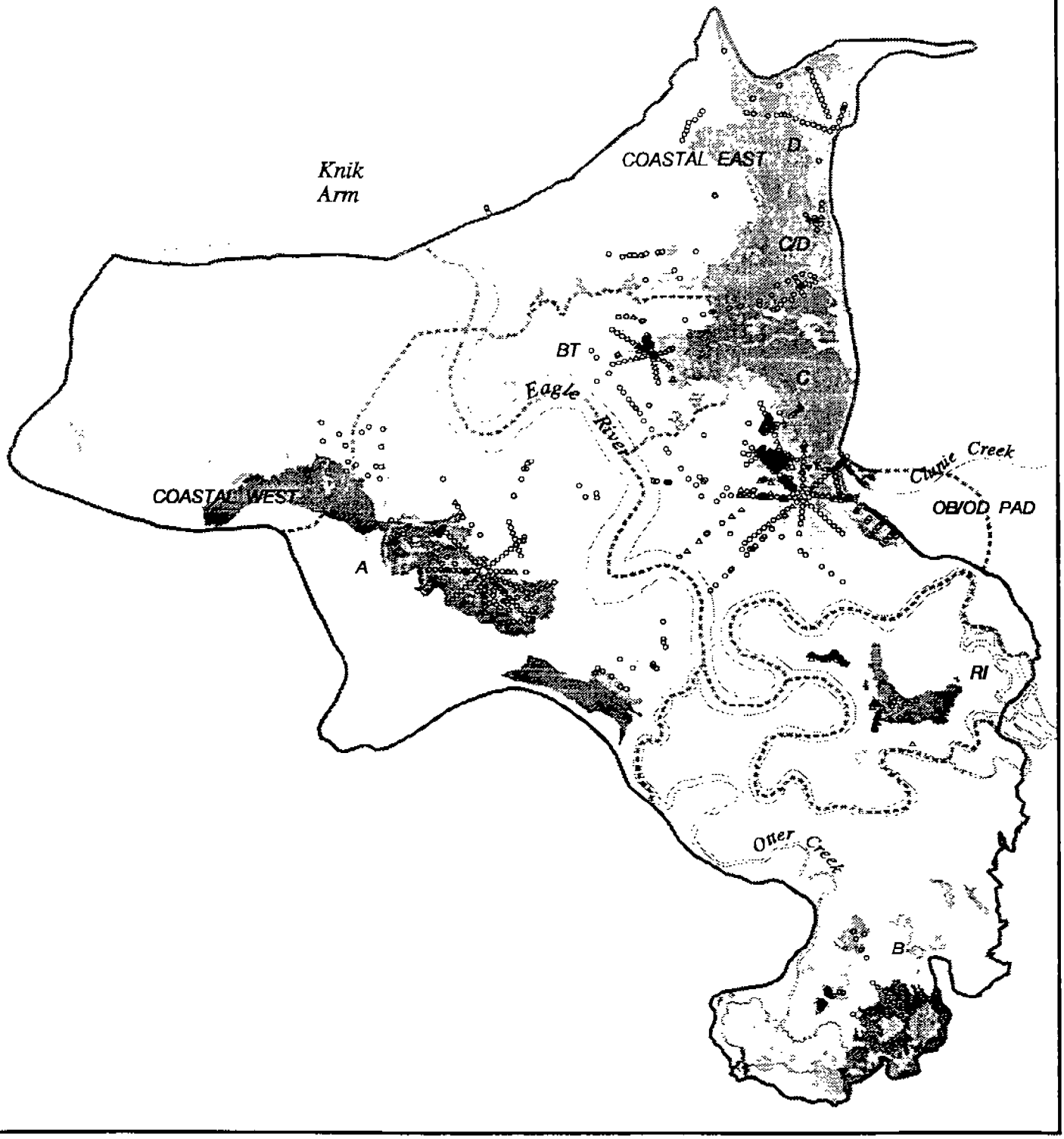


Figure 4-1

Surface Sediment Samples

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

Scale 1:24000
1 cm = 240 m

0 meters 720

Mapping and database source:
Racine et al., 1996.

White Phosphorus Concentration (ug/g)

- ○ 0 (n = 638)
- △ 0 - 1 (n = 348)
- ▼ 1 - 10 (n = 14)
- ● 10 - 100 (n = 12)
- ▲ > 100 (n = 7)

- Intermittent Pond
- Permanent Pond
- Sedge Marsh
- River/Creek
- Area Boundary
- OUC Site Boundary

CH2MHILL

January 22, 1997 AML: /proj2/arf/fig4-11.aml PLOT FILE: /proj2/arf/fig4-11.eps

TABLE 4-1
WP Concentrations in ERF Surface Sediment

Area	Number of Locations	Number of Positive Concentrations and (% of locations)	Maximum Concentration (µg/g)	Arithmetic Mean Concentration (µg/g)	Standard Deviation (µg/g)
A	195	26 (13)	0.06202	0.00131	0.00705
B	43	0 (0)	0	0	0
C	520	267 (51)	1100	3.49	49.5
C/D	42	4 (10)	0.0121	0.000457	0.00195
D	36	0 (0)	0	0	0
Bread Truck	85	38 (45)	33.7	0.685	3.90
Racine Island	62	45 (73)	3071	65.7	394
Coastal East	30	1 (3)	0.217	0.000725	0.00397
Coastal West	6	0 (0)	0	0	0
All ERF	1019	381 (37)	3071	5.84	104

TABLE 4-2
Categories of WP Concentration in ERF Surface Sediment

Area	Number of Locations	WP Concentration (µg/g)				
		Nondetect	DL < c ≤ 1	1 < c ≤ 10	10 < c ≤ 100	c > 100
A	195	169 (87%)	26 (13%)			
B	43	43 (100%)				
C	520	253 (49%)	246 (47%)	11 (2%)	7 (1%)	3 (1%)
C/D	42	38 (90%)	4 (10%)			
D	36	36 (100%)				
Bread Truck	85	47 (55%)	34 (40%)	2 (2%)	2 (2%)	
Racine Island	62	17 (27%)	37 (60%)	1 (2%)	3 (5%)	4 (6%)
Coastal East	30	29 (97%)	1 (3%)			
Coastal West	6	6 (100%)				
All ERF	1019	638 (63%)	348 (34%)	14 (1%)	12 (1%)	7 (1%)

Notes:
Values in parentheses are the percentage of locations in a concentration category within an area. Rows may not sum to 100 percent because values have been rounded off.
c = Concentration
DL = Detection limit

4.2.1 Area A

Area A contains many intermittent and permanent ponds (Figure 4-2). Total area of ponds is 24 ha. Most sampl ng has occurred in or near the main pond area in the center. Many other ponds have had no sampling. In addition, large areas of the sedge marsh also have not been sampled. A relatively large numbe: of carcasses have been observed in this area, and a high crater density is found north of the main ponds (Racine, in Racine *et al.*, 1994); however, crater density could not be determined immediately adjacent to the main ponds.

Area A contains many ponds, and a relatively large number of carcasses has been observed there. No sample had a WP concentration greater than 1 µg/g, and 87 percent of the samples had no detectable WP.

Of the 195 locations sampled, 87 percent had no detectable concentrations, and the remainder were below 1 µg/g. The maximum concentration was 0.06202 µg/g. Most locations with detectable concentrations are from the marsh southeast to south of the A tower (located at the intersection of the radial sampling transects); a few are in a pond to the northwest of the A tower. Possible explanations for the apparent contradiction between the relatively large number of carcasses and yet relatively small amounts of WP present include (1) waterfowl that die in Area A have traveled from other areas where they ingested the WP and (2) higher concentrations of WP are present in Area A, but have not been detected.

The maximum crater density in Area A is in the intermittent ponds. Before 1990, active firing of WP into the intermittent ponds provided an abundance of WP particles to dabbling waterfowl. These intermittent ponds probably dried somewhat in 1990 and 1992, and most certainly during summer 1993 when there was an extended period between flooding tides and fairly warm, dry weather. Significant loss of WP is believed to have occurred in summer 1993 in the intermittent ponds of Area A.

Eight cores were obtained from sites just south and east of the tower where surface sediment samples had previously detected WP. These cores were obtained to get an indication of whether WP existed in the subsurface, and therefore what might become exposed with erosion. Only two of the cores had detected WP at any depth, and it was only found in the top 10 cm. The sampling locations are shown in , Figure 4-3, which also identifies which cores had detectable WP in the subsurface.

Area A contains intermittent ponds and sedge marsh that have not been sampled.

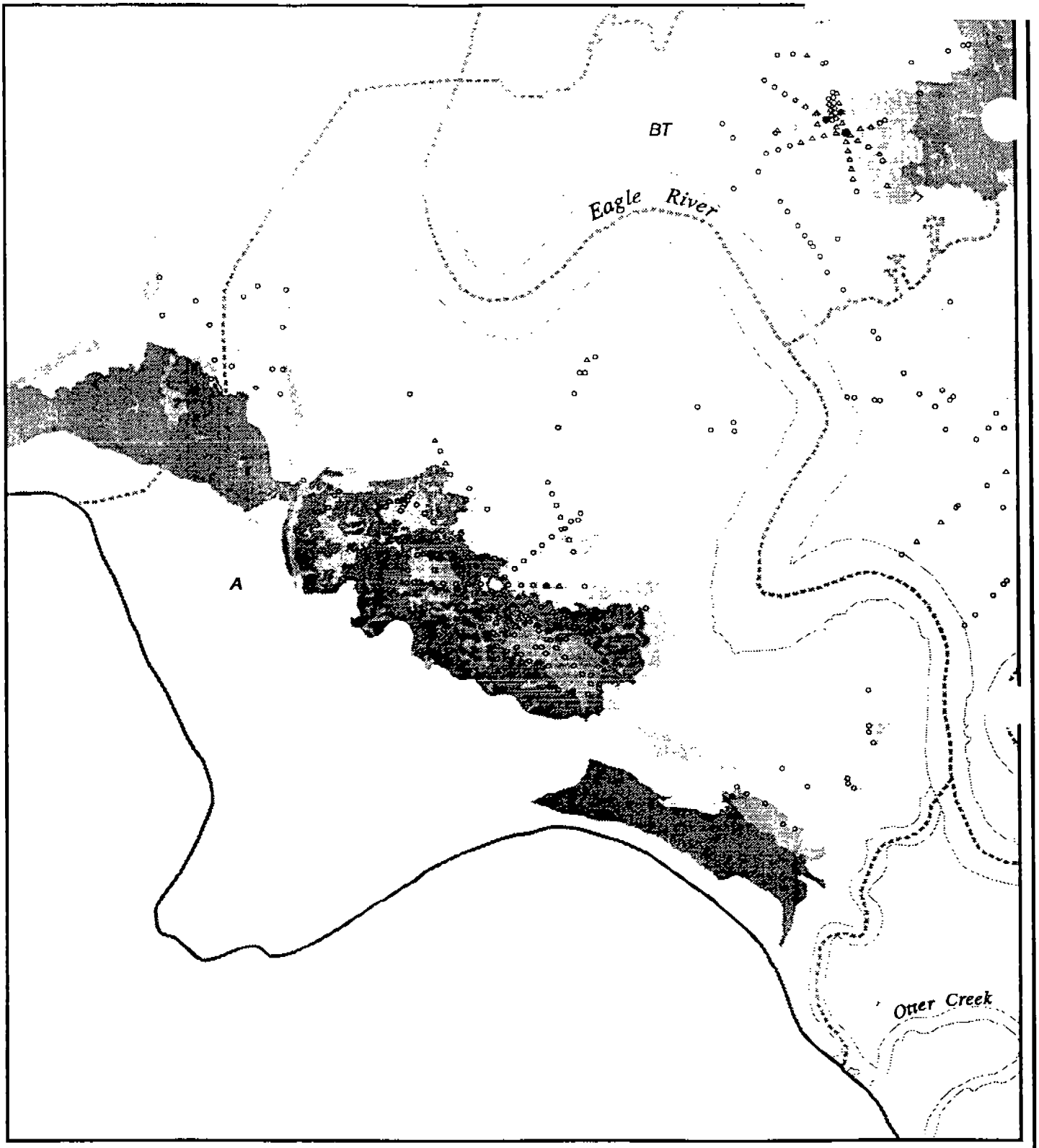


Figure 4-2

Surface Sediment Samples
Area A

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

Scale 1:11000
1 cm = 110 m

0 meters 330

Mapping and database source:
Racine et al., 1996.

White Phosphorus Concentration (ug/g)

○ 0	(n = 169)
△ 0 - 1	(n = 26)
▼ 1 - 10	(n = 0)
● 10 - 100	(n = 0)
▲ > 100	(n = 0)

Intermittent Pond
Permanent Pond
Sedge Marsh
River/Creek
Area Boundary
OUC Site Boundary



CH2MHILL

January 22, 1997 AML: /proj2/arf/fig.aml PLOT FILE: /proj2/arf/fig4-22.eps

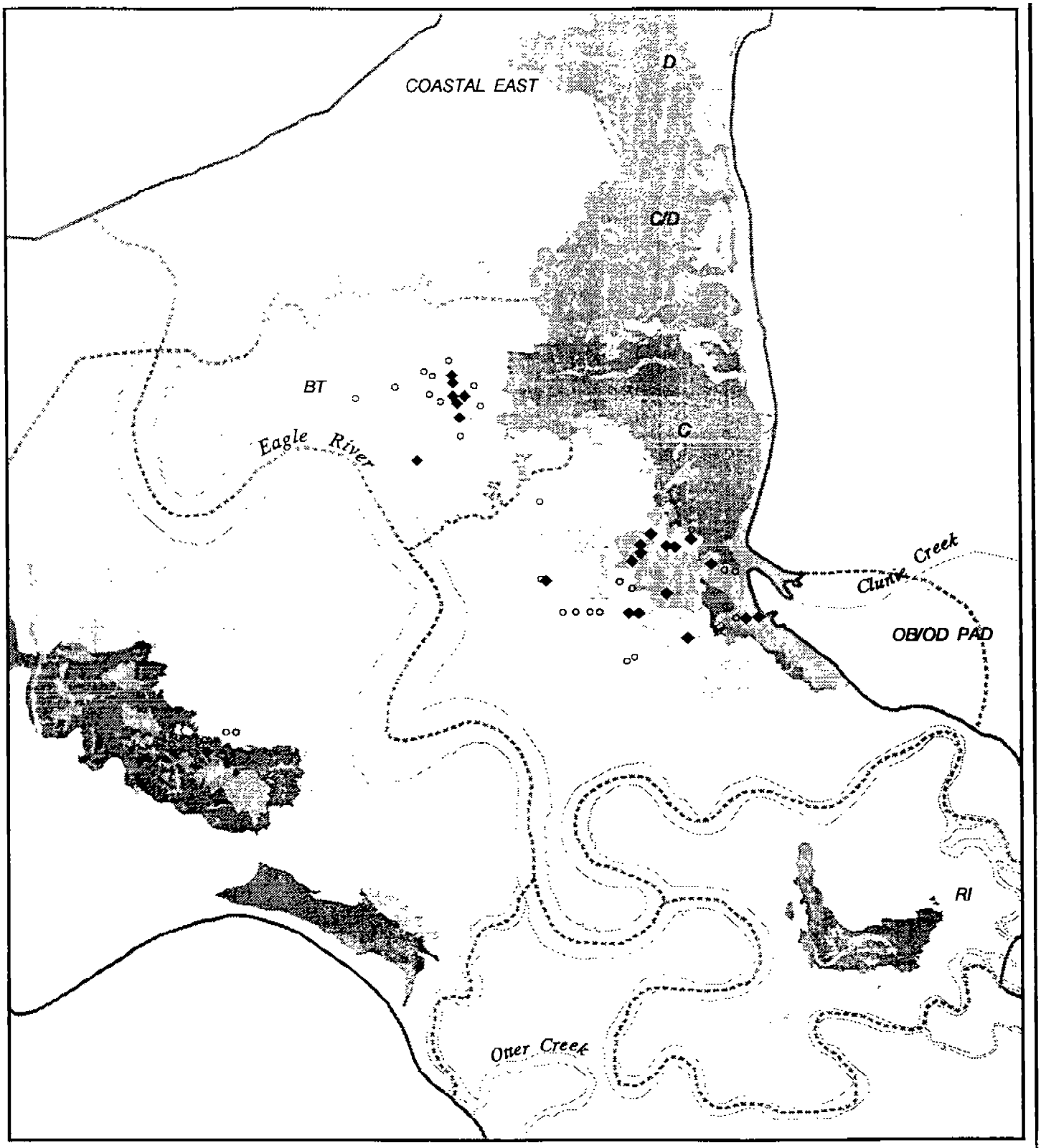


Figure 4-3

Cored Sediment Samples

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

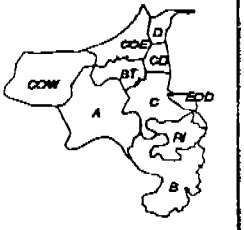
Scale 1:14400
1 cm = 144 m

0 meters 432

Mapping and database source:
Racine et al., 1996.

- Subsurface Sample No WP detection
- Subsurface Sample WP detection

- Intermittent Pond
- Permanent Pond
- Sedge Marsh
- River/Creek
- Area Boundary
- OUC Site Boundary



CH2MHILL

January 27, 1997 AML: /proj2/arf/fig.aml PLOT FILE: /proj2/arf/fig4-314.eps

4.2.2 Area B

Area B has no targets and no detectable concentrations of WP. Very few carcasses have been observed.

Area B has a total pond area of about 9 ha. No detectable concentrations of WP have been found in the 43 locations sampled in Area B (Figure 4-4). Although many areas of ponds and sedge marsh have not been sampled, there are no large targets in the area, the area does not have many craters, and very few carcasses have been observed since ERF investigations began in the early 1980s.

4.2.3 Area C

Area C has many ponds and locations with WP concentrations greater than 1 µg/g. WP also has been detected at depths up to 60 cm. Many carcasses have been observed over the surface.

Total pond area is 21 ha in Area C, where 520 locations have been sampled and 51 percent of the locations had detectable WP concentrations (Figure 4-5). Figure 4-6 provides an enlargement of the area with dense sampling. Total pond area of Area C is about 18 ha. The main permanent pond has received most of the sampling. The maximum concentration was 1,100 µg/g, and the average concentration across all locations was 3.49 µg/g. Three locations had concentrations greater than 100 µg/g. Most of the contamination is north and east of the tower (at the intersection of the radial sampling transects). Additional contaminated areas include an area of shallow water on the west edge of the main pond, areas with bulrush vegetation on the east edge of the pond, the Clunie Creek region, and a small bulrush pond on the north side of Area C. Area C also is characterized by high crater density and persistently high levels of mortality.

The main pond in Area C was sampled at depth during 1991-1992. In thirty-five locations (shown in Figure 4-3) core samples were taken (31 in ponds, 2 in marsh, 1 in a mud flat, and 1 in a gully). Twelve cores detected WP in the surface (maximum concentration of 1,566 µg/g); 15 detected WP in the 5- to 10-cm depth (maximum concentration of 198 µg/g); 9 detected WP in the 10- to 20-cm depth (maximum concentration of 18.5 µg/g); and 5 detected WP in the 20- to 30-cm depth (maximum concentration of 0.869 µg/g). At the lower depths, there were one detection at 30 to 40 cm (0.561 µg/g), two detections at 40 to 50 cm (maximum concentration of 0.891 µg/g), and one at 50 to 60 cm (0.00216 µg/g). The large area of the sedge marsh has received little sampling. In 1996, some post-dredging sampling was performed in Area C.

4.2.4 Area C/D

Area C/D has 90 percent of the sampled locations with no detectable WP concentrations and no concentration over 1 µg/g. Many carcasses have been observed.

Total pond area is 4.7 ha in Area C/D, where 42 locations have been sampled, and 90 percent of the locations had no detectable WP (Figure 4-7). The four locations with detectable concentrations were all below 1 µg/g, and were located in ponds in the middle and northern sections of the area.

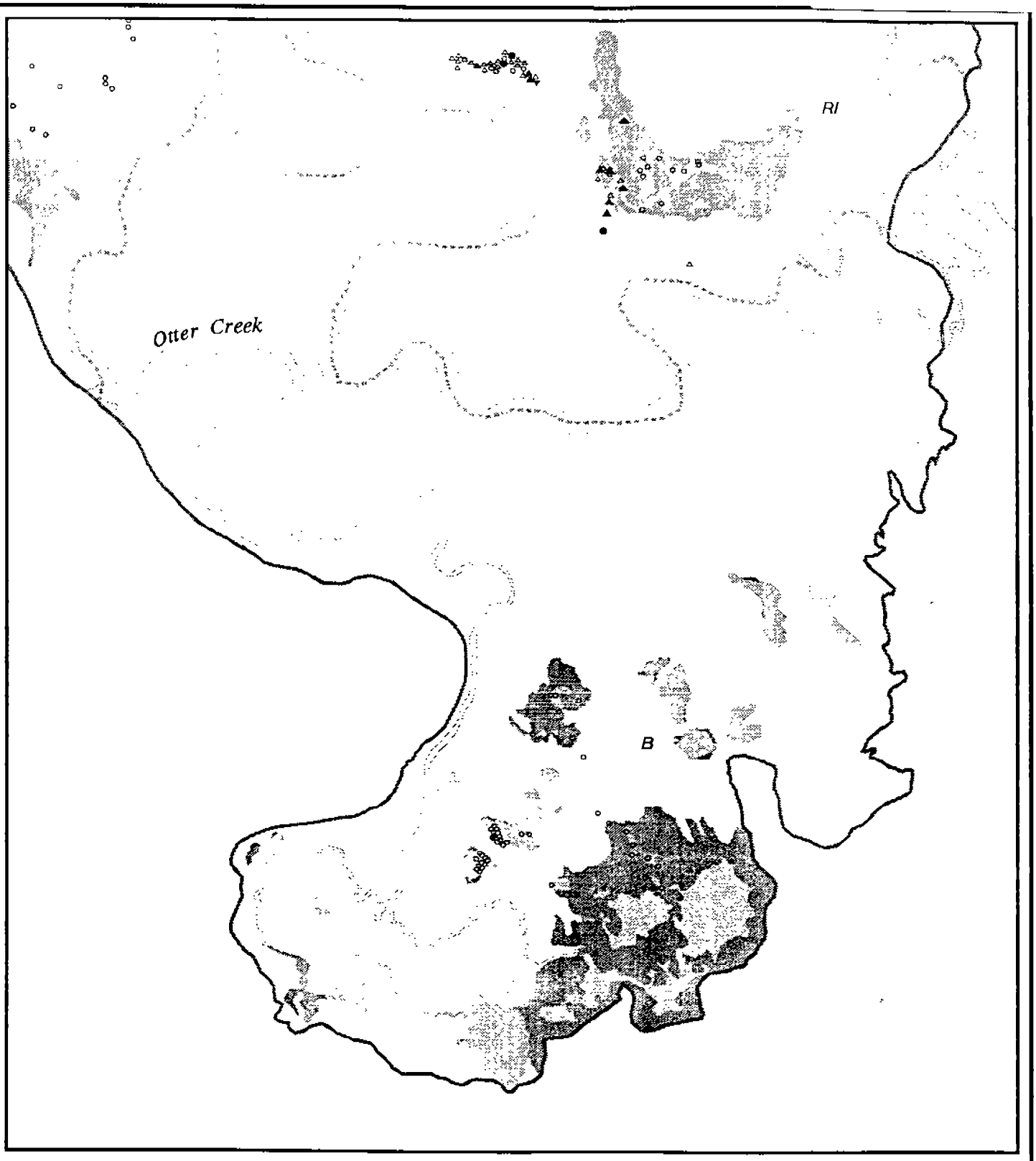


Figure 4-4

Surface Sediment Samples
Area B

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

Scale 1:10000
1 cm = 100 m

0 meters 300

Mapping and database source:
Racine et al., 1996.

White Phosphorus Concentration (ug/g)

▫ 0	(n = 43)
△ 0 - 1	(n = 0)
▼ 1 - 10	(n = 0)
● 10 - 100	(n = 0)
▲ > 100	(n = 0)

Intermittent Pond
Permanent Pond
Sedge Marsh
River/Creek
Area Boundary
OUC Site Boundary



CH2MHILL

January 22, 1997 AML: /proj2/arf/fig.aml PLOT FILE: /proj2/arf/fig4-43.eps

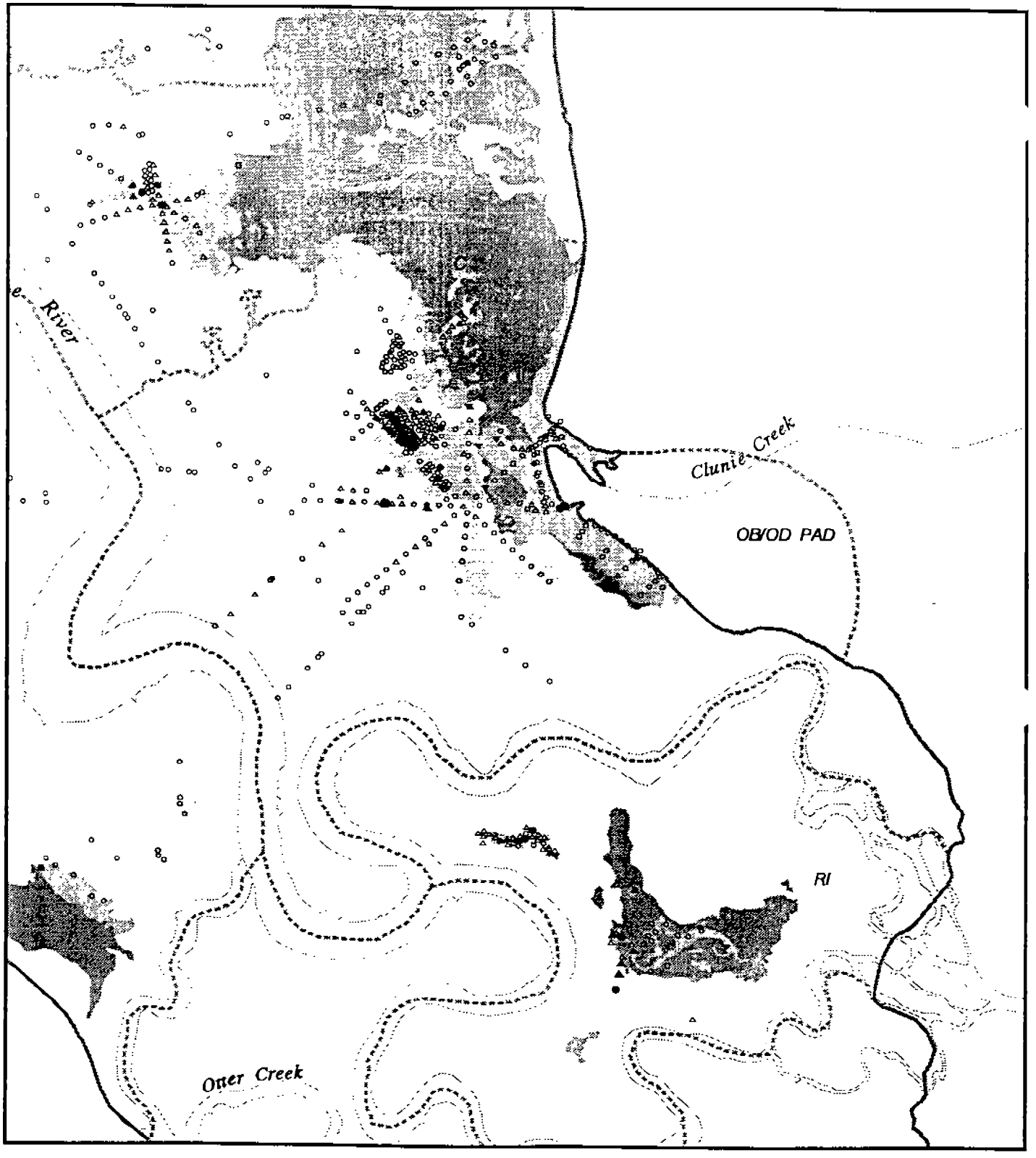


Figure 4-5

Surface Sediment Samples
Area C

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

Scale 1:11000
1 cm = 110 m

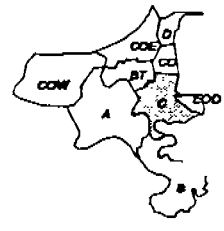
0 meters 330

Mapping and database source:
Racine et al., 1996.

White Phosphorus Concentration (ug/g)

○ 0	(n = 253)
△ 0 - 1	(n = 246)
▼ 1 - 10	(n = 11)
● 10 - 100	(n = 7)
▲ > 100	(n = 3)

Intermittent Pond
Permanent Pond
Sedge Marsh
River/Creek
Area Boundary
OUC Site Boundary



CH2MHILL

January 22, 1997 AML: /proj2/arf/fig arnl PLOT FILE: /proj2/arf/fig4-54.eps

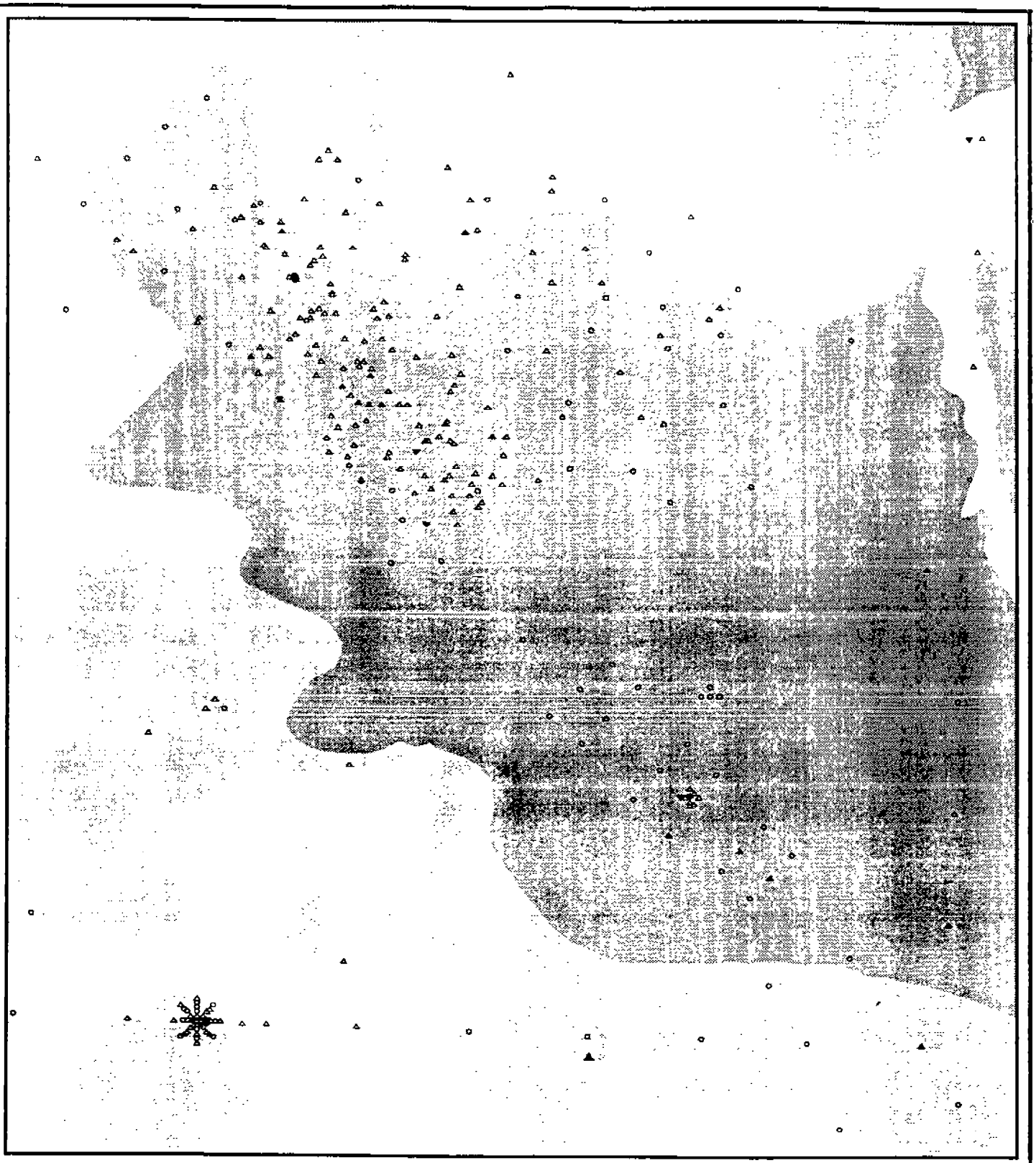


Figure 4-6

Surface Sediment Samples
Part of Area C

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

Scale 1:1200
1 cm = 12 m

0 meters 36

Mapping and database source:
Racine et al., 1996.

White Phosphorus Concentration (ug/g)

○ 0	(n = 81)
△ 0 - 1	(n = 204)
▼ 1 - 10	(n = 8)
● 10 - 100	(n = 4)
▲ > 100	(n = 2)

Intermittent Pond
Permanent Pond
Sedge Marsh
River/Creek
Area Boundary
OUC Site Boundary

BT
EOD
R

CH2MHILL

January 22, 1997 AML: /proj2/arlrifft/g.aml PLOT FILE: /proj2/arlrifft/g4-613.eps

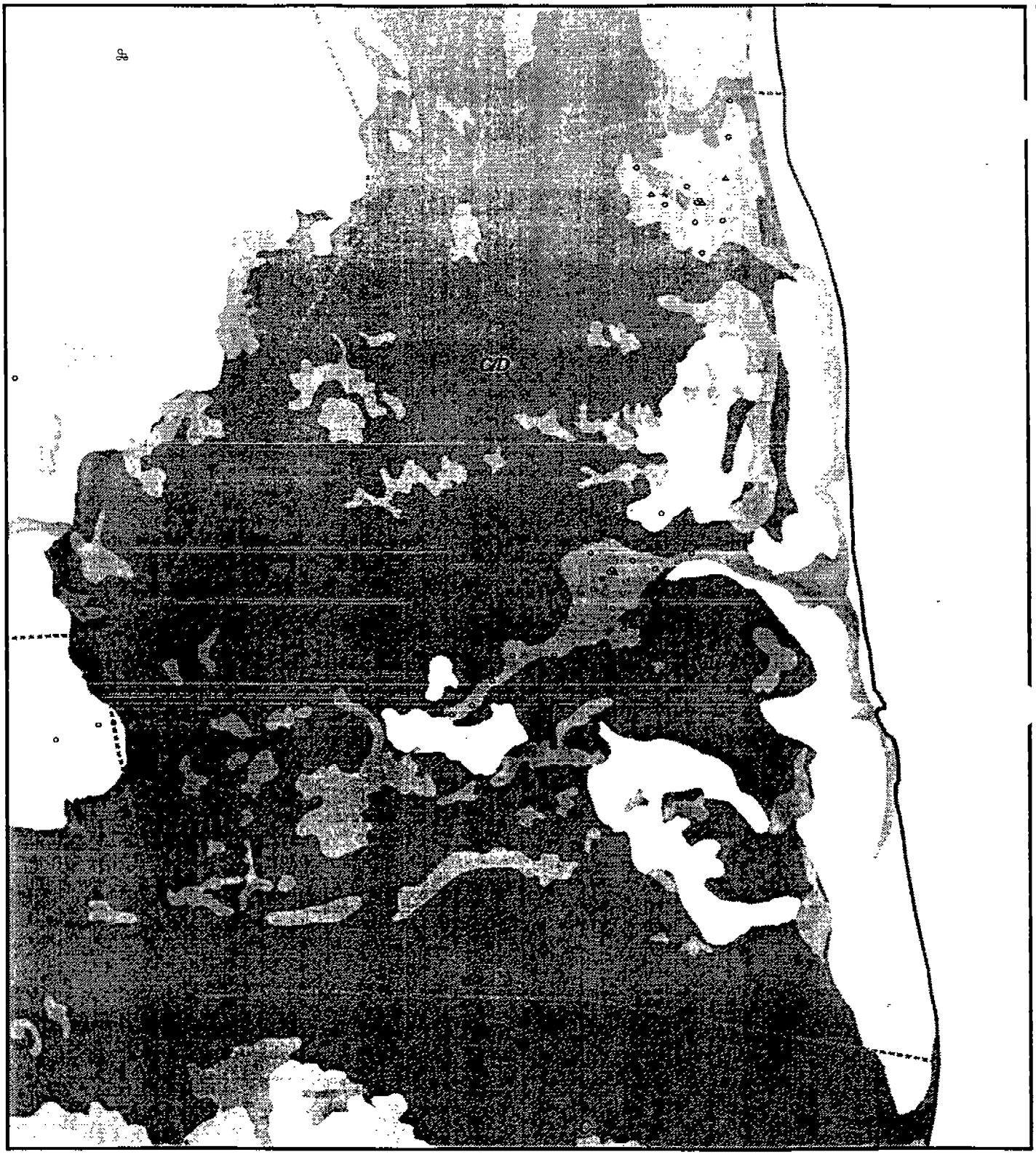


Figure 4-7

Surface Sediment Samples
Area C/D

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

January 29, 1997 AML: /proj2/arl/fig.aml PLOT FILE: /proj2/arl/fig4-7d.eps

Area D has had no detectable WP concentrations. Very few carcasses have been observed.

Sampling was conducted in Area C/D because of its proximity to other areas where WP has been observed and because a large number of carcasses have been found in this area. Only a few of these samples, however, have been taken in the sedge marsh that covers a significant portion of the area. Area conditions generally have precluded observing any craters in the aerial photograph, but a region of low crater density is found just to the west of Area C/D (Racine, in Racine *et al.*, 1994).

4.2.5 Area D

Area D contains about 11 ha of ponds. In this area, 36 locations have been sampled, and all had no detectable concentrations (Figure 4-8). Only a few samples have been taken in the sedge marsh. There are few craters in the area (Racine, in Racine *et al.*, 1994). As with Area B, very few carcasses have been found in this area.

4.2.6 Bread Truck

Bread Truck contains one main pond and a few smaller ones. WP concentrations above 1 µg/g have been detected and many carcasses have been observed.

Total pond area is 11 ha at the Bread Truck area, which contains one large pond (about 6.5 ha) and a few smaller ponds to the north (Figure 4-9). Several target vehicles are located in the area. Eighty-five locations have been sampled, and 45 percent of them had detectable WP concentrations, including two locations with concentrations between 10 and 100 µg/g. The main region of contamination and the highest WP concentrations are near the center of the large pond. The sedge marsh on the east side has not been sampled, however. As with Area C, this area is characterized by persistently high mortality and high crater density.

Seventeen core samples (14 pond and 3 gully) also were obtained, and six had nondetect concentrations of WP at all depths. The sampling locations are shown in Figure 4-3. Detected concentrations of cores were six down to 10 cm or less (as high as 7.7 µg/g at the surface and 0.847 µg/g in the 5- to 10-cm core), four down to 20 cm (up to 0.194 µg/g), and one in the 20- to 30-cm sample (1.16 µg/g).

Several samples on Racine Island had concentrations exceeding 1 µg/g. Numerous carcasses have been observed.

4.2.7 Racine Island

Total pond area is 1.4 ha on Racine Island, where 62 locations have been sampled and 63 percent have detectable WP concentrations (Figure 4-10). The pond in the middle of Racine Island has the highest detected WP concentration, 3071 µg/g, of all samples collected at ERF. Four locations had concentrations greater than 100 µg/g. These measurements contribute to the high average concentration, 65.7 µg/g, for the area. The samples with detected concentrations are on the west side of the area. Samples with nondetected concentrations were all on the east side. A target is located in this region, and some areas of the sedge marsh have not been sampled. Craters were

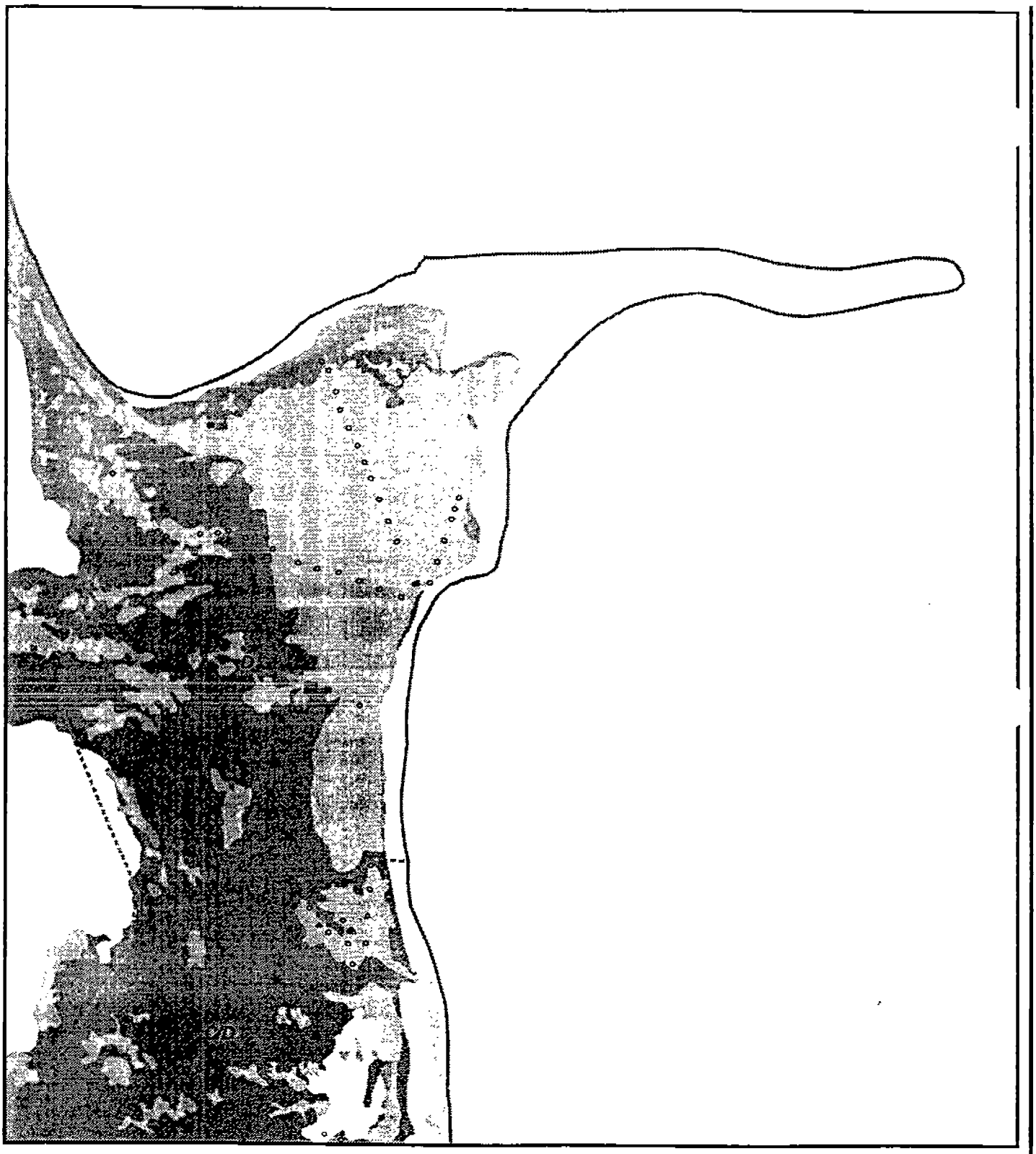


Figure 4-8

Surface Sediment Samples
Area D

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

N

Scale 1:6000
1 cm = 60 m

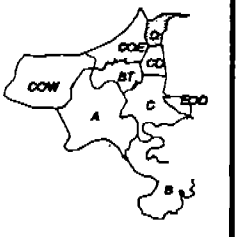
0 meters 180

Mapping and database source:
Racine et al., 1996.

White Phosphorus Concentration (ug/g)

○ 0	(n = 36)
△ 0 - 1	(n = 0)
▼ 1 - 10	(n = 0)
● 10 - 100	(n = 0)
▲ > 100	(n = 0)

Intermittent Pond
Permanent Pond
Sedge Marsh
River/Creek
Area Boundary
OUC Site Boundary



CH2MHILL

January 22, 1997 AML: fprg2\erfifig.aml PLOT FILE: fprg2\erfifig4-8S.eps

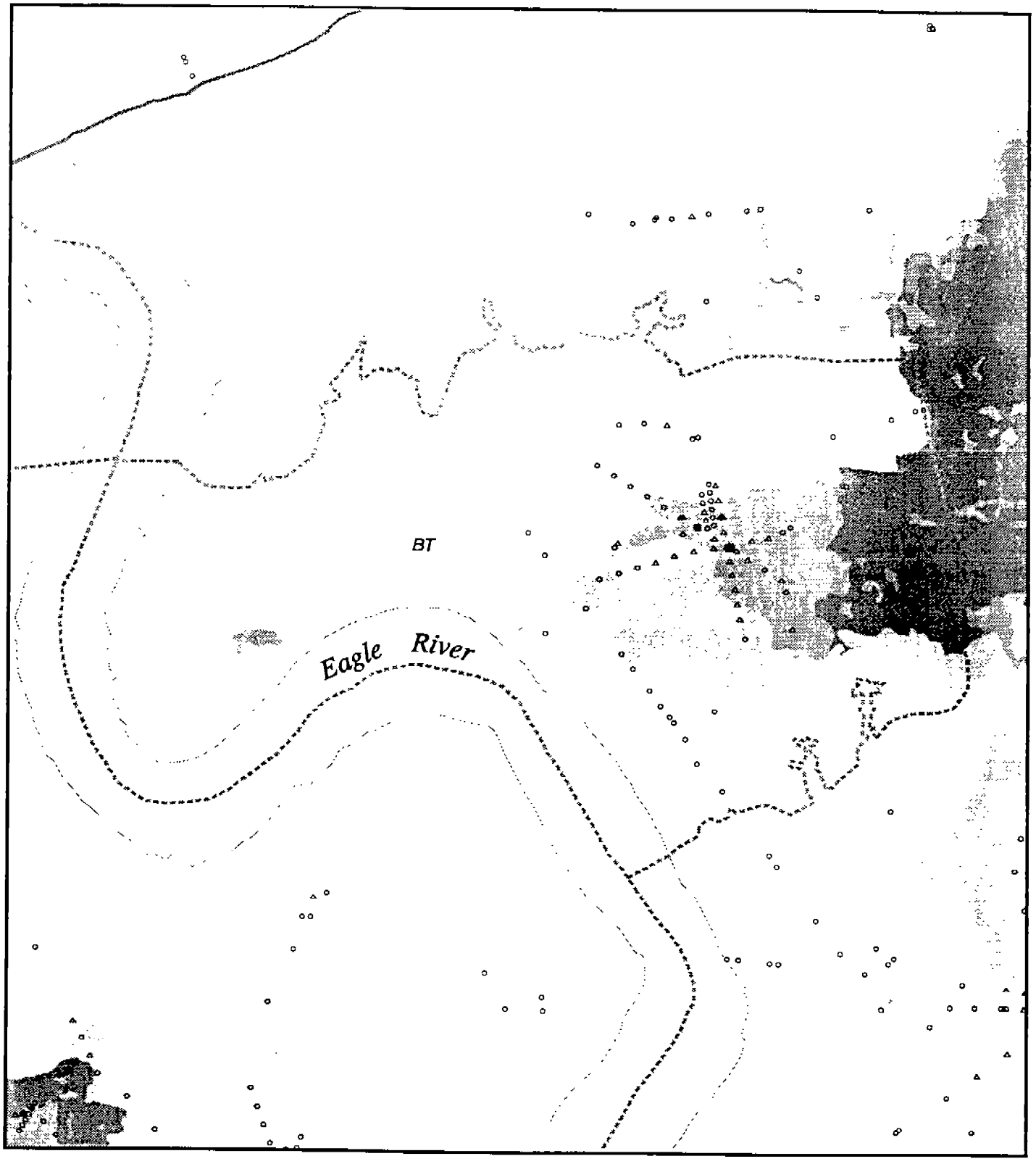


Figure 4-9

Surface Sediment Samples

Bread Truck Area

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

Scale 1:7000
1 cm = 70 m

0 meters 210

Mapping and database source:
Racine et al., 1996.

White Phosphorus Concentration (ug/g)

○ 0	(n = 47)
△ 0 - 1	(n = 34)
▼ 1 - 10	(n = 2)
● 10 - 100	(n = 2)
▲ > 100	(n = 0)

Intermittent Pond
Permanent Pond
Sedge Marsh
River/Creek
Area Boundary
OUC Site Boundary



CH2MHILL

January 22, 1997 AML: /proj2/arfirlfg.aml PLOT FILE: /proj2/arfirlfg4-98.eps

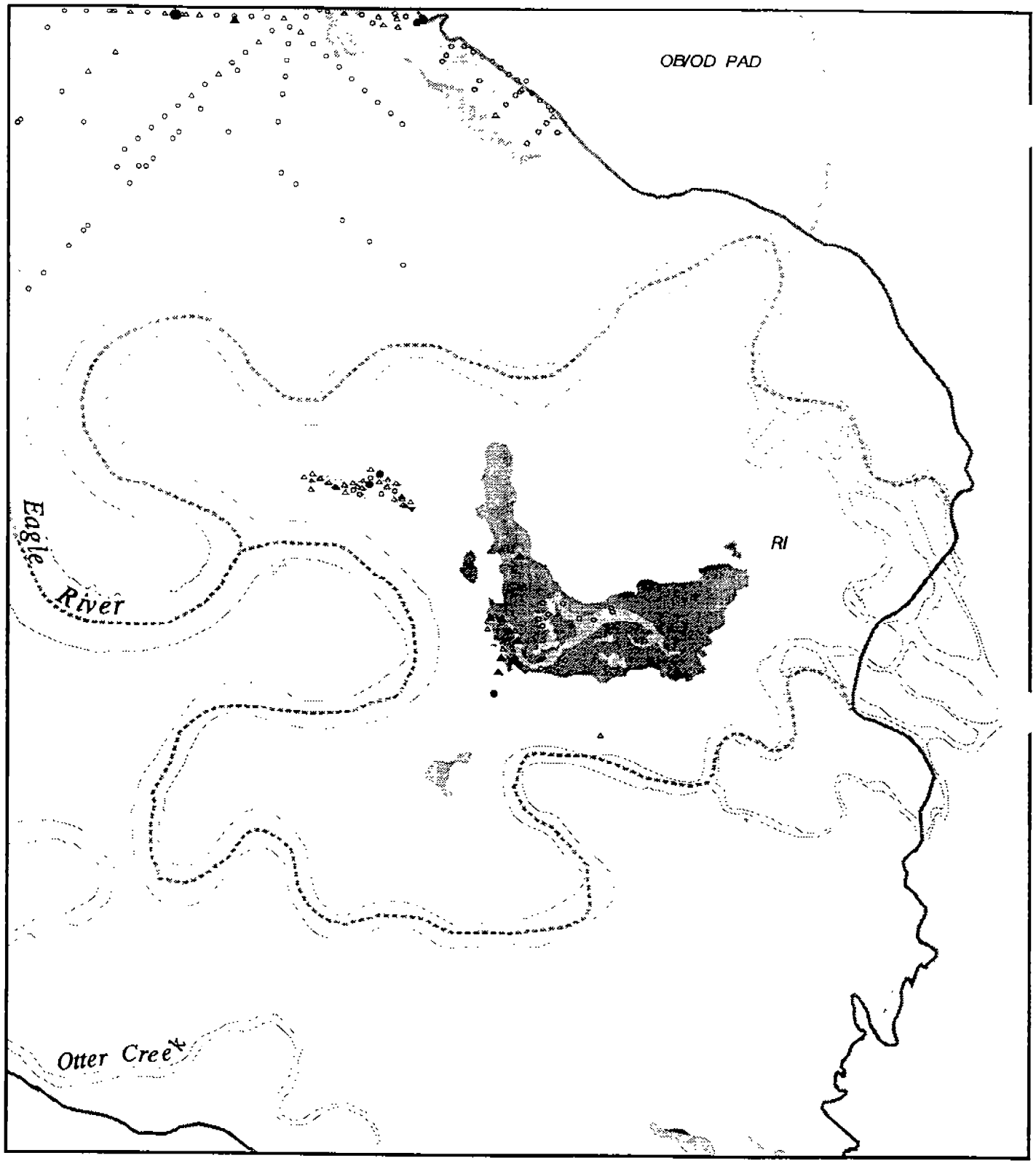


Figure 4-10

Surface Sediment Samples

Racine Island Area

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

Scale 1:8000
1 cm = 80 m

0 meters 240

Mapping and database source:
Racine et al., 1996.

White Phosphorus Concentration (ug/g)

○ 0	(n = 17)
△ 0 - 1	(n = 37)
▼ 1 - 10	(n = 1)
● 10 - 100	(n = 3)
▲ > 100	(n = 4)

Intermittent Pond
Permanent Pond
Sedge Marsh
River/Creek
Area Boundary
OUC Site Boundary



CH2MHILL

January 22, 1997 AML: /proj2/arcfl/rifig.aml PLOT FILE: /proj2/arcfl/fig4-1010.eps

observed on the northeast and southwest portions of Racine Island, and numerous carcasses have been observed on Racine Island.

In the coastal areas, 97 percent of the samples had no detectable concentrations. Few carcasses have been observed.

4.2.8 Coastal East and West

The coastal areas contain a few ponds, and total pond area is 27 ha. Thirty-six locations have been sampled (Figures 4-11 and 4-12). Only one sample had a detectable concentration, which was less than 0.217 µg/g. Craters are well distributed and very few carcasses have been observed in the coastal east and west areas.

4.2.9 Sampling Results by Landcover

Table 4-3 summarizes the WP concentrations by landcover. Only five landcovers contain locations where WP concentrations exceeded 1 µg/g: permanent ponds, intermittent ponds, sedge marsh, interior sedge meadow, and Ramenski's sedge meadow. Locations in only the first four landcovers have exceeded 10 µg/g in concentration.

TABLE 4-3
White Phosphorus Concentrations by Landcover

	White Phosphorus Concentration (µg/g)				
Landcover	**Nondetect**	**DL < c ≤ 1**	**1 < c ≤10**	**10 < c ≤ 100**	**c > 100**
Gully	1 (50%)	1 (50%)			
Halophytic herb meadow	53 (95%)	3 (5%)			
Interior sedge meadow	5 (42%)	4 (3%)		2 (17%)	1 (8%)
Intermittent ponds	147 (71%)	55 (26%)	2 (1%)	2 (1%)	2 (1%)
Levee grass meadow	2 (100%)				
Marine algae	2 (100%)				
Mud flat barrens	8 (73%)	3 (27%)			
Permanent ponds	273 (51%)	243 (46%)	10 (2%)	6 (1%)	2 (0.4%)
Ramenski's sedge meadow	38 (76%)	11 (22%)	1 (2%)		
River	2 (100%)				
River meander scars	1 (100%)				
Sedge bog	1 (100%)				
Sedge marsh	87 (78%)	21 (19%)	1 (1%)		1 (1%)
Wet swale	9 (60%)	6 (40%)			
Unclassified[a]	9 (75%)	1 (8%)		2 (17%)	

[a]Present because of small errors in the landcover and WP coverages.

Notes:
Values in parentheses are the percentage of locations in a concentration category within a landcover. Rows may not sum to 100 percent because values have been rounded off
c = Concentrations
DL = Detection limit

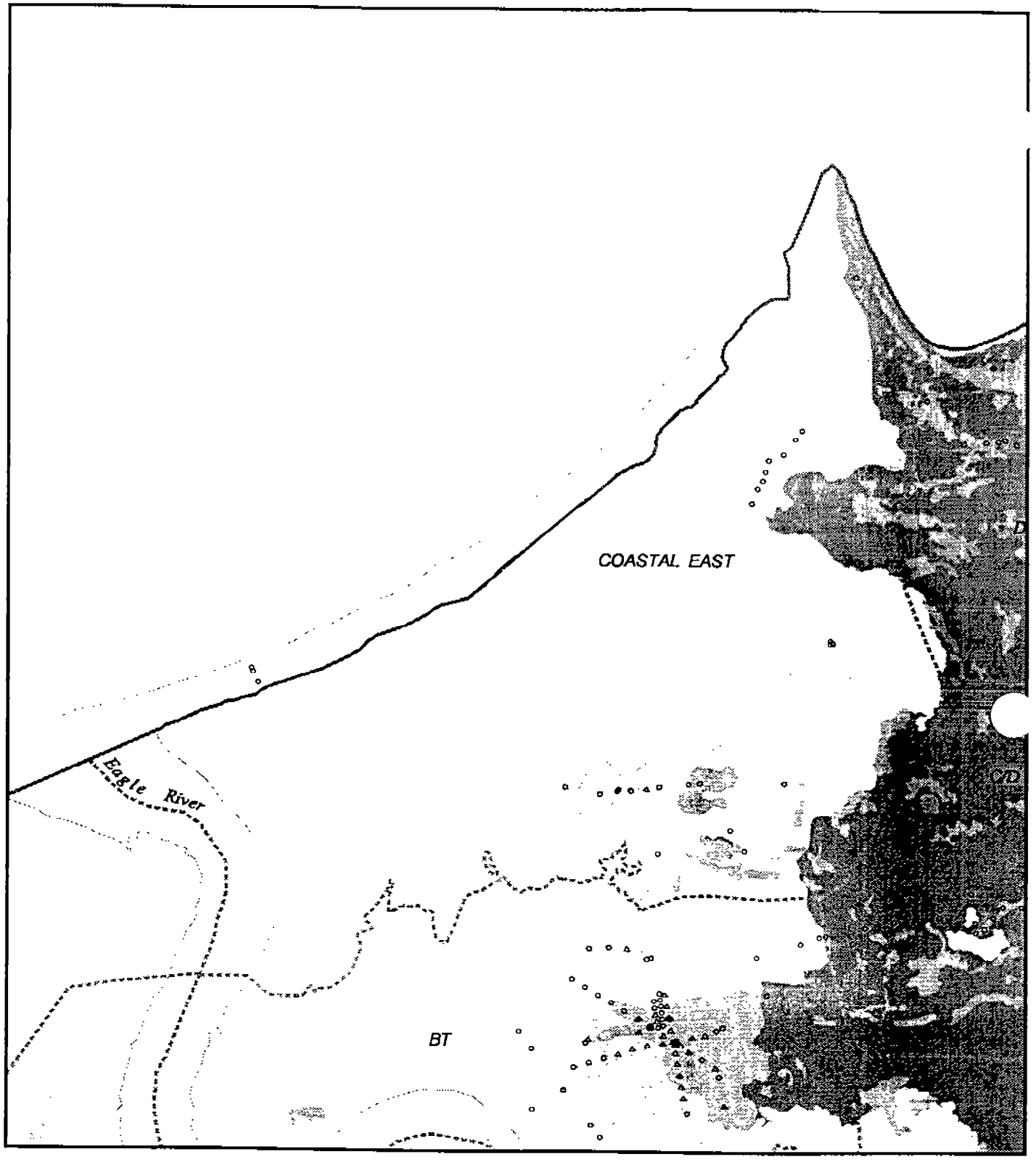


Figure 4-11

Surface Sediment Samples
Coastal East Area

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

January 22, 1997 AML: /proj2/ert/fig/ PLOT FILE: /proj2/ert/fig4-11ß.eps

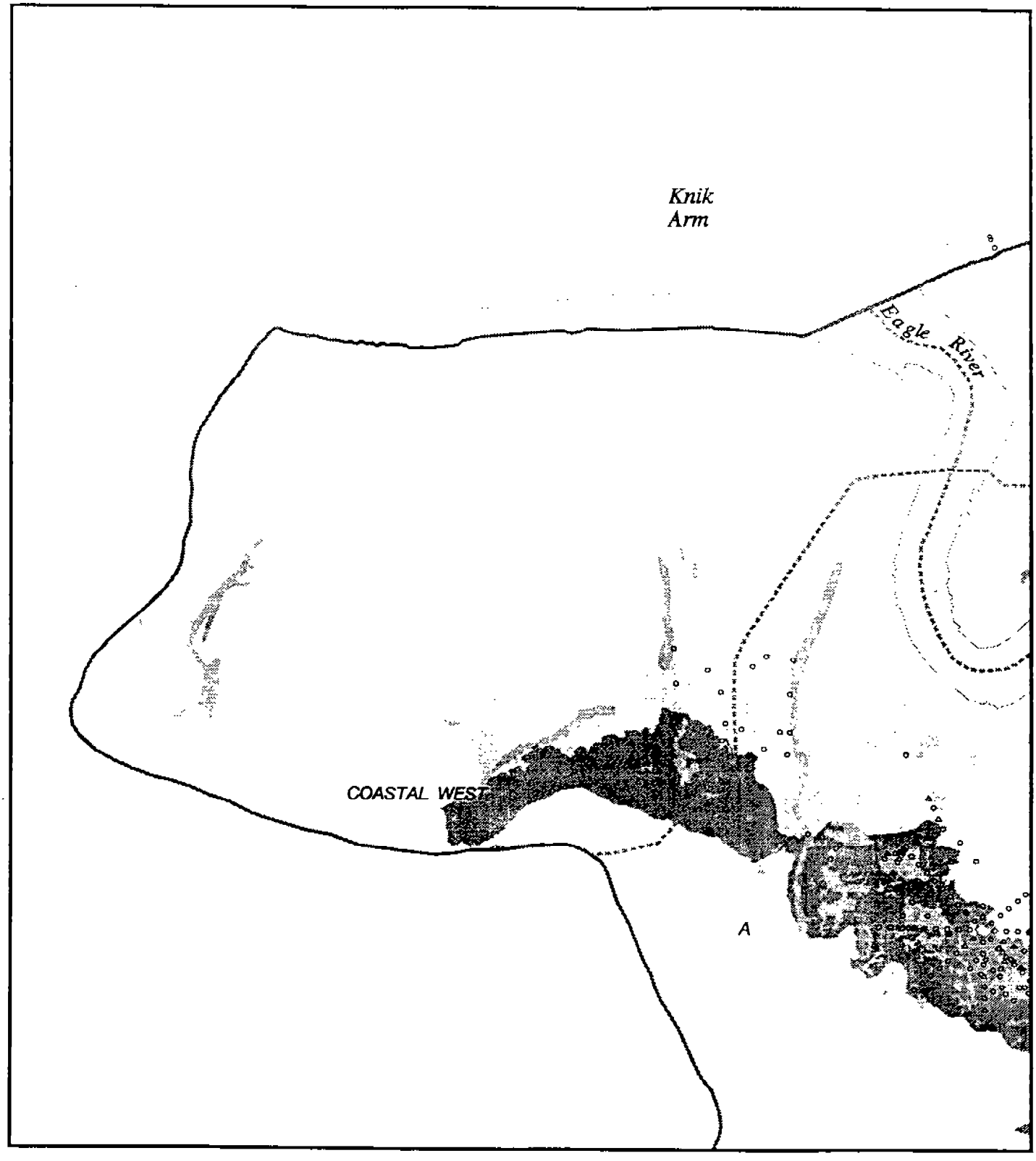


Figure 4-12

Surface Sediment Samples
Coastal West Area

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

Scale 1:12000
1 cm = 120 m

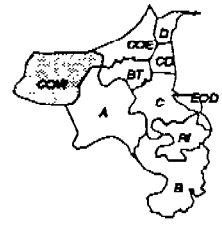
0 meters 360

Mapping and database source:
Racine et al., 1996.

White Phosphorus Concentration (ug/g)

○ 0	(n = 6)
△ 0 - 1	(n = 0)
▼ 1 - 10	(n = 0)
● 10 - 100	(n = 0)
▲ > 100	(n = 0)

Intermittent Pond
Permanent Pond
Sedge Marsh
River/Creek
Area Boundary
OUC Site Boundary



CH2MHILL

January 22, 1997 AML: /proj2/ar/fig4.aml PLOT FILE: /proj2/ar/fig4-127.eps

The landcovers have not received the same sampling frequency. Intermittent ponds and sedge marsh have much lower frequencies compared to permanent ponds.

The sampling frequency per hectare is quite variable across the landcovers, even within the same ERF area. For example, in Area A, the frequencies were 8.2, 1.9, and 3.1 sampled locations per hectare for permanent ponds, intermittent ponds, and sedge marsh, respectively. These three landcover types were chosen for this example because of their high duck usage, as discussed in Section 8. In Area C, the frequencies of sampling locations for surface sediment were 29, 12, and 0.63 sampled locations per hectare for permanent ponds, intermittent ponds, and sedge marsh, respectively. Over the entire ERF, the frequency was 10, 3.3, and 1.2 sampled locations per hectare for permanent ponds, intermittent ponds, and sedge marsh, respectively. In general, then, sedge marsh and intermittent ponds have not had the sampling intensity of permanent ponds.

4.2.10 WP Concentrations Changes with Time

Two sites in the intermittent ponds of Area C have been examined for several years to assess the potential for natural attenuation of WP concentrations at ERF: Site 883 and Miller's Hole. In 1992, Site 883 was found to have very high WP concentrations (greater than 200 µg/g). Sediments were desaturated during the summers of 1993 and 1994. The sediment samples in 1994 had a moisture content that ranged from 40 to 46 percent (dry weight). During 1995, the sediments were continually under water, but the tides were a source of new, presumably uncontaminated sediment.

In two small areas, WP sampling over several years has demonstrated a substantial decline in concentration.

Site 883 was sampled with the same radial pattern of 41 samples in 1992, 1994, and 1995. The number of samples exceeding 10 µg/g declined from 4 to 1 to zero during the three periods. The number of samples with concentrations less than 0.001 µg/g increased from 15 to 25 to 28 during the three periods. In 1992, when 270 mL of sediment were sieved, 100 WP particles were isolated. In 1995, only 1 WP particle was detected in 1,000 mL of sieved sediment (Walsh *et al.*, in Racine *et al.*, 1996).

Miller's Hole was created on May 20, 1992, when an 81mm mortar round containing WP was exploded for safety reasons. The center of the crater is 32 cm below the rim, and therefore is typically saturated with water while sediment along the rim periodically dries out. The center had initial WP concentrations exceeding 2,000 µg/g. In 1994, the samples of the center had concentrations of 9.5 and 49.5 µg/g. The rim of the crater started at nearly 1,000 µg/g in 1992, and had declined to 0.0006 µg/g when sampled in June 1995 (Walsh *et al.*, in Racine *et al.*, 1996). It appears that at the beginning of each summer, the WP concentrations on the rim temporarily increase, perhaps because of local mixing with materials. The concentrations decline over the summer (Walsh and Collins, in Racine *et al.*, 1995).

4.3 White Phosphorus in Water

4.3.1 Ponds

WP was detected in the water above contaminated sediments. In craters where water flow was restricted (Site 110 and Miller's Hole) or WP was very high in the sediment (concentrations greater than 2,000 µg/g), water concentrations were around 7 µg/L. In open water areas over undisturbed sediments (WP concentration of about 1 µg/g), the WP concentrations in water were only 0.01 µg/L. Disturbance of the contaminated sediments increased the concentration to greater than 1 µg/L. Filtered samples usually had lower concentrations. The interpretation of filtered samples as representing dissolved WP, however, was complicated by the turbulence of the filtering, which may have caused volatilization from the samples. Because of the dilution effect of the flooding tides, water concentrations away from localized hot spots likely is insignificant. Indeed, no WP was detected in water over uncontaminated sediment, even though the ponds had other areas of localized high concentrations of WP (Walsh, in Racine *et al.*, 1994).

4.3.2 Gullies

Plankton net samples in the water of four gullies obtained sediment with detectable WP concentrations (typically less than 0.01 µg/g, but as high as 0.9 µg/g) in 1995 when the tide reached about 5.1 m (Lawson *et al.*, in Racine *et al.*, 1996). Sampling locations are shown in Figure 4-13. A few sediment samples from the net also had detected quantities of WP in 1994. These results indicate that WP-contaminated sediment is being transported in the sediment through the gullies by the water. Sampling of the water itself, however, has never found detectable WP.

White phosphorus has been observed at low concentrations in the pond water, but has not been detected in Eagle River.

4.3.3 River

The surface sampling locations in Eagle River are shown in Figure 4-14. The 12 sediment and 14 water samples had nondetectable concentrations of WP.

4.4 Other Chemicals in Sediment and Water

Sampling and analyses of water and sediment in ERF for chemicals other than WP have been summarized previously (CH2M HILL, 1994). Appendix C provides further details on these studies.

A total of 235 sediment samples were taken in 1989 and 1990. Munition compounds were detected in sediments in Area C adjacent to OB/OD Pad. Sixty-two samples contained detectable 2,4-DNT. In most samples containing greater than 1 µg/g of 2,4-DNT, 2,6-DNT

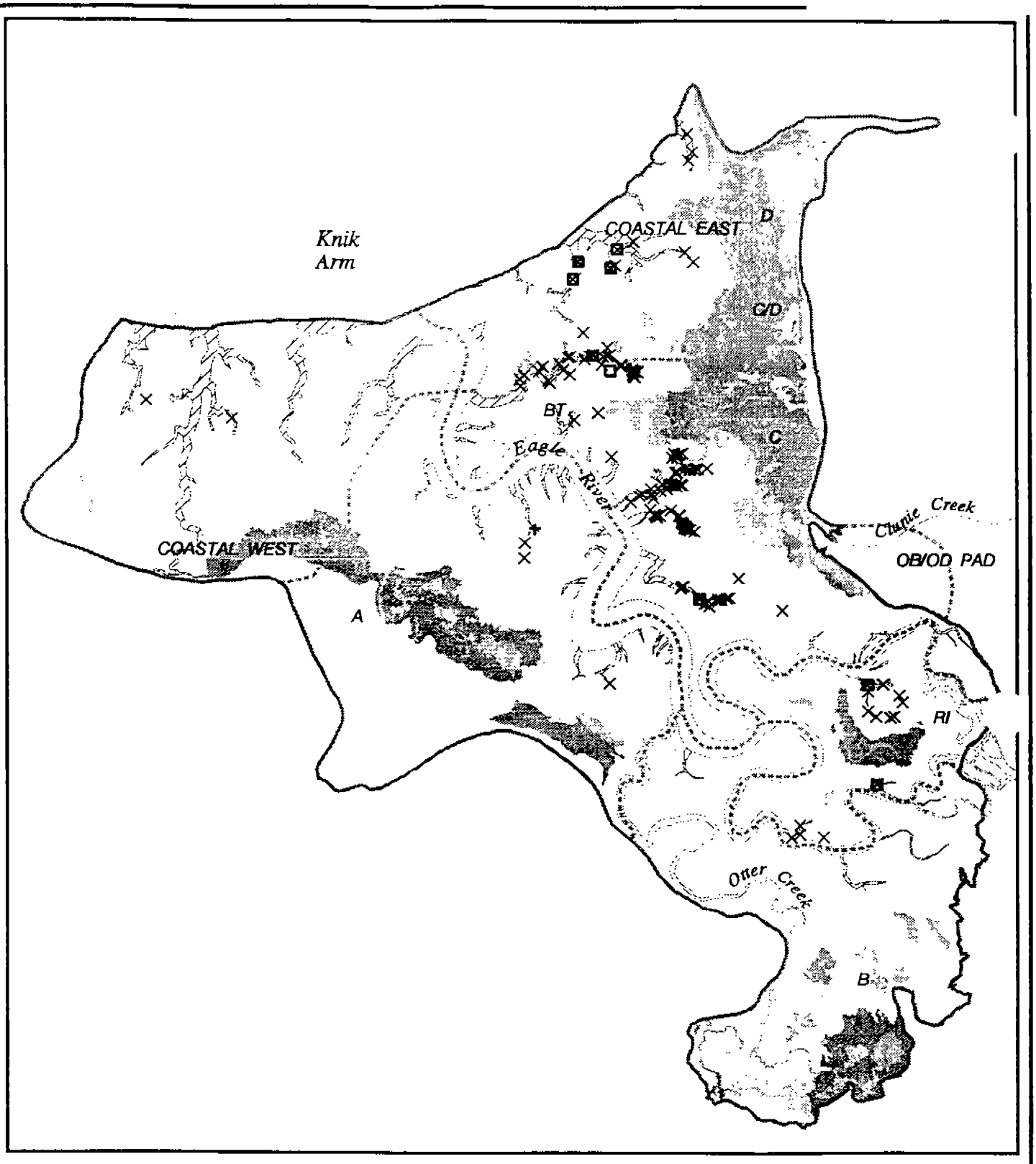


Figure 4-13

Gully Samples

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

N

Scale 1:24000
1 cm = 240 m

0 meters 720

Mapping and database source:
Racine et al., 1996.

Selected White Phosphorus Samples
- + Water Column Sediment
- × Surface and Cored Sediment
- □ Water

Intermittent Pond
Permanent Pond
Sedge Marsh
Gully
Area Boundary
OUC Site Boundary

CH2MHILL

January 22, 1997 AML: /proj2/arf/fig4.aml PLOT FILE: /proj2/arf/fig4-131.eps

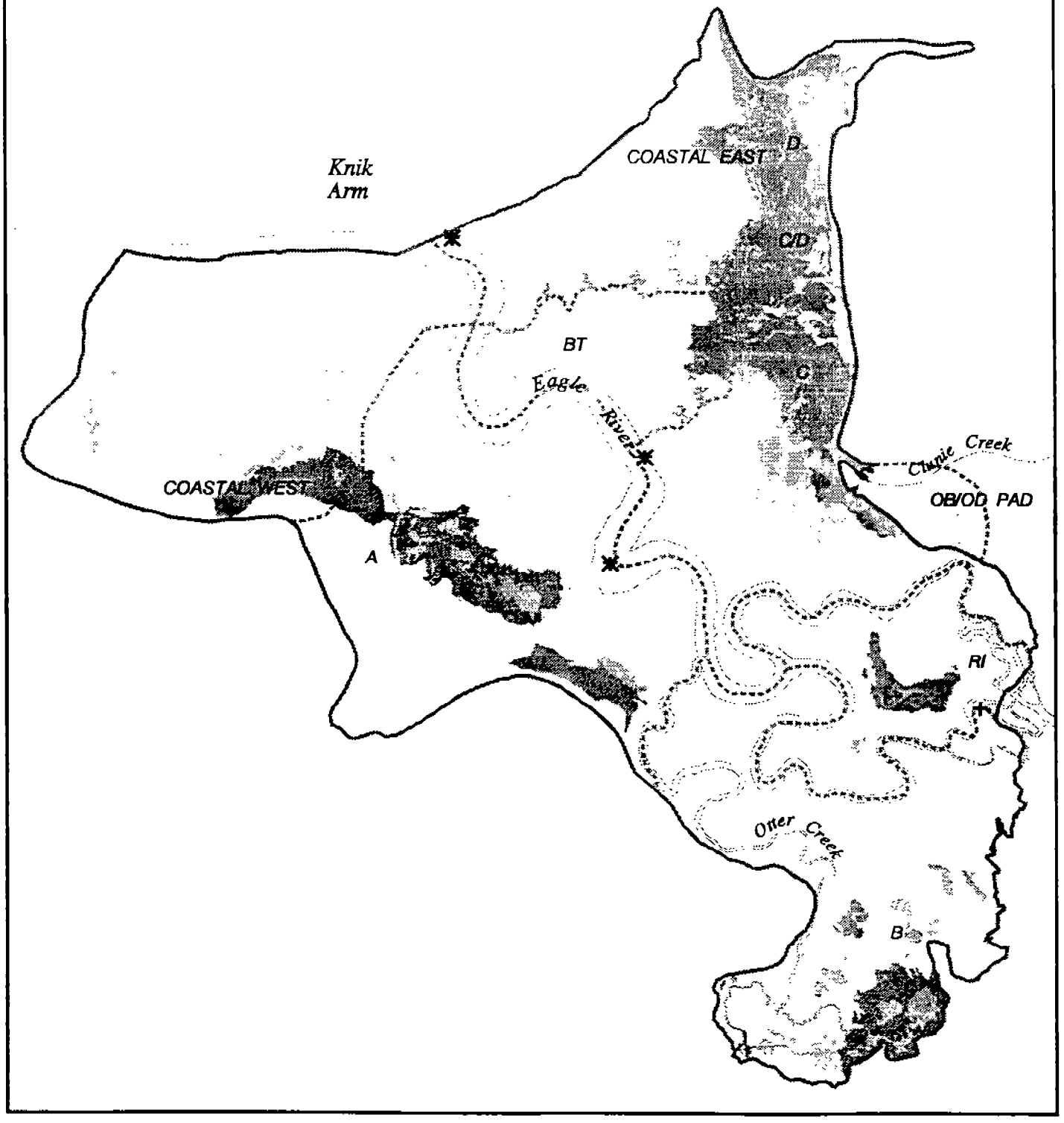


Figure 4-14

River Samples

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

N

Scale 1:24000
1 cm = 240 m

0 meters 720

Mapping and database source:
Racine et al., 1996.

Selected White Phosphorus Samples
+ Sediment
X Water

Intermittent Pond
Permanent Pond
Sedge Marsh
Area Boundary
OUC Site Boundary

CH2MHILL

February 13, 1997 AML: /proj2/arf/fig.aml PLOT FILE: /proj2/arf/fig4-141.eps

and 2,4,6-TNT also were confirmed, but at much lower concentrations. Also present in some samples were trace amounts of the TNT biotransformation products 2-amino-4,5-DNT and 4-amino-2,6-DNT, as well as pentaerythritol tetranitrate and RDX.

Munition compounds have been detected at low concentrations in Area C adjacent to OB/OD Pad.

In 1993, 23 sediment samples were taken. Munition compounds were not detected. (Detection limits were between 0.3 and 3 µg/g dry weight.)

Metals concentration of the ERF sediment generally appeared to be within range of other reference areas. These reference areas are presented in Section 6.

Water sampling included 26 samples collected by ESE in 1989, 47 samples collected by CRREL in 1990, and 23 samples collected by USAEHA in 1993. The samples collected by ESE found detectable concentrations (a few µg/L) of 1,2,4,5-tetranitro-N-methylaniline, nitrobenzene, 2,4-DNT, 2,6-DNT, and 1,3-dinitrobenzene in two of the samples collected near OB/OD Pad. None of the samples collected by CRREL or USAEHA showed detectable concentrations of munition residues.

ESE also detected acetone and 4-methylphenol in the water in Area C. 1,1,2,2-Tetrachloroethane and 1,1,2-trichloroethane also were identified tentatively. None of these organic compounds appeared widespread in ERF or abundant in terms of concentration of number of samples. No non-munition organic compounds were detected by USAEHA.

The most contaminated sediment areas of WP are Area C, Bread Truck, and Racine Island.

Some metals also appeared to be elevated in water samples, but they were within freshwater criteria based on site-specific hardness.

4.5 Conclusions

Sampling of Area C, Bread Truck, and Racine Island presented the most frequent detection of WP and the highest concentrations. Detections above 1 µg/g are more common in these areas. In addition, WP also has been detected at depths in the sediment as low as 50 to 60 cm, but more commonly only down to about 20 cm at the locations sampled. Although the permanent and intermittent ponds have received substantial sampling in these areas, the density of sampling in the sedge marsh is substantially lower.

Data have shown that WP concentrations do decrease with time if they are exposed to air. There is evidence that this is occurring in two localized sites in Area C where sampling has been performed over several years. Because the length of time that the sediments are unsaturated increases with increasing elevation, a conclusion can be extrapolated from the results for these two sites that natural attentuation is occurring at elevations equal to or higher than these

two sites in Area C. These areas would include the mud flats and much of the intermittent ponds of Area C.

Although WP has been detected in the sediments traveling through the gullies, all water samples in the gullies and Eagle River have had no detectable quantities of WP. Sediment sampling in Eagle River also has not detected any WP; therefore, the movement of WP through Eagle River to Knik Arm appears to be minimal.

Although WP has been detected in pond water and gully sediments, it has not been detected in the Eagle River sediment or water.

The particulate nature and the explosive method of release of WP has created a high degree of spatial variability in the WP concentrations, both within local areas and across ERF. Therefore, these results must be interpreted cautiously; there may still be significant areas of WP contamination that have not been identified.

Although the sampling for chemicals other than WP has been limited, detections of organics and metals associated with munitions only has occurred in Area C along the boundary with OB/OD Pad.

SECTION 5

ERF Conceptual Site Model

5.1 Introduction

A CSM provides a visualization of the surface and subsurface features at a site. This model details the nature of the surfaces themselves; it identifies the nature, extent, relationships, and movement of contaminants within them, and the exposures and risks caused by those contaminants. To understand the form, distribution, and movement of WP in the environmental media at ERF, the chemical and physical behaviors of WP also are examined.

Previous studies have identified WP as the primary contaminant of concern on ERF. Other contaminants have been reported to be present on OB/OD Pad. Because of this difference in contaminant type, separate CSMs were developed for each of these two sections of OUC. This section discusses development of the ERF CSM; Section 6 describes the CSM for OB/OD Pad.

The ERF CSM has been developed based on WP contamination, because WP is the primary cause of waterfowl mortality observed in ERF.

The ERF CSM has been developed based on WP contamination, because WP is the primary cause of waterfowl mortality observed in ERF. Contaminants other than WP have been investigated but not observed anywhere in ERF, except the wetlands adjacent to OB/OD Pad. The CSM for ERF is graphically summarized in Figure 5-1, which shows how WP particles are released into the ponds (as a result of exploding white smoke shells) where the oxidation process ceases. This process is described in this section. The sources, releases, fate and transport in sediment and water, exposure routes and receptors, and bioaccumulation and bioconcentration potential of WP also are examined.

5.2 Sources of White Phosphorus

WP is one of the three forms of elemental phosphorus formerly used in matches, fireworks, and rat poison (Van Wazer, 1958). WP obscurants are set to burst in the air or upon impact. If the charge explodes in the air, the WP particles melt and burn. Portions of WP particles that are not fully oxidized hit the sediment or water surface and are extinguished. Because the density of the WP (1.8 grams per cubic centimeter [g/cm^3]) is greater than that of water, any unreacted WP sinks through the water column to the bottom sediment.

The aerial extent of the WP deposits is expected to vary with the size of WP smoke projectile. WP smoke projectiles were commonly followed by HE munitions. These HEs displaced significant volumes of sediment upon impact with the ground to form craters that are 1- to 2-m in diameter. At ERF, sediment containing high concentrations of WP has been found immediately surrounded by areas of much lower WP concentrations, suggesting that there is significant heterogeneity with respect to WP deposition. The portion of WP in a smoke projectile that is not oxidized following impact has been estimated based on laboratory tests and field observations. Estimates range from 1 to 30 percent of the WP fired (Racine *et al.*, 1992b; Racine *et al.*, 1991).

The presence of sediment containing lower concentrations of WP surrounding areas of high concentrations suggests substantial deposition of WP at the point of impact.

5.3 Releases

The release of chemicals, particularly WP, from exploding ordnance is discussed in Section 2. Measured chemical concentrations, which are described in Section 4 are highlighted below to summarize the form and extent of WP contamination.

The sampling reported in Section 4 demonstrated that small distances between WP samples can present substantial differences in WP concentrations. It is extremely difficult to predict the extent of WP contamination in such a heterogeneous environment. Therefore, WP concentrations between measured points and in ponds that have not received any sampling should be considered to be very uncertain.

As discussed in Section 4, the highest frequencies and concentrations for WP detection in sediment were found in Area C, Bread Truck Pond, and Racine Island. Areas A and C/D had low frequencies of detections and low concentrations (up to 0.062 µg/g); Areas B and D had no detections.

It is difficult to predict the extent of WP contamination in the heterogeneous environment of ERF.

Fifty-eight cores were taken as deep as 60 cm in Areas A, C, and Bread Truck in 1991 and 1992 and were analyzed for WP. Twenty-one cores had nondetectable concentrations of WP at all depths. Of the remaining cores, most had detectable concentrations only down to 10 to 20 cm, but two had detectable concentrations down to 50 to 55 cm. A few samples of gully sediments also have had detectable WP concentrations, but no WP has been detected in Eagle River.

5.4 Fate and Transport

The fate and transport of chemicals in the environment is determined by the physical characteristics of the site, discussed in Section 2, as well as by the physical properties of WP and other contaminants present.

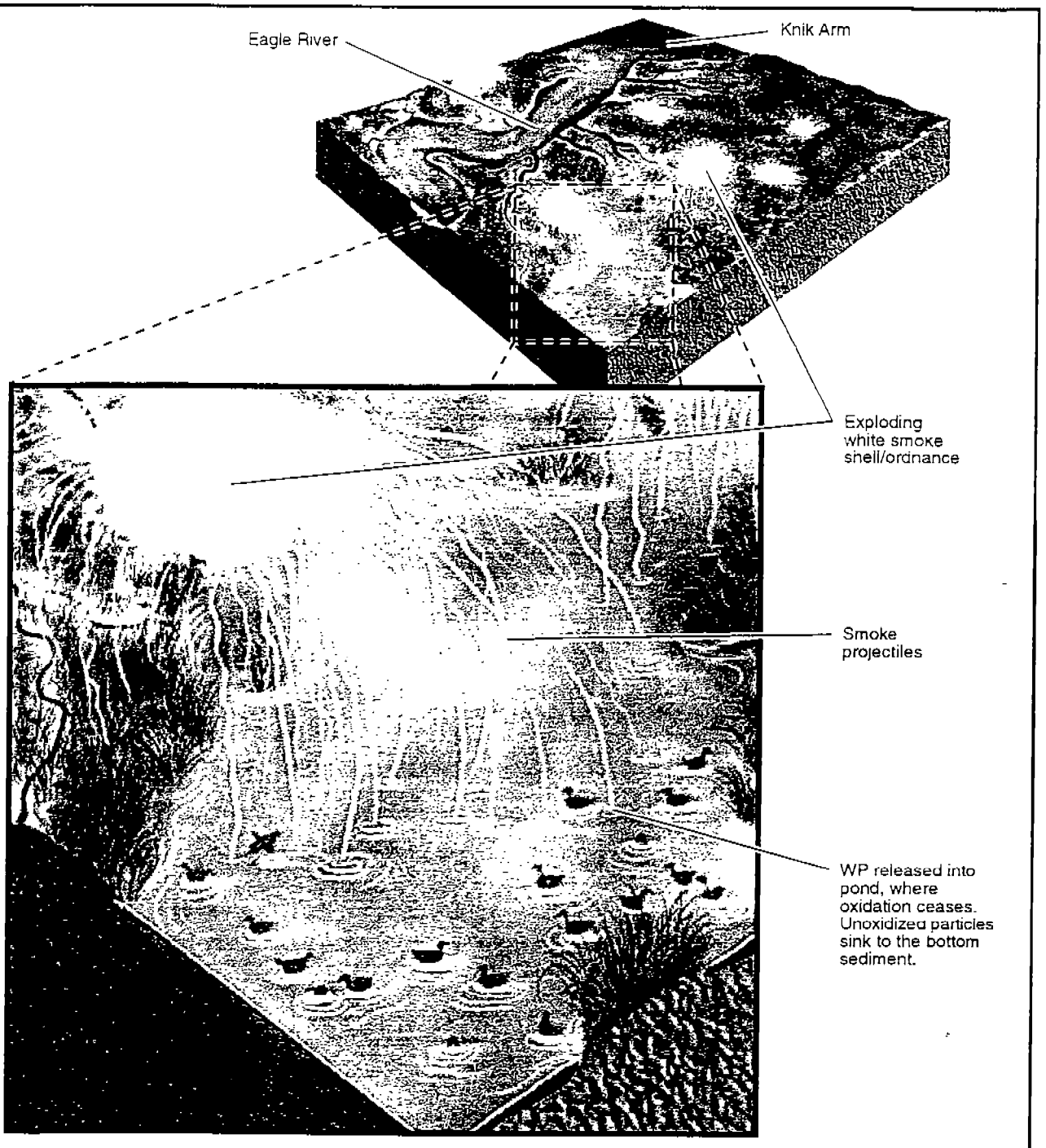


Figure 5-1

Conceptual Site Model for White Phosphorus

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5.4.1 Sediment

5.4.1.1 Fate of White Phosphorus in Sediment

The unreacted WP of concern at ERF is not evenly distributed in the ERF sediment, but is present as discrete particles. The individual particles are surrounded by sediment. The particles and the sediment continuously or at least frequently are saturated with water. When WP particles from the Bread Truck Pond and Area C sediments were isolated and characterized, their lengths ranged from 0.26 to 2.9 mm and shapes were described as angular to globular (Racine *et al.*, 1992a). Very small WP particles were found suspended in the water column as colloidal particles. Concentrations of the suspended WP particles increased after the sediment was disturbed.

In sediment, the unreacted WP of concern is present as discrete particles. Laboratory studies have shown that the particles persist in moisture conditions that are at or above saturation.

The persistence of WP at ERF is largely a function of the characteristics of the tidal flats environment. WP reacts violently with air (oxygen) because it is a strong reducing agent and oxygen is a powerful oxidizer. In the absence of oxygen (or other strong oxidizers), WP will persist. One measure of the oxygen concentration is the redox potential (Eh); the lower the Eh, the less oxidized and the more reduced the environment. In Area C, Ehs ranged from -100 millivolts (mV) to -400 mV. These extremely low values indicate that WP will persist. These low values are attributable to the abundance of organic material decomposing in the water and sediments of a salt marsh environment.

Laboratory studies have shown that WP particles persist in the sediment at moisture conditions at or above saturation. When WP particles were incubated well below saturation, the particles persisted longer than 60 days at 4°C, and disappeared in about 24 hours at 20°C. When the particles were incubated slightly below saturation, variable results were obtained. These results generally were confirmed by field tests that measured implanted particles and took repeated samples from the same locations. WP particles persisted in permanently flooded areas, but reduction was noted in areas where the sediments became unsaturated (Walsh and Collins, in Racine *et al.*, 1995).

The frequent flooding of the tidal flats also contributes to WP persistence. Because so much of the area is frequently submerged, the sediments remain saturated. Oxygen cannot diffuse through the saturated sediment to react with the WP. WP is also resistant to photolysis and anaerobic biodegradation, making it stable in oxygen-deficient sediments (USAEHA, 1993).

5.4.1.2 Transport of White Phosphorus in Sediment

Tidal forces cause sediment erosion, transport, and deposition; these conditions may affect the location and availability of WP for ingestion by waterfowl and other organisms. Sediment transport occurs in both

the flood and ebb stages of the tidal cycle during summer and winter. Deposition onto the mud flats occurs during slack high tide and during the initial period of the ebb cycle, but water in the ponds and marshes continues to mix and exchange; sediment in the pond bottoms may be resuspended before settling occurs.

Sediment deposition buries WP particles, making them unavailable to waterfowl and other organisms.

Sediment deposition buries WP (Figure 5-2); particles that were accessible to waterfowl and other organisms become unavailable. This mechanism has an impact on the risks posed by WP. The sediment deposition in ponds occurs when the tidal ponds are flooded. Field observations suggest that more than 20 cm of deposition must occur before significant consolidation would occur in permanent ponds. Erosion may uncover WP that was previously buried (Figure 5-2). WP that currently poses no immediate risk to waterfowl could pose a risk when uncovered. Dabbling ducks easily disturb fine sediments that have settled to pond bottoms.

Erosion, suspension, and deposition will vary with the terrain, primarily through the water flow paths. Vegetation also affects material transport. Plants such as grasses may act as filters, trapping suspended solids. In marshes, mats of vegetation will hold existing sediment in place and provide a physical barrier to waterfowl ingestion of WP.

WP transport in gullies was measured by multiple methods in gullies draining Areas A and C and Bread Truck Pond. Composite water samples were collected at 1 cm and 30 cm above the channel bottom. Sediment in bed load transport and recently deposited material on channel bars also were sampled. Sediment samples also were taken from other gullies and from the silt beach near the tide gauge. Through this sampling, it was confirmed that WP transport in gullies occurs (Lawson *et al.*, 1996). Although WP in the gullies could make its way to Eagle River and perhaps to Knik Arm, it was not detected in the two sediment and water samples collected at the mouth of Eagle River in 1993 (Bouwkamp, 1993). There is no evidence to suggest that WP would be detected in Knik Arm.

5.4.2 Surface Water

Peak water velocities during ebb tide were estimated at 0.7 m/sec for the Bread Truck Pond drainage and 0.5 meters per second (m/sec) in the Parachute Pond (Area C) drainage based on survey data and hydraulic equations. Discharge values were calculated as 8.05 m^3/sec for the Bread Truck Pond drainage and 7.42 m^3/sec for the Parachute Pond drainage during peak flows (Lawson, Bigl, Hunter, Nadeau, Weyrick, and Bodette, in Racine *et al.*, 1995).

TSS in the gullies varied during a tidal cycle; values were low through a rising tide, increased with the flood waters, and decreased as the ebb tide occurred. In general, Knik Arm, and not Eagle River, is the

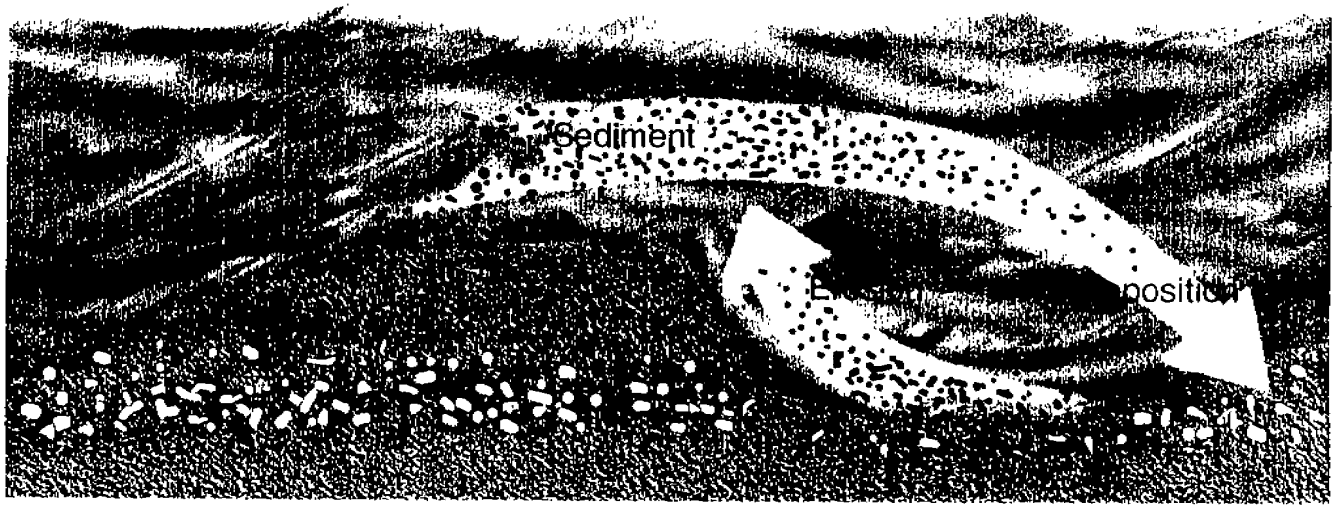


Figure 5-2

Transport of Contaminated Sediment

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primary sediment source in ERF. Sediment loading tends to be greater during the fall months and early spring months, possibly because of increased particle buoyancy created by colder temperatures and higher salinity. Sediment loads in Knik Arm and Eagle River tend to fall during the winter months because frozen ground prevents active erosion.

WP may be present in surface waters in two forms: as suspended particles or dissolved.

WP concentrations have persisted over time in the sediment, and there is potential for particle resuspension, transport, and redeposition into surface water. Laboratory and field experiments indicate that very small colloids (microgram sized) of WP are readily suspended in the water column following agitation of the underlying substrate (Bouwkamp, 1993). However, there is no evidence that milligram-sized particles can be resuspended or transported. It is these larger particles that are of concern with regard to dabbling ducks and lethal WP doses. The fate and transport of WP in surface water is discussed below.

5.4.2.1 Fate of White Phosphorus in Surface Water

WP may be present in surface waters in three forms: as suspended colloids, settled particles, or dissolved. The fate of the soluble WP is primarily controlled by volatilization in shallow or highly turbulent water bodies (Spanggord *et al.*, 1985).

In colloidal form, the microgram-sized WP is introduced into the water column following physical disturbance of the sediment. Larger particles (milligram-sized) will settle with the sediment in less than 1 second, but very small microgram-sized colloids remain suspended in the water phase for long periods (approximately 40 seconds). In surface waters at ERF, oxygen concentrations are typically in equilibrium with atmospheric oxygen, but sediments are anoxic because of high organic material content. Aeration and potential volatilization of waters occurs from tidal mixing or waterfowl disturbances.

White phosphorus can be suspended in surface water by waterfowl activity, wind, and severe tidal movements.

In dissolved phase, WP concentrations will decrease as a result of oxidation, volatilization, and hydrolysis (Spanggord *et al.*, 1985); however, the mass of WP disappearance through these mechanisms will be small because of the low solubility of WP in water. The overall half-life for soluble WP in aerobic water is estimated at 42 hours from hydrolysis and oxidation, but drops to 48 minutes in shallow, turbulent water from increased volatilization (Spanggord *et al.*, 1985). The volatilization rate will be controlled by transport of WP to the water surface (through diffusion or mixing). Oxidation rates will be controlled by oxygen availability, and hydrolysis to acids will occur with or without oxygen present. Overall, these loss mechanisms will be insignificant when compared with the total mass of WP present at ERF.

5.4.2.2 Transport of White Phosphorus in Surface Water

Microgram-sized WP colloids could be resuspended and transported through drainage channels in ERF without undergoing complete oxidation. Mechanisms for WP suspension include waterfowl activity, wind, and severe tidal movements. Moving waters in ERF, such as the network of drainage gullies that flow toward Eagle River, act as a transport medium for microgram-sized WP colloids within suspended material (USAEHA, 1993). However, larger, milligram-sized particles are not easily resuspended and likely stay settled at pond bottoms.

Microgram-sized WP colloids may be resuspended by tidal currents, waves propagated by wind, rain events, and physical disturbances such as waterfowl swimming and feeding. Once the WP is suspended, it may be transported with the water phase.

5.4.3 White Phosphorus Transformations

WP is the most reactive of the three phosphorus allotropes (white, red, and black) and does not occur naturally. In unreacted WP, four phosphorus atoms form a tetrahedral-shaped molecule that forms a waxy solid at room temperature. Pure WP is colorless, but it is usually slightly yellow from trace amounts of red phosphorus, an impurity. Table 5-1 lists some characteristics of WP. It is nonpolar and does not dissolve readily in water.

White phosphorus is nonpolar and does not dissolve readily in water.

Above 30°C, WP will ignite when exposed to the atmosphere. Because WP has a high burning temperature and low melting point, WP particles will melt and burn in liquid form following ignition. The particles continue to burn until the WP is depleted or the material comes into contact with water or is buried in sediment.

When WP burns in excess oxygen or air, it forms phosphorus pentoxide, P_4O_{10} (Figure 5-3). This is the reaction that produces white vapor. In this state, the phosphorus is in its most oxidized form. If excess oxygen is not available, but some oxygen is present, the phosphorus may undergo incomplete combustion to form phosphorus trioxide, P_4O_6. Both phosphorus pentoxide and phosphorus trioxide are acid anhydrides that will react with moisture in the air or water phase to form orthophosphoric acid or phosphoric acid. WP forms a cloud of white smoke when in contact with oxygen to produce phosphorus oxides (P_4O_2, P_2O, P_2O_3, P_2O_4, P_2O_5, P_2O_6), which react with water vapor to form various phosphoric acids. Rapid oxidation of WP particles generates heat, and smoke (primarily P_2O_5) rises. Combustion of WP in a confined space can produce an oxygen-deficient atmosphere incapable of supporting life (Yon *et al.*, 1983).

The acid forms of phosphorus are water soluble, and in the water or air phases, the phosphorus will form salts with available inorganic compounds. In an aqueous medium, the solubility of these salts depends on the redox potential of the environment and the inorganic

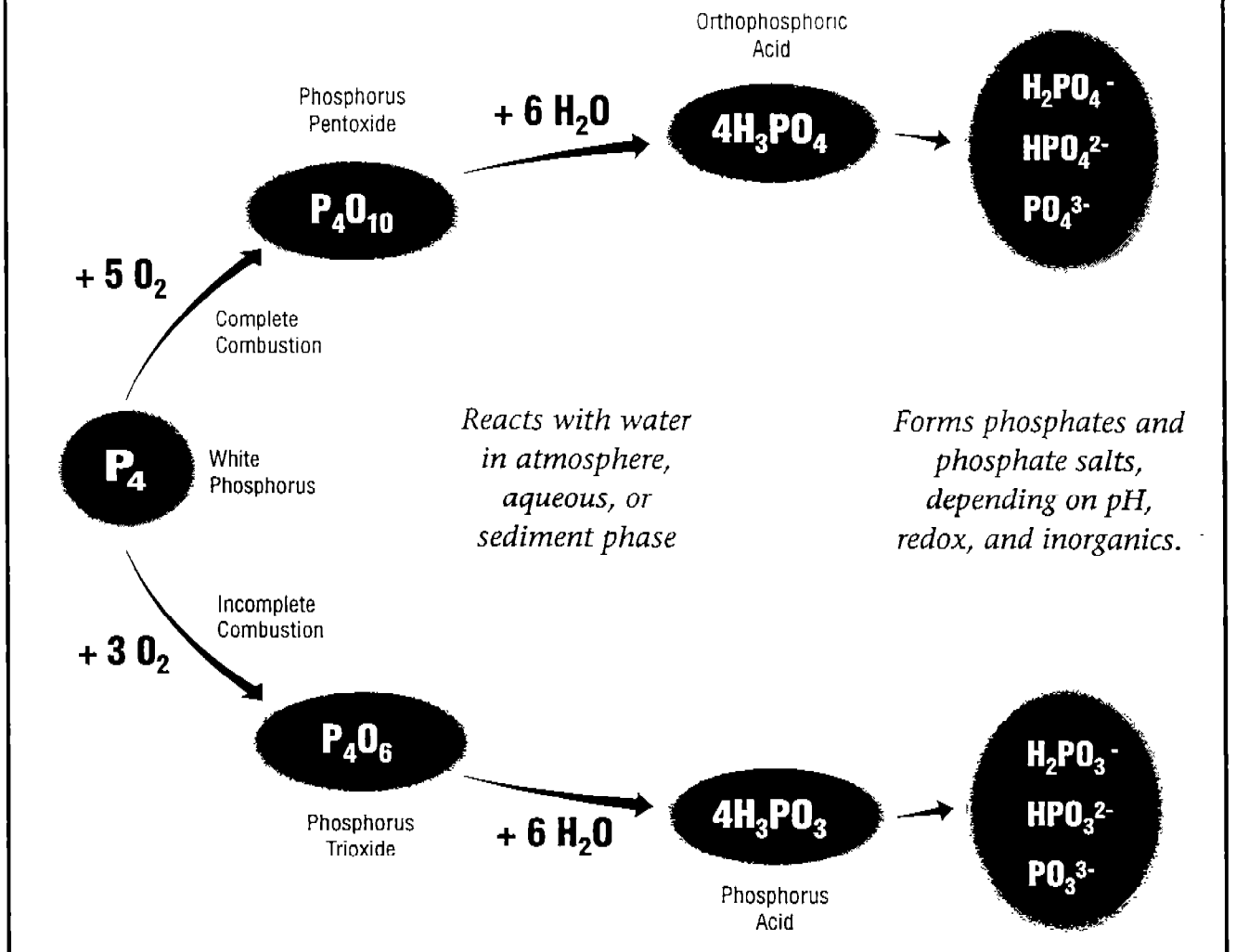


Figure 5-3

White Phosphorus Transformations

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TABLE 5-1
Chemical and Physical Properties of White Phosphorus

Molecular Structure	P_4
Molecular Weignt	124 atomic mass unit
Solid–Melting Point	44°C
Auto Ignition Temperature	20-40°C
Appearance	Waxy Transparent Colorless (pure)
Density (20°C)	1.8 g/cm^3
Vapor Pressure	0.026 mm of mercury at 20°C
Solubility–in water (15°C) in olive oil in mineral oil	2.4 or 3 mg/L 12.5 g/L 14.5 g/L
Henry's Law Constant	2.1 x 10^{-3} (atm · m^3)/mole at 25°C
Octanol-Water Partition Coefficient	1,200
Oxidation States Fully Oxidized	 +5 P_4O_{10} (solid)[a] +3 P_4O_6[b] 0 P_4 -2 P_2H_4
Fully Reduced	-3 PH_3 (gas)

[a]Forms H_3PO_4, $H_2PO_4^-$, HPO_4^{2-}, or PO_4^{3-} in water, depending on pH.

[b]Forms H_3PO_3, $H_2PO_3^-$, HPO_3^{2-}, or PO_3^{3-} in water, depending on pH.

Notes: mg = milligram.
L = liter.
g = gram.

Sources: Racine *et al.*, 1991; Racine *et al.*, 1993; Walsh, in Racine *et al.*, 1994.

compounds that are present. Insoluble phosphates are not available for uptake by organisms, but some microorganisms are capable of converting the phosphates to soluble and mobile forms. The main oxidation products of WP in water are phosphoric acid (H_3PO_4) and phosphorus/phosphoric acid (H_3PO_3) (Yon *et al.*, 1983). Soluble phosphates are available for plant and microorganism uptake,, conversion to organic phosphates, and assimilation into the food chain. In this form, phosphorus is not highly toxic to potential receptors, however.

At ambient temperatures and pressures, WP is relatively insoluble and stable in water. Although WP will react with oxygen in water, the WP disappears very slowly. It is estimated that a 1-mm-diameter particle would take 8 years to dissolve at 25°C in slowly flowing water, and even longer in salt water (Walsh, in Racine *et al.*, 1994).

Phosphoric acids in water are organically bound (greater than 90 percent). Eventually, they are concentrated in the sediment and

3. An environmental medium (such as sediment)
4. An exposure point (ponds at ERF, for example)
5. Current or potential receptors and feasible routes of exposure (such as ingestion)

An exposure pathway is complete if there is a reasonable likelihood that a receptor may take in contaminants through contact with contaminated media. No exposure (and thus no risk) exists unless the exposure pathway is complete.

5.6 Secondary Sources

5.6.1 Unexploded Ordnance

Unexploded ordnance is considered the single most important human health hazard.

Because of the loss by fire of early military records concerning munition use in ERF, it is difficult to accurately determine the potential hazard of UXO. Army policy has been to discontinue use of projectiles with more than a 10 percent "dud" rate. Assuming the occurrence of duds, it would be possible for between 40 and 400 duds per year to have been deposited in ERF (Racine *et al.*, 1992b).

Unexploded ordnance has been discovered by researchers and Army EOD personnel. This secondary source is considered the single most important human health hazard. Although this area is a restricted area, researchers in ERF are potentially exposed. Unexploded ordnance has been given a high hazard probability in the conceptual model.

5.6.2 Sediment

Research has indicated that WP particles in the sediment of pond bottoms is the single most important source of acute toxicity to waterfowl in ERF.

Unreacted WP is present in the ERF sediment as discrete particles. Reacted phosphorus also may be present in its oxidized form as soluble or insoluble phosphates, depending on the inorganic compounds present, redox potential, and pH. If WP particles of less than 0.1 mm exist, they could be toxic to fish, shorebirds, and other filter-feeders (USATHAMA, 1992). WP particles sieved from sediment samples ranged from 0.26 to 2.9 mm in length, with masses from less than 0.1 to 3.4 milligrams (mg). The number of particles ranged from none to more than 100. Sediment sample volumes ranged from 202 to 430 mL (Racine *et al.*, 1993). This material is available for ingestion or dermal contact.

Of the 1,019 surface sediment sample locations at ERF, no WP was detectable in about 63 percent of the most recent samples (from Section 4). Of the locations with detectable concentrations, only 9 percent had concentrations above 1 µg/g. Where WP contamination exists, it is in very low concentrations, except for localized hot spots.

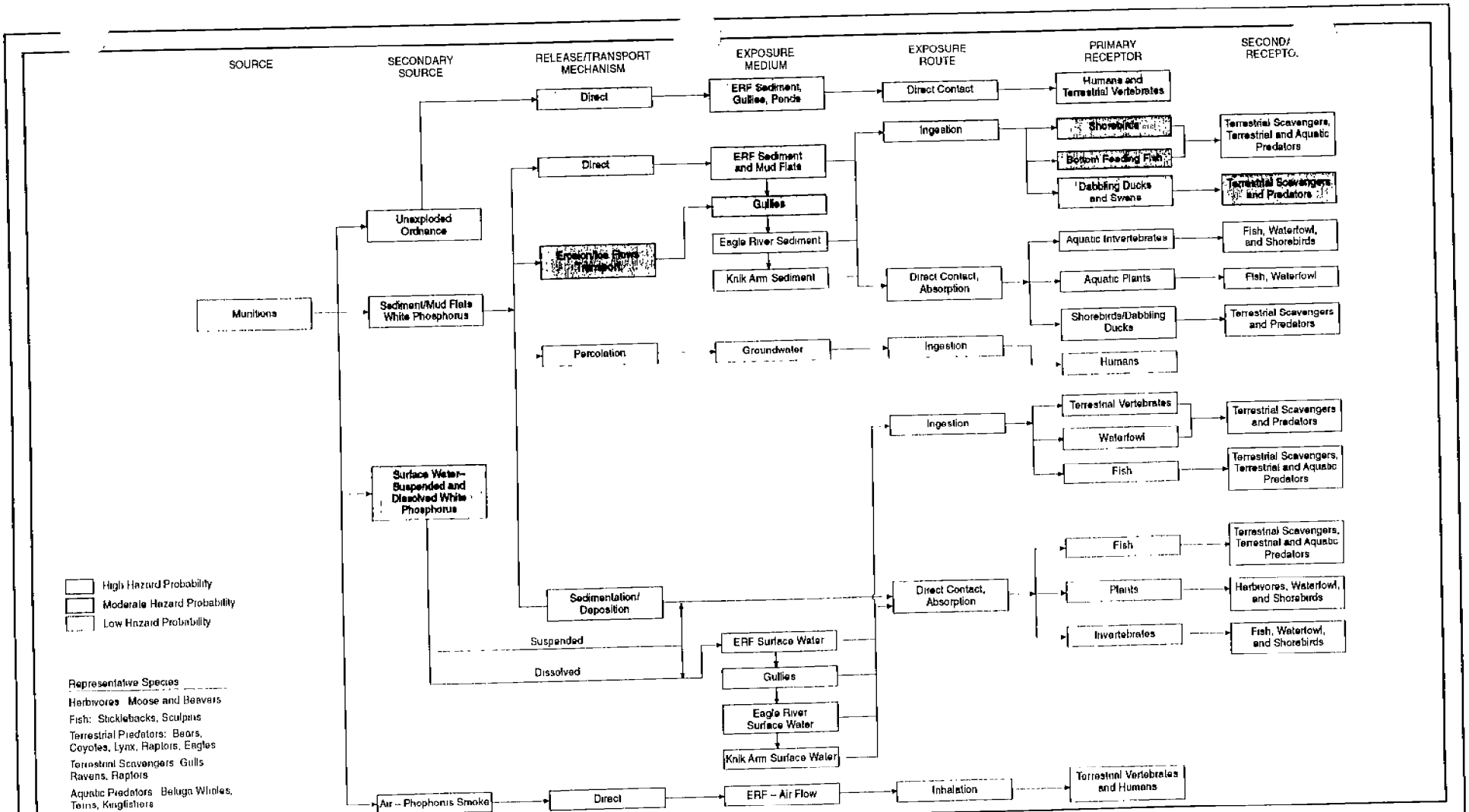


Figure 5-4

Potential Exposure Routes and Pathways for Sediment

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On the basis of the last 10 years of research at ERF, WP particles in the sediment of pond bottoms is the single most important source of acute toxicity to waterfowl in ERF. This source is therefore rated as having a high hazard probability in Figure 5-6.

It is possible that WP has migrated through Eagle River to Knik Arm, but limited sampling failed to detect it in 1993.

5.6.3 Surface Water

Deposition and resuspension of small WP particles can affect the WP content in water.

No WP was detected in the water in any gully or the Eagle River in any of the three sampling periods. The detection limit during these sampling events was 0.01 µg/L. WP was detected in ponded areas over WP contaminated sediments at concentrations between <0.01 and 4.40 µg/L with no apparent impact on the benthic macroinvertebrate community structure. Because WP at concentrations as low as 0.4 µg/L have been shown to have chronic effects on the fathead minnow, WP has been given a low to moderate hazard probability for aquatic organisms (Bouwkamp, 1996).

5.6.4 Air/Phosphorus Smoke

The possibility has existed for the exposure of waterfowl and other vertebrates through the inhalation and/or direct contact of phosphorus particles or smoke in the air. Because the military has discontinued use of WP since 1990, this secondary source has been given a ranking of low hazard probability. The remote potential exists for disturbance of unexploded rounds or large particles of WP, and a localized exposure could exist through this air source.

5.7 Release/Transport Mechanism

The discontinued use of WP by the military since 1990 has reduced the risk of inhalation or direct contact with phosphorus particles or smoke in the air.

This section describes and identifies the transport mechanisms for the four secondary sources: unexploded ordnance, sediment, surface water, and air.

5.7.1 Unexploded Ordnance

The direct contact route through human contact or equipment disturbance is considered to have a high hazard probability for UXO.

5.7.2 Sediment

a. **Direct contact** by waterfowl is considered to have a high hazard probability for exposure to contaminated sediment (more specifically pond bottoms) during feeding periods.

b. **Erosion and ice plucking** of contaminated WP soil, which move contamination downgradient to gullies, other ponds, or Eagle River and Cook Inlet, is considered a transport mechanism in ERF.

Gullies are progressively extending into the mud flats toward the pond complexes of the Bread Truck Pond and Areas A, C, C/D, and D. Eventually this erosion will increase the drainage of these ponds. Rates of gully erosion ranged from 0.1 to 4.9 m during the summer of 1992 and 0.4 to 6.3 m during winter of 1992-1993 (Lawson *et al.*, in Racine *et al.*, 1994). Erosion rates were 0.1 to 5.0 m during the winter of 1993-1994, 0.1 to 2 m in the summer of 1994, 0.1 to 11.7 m during the winter of 1994-1995, and 0.1 to 20 m during the summer of 1995. Net headwall recession was 0.1 to about 33 m between 1992 and 1995 (Lawson *et al.*, 1996). Estimated erosion rates have varied considerably from one year to the next, indicating the erratic nature of this process in ERF.

Gully erosion increases the drainage at ERF ponds.

Although there is a strong possibility that erosion, and to a much lesser degree ice scouring, moves contaminated sediment in the pond/gully areas, the subsequent draining of ponds and potential degradation of WP in those ponds reduces toxicity. In addition, the eroded material moves eventually to Eagle River and Cook Inlet, where dilution minimizes risks. For the above reasons, erosion as a transport mechanism is considered to be only a moderate hazard probability.

c. **Percolation** is considered to have a low hazard probability. Because WP is relatively insoluble and is found at minimal depths resulting from projectile penetration of the soil, percolation to groundwater of WP at toxic levels is unlikely.

d. **Sedimentation** ranges from several millimeters per year on levees, to 10 to 15 mm per year on mud flats, and up to 20 to 40 mm per year in ponds (Lawson *et al.*, in Racine *et al.*, 1994). The sources for most sedimentation appear to be Eagle River, which forms an alluvial fan at the head of ERF, and the tidal influence of Knik Arm, especially in the northern two thirds of ERF (Lawson *et al.*, in Racine *et al.*, 1994). Over time, sedimentation from "clean" sources could cover large areas of ERF and reduce exposure of waterfowl to WP. For the above reasons, sedimentation is most often considered a positive phenomenon and only rarely would contribute to contaminant movement. In the CSM, therefore, sedimentation is assigned a low hazard probability.

Sedimentation from clean sources such as Eagle River and Knik Arm reduces exposure of waterfowl to WP.

5.7.3 Surface Water

The resuspension and subsequent **deposition and sedimentation** of WP from a surface water source is considered to have a low hazard probability. This classification is based on the small size of the particles and previously described benthic and fish studies that show minimal acute effects of WP from surface water.

5.7.4 Air

As previously mentioned, **air** exposure would result from direct exposure to WP; however, because of the infrequency of such an incident, this transport mechanism is given a low hazard probability.

5.8 Exposure Medium

5.8.1 Unexploded Ordnance

The exposure medium most likely encountered would be **mud flat** and **pond bottom sediments** containing these ordnance. Because of current research activities, this exposure medium is given a high hazard probability.

5.8.2 Sediment

Exposure to WP in sediment during research activities is a hazard of concern.

a. The **ERF sediment and mud flats**, especially on pond bottoms, is considered to be the major exposure media for WP. Therefore, ERF sediment is given a high hazard probability.

b. **Gullies** are continually being eroded, but do not present a major feeding source for waterfowl. Therefore, gullies as an exposure medium are rated as having a moderate hazard probability.

c. **Eagle River sediment** would most likely be made up of clean, alluvial deposits with only incidental mud flat deposits from river erosion. For this reason, Eagle River sediment has been given a low hazard probability.

d. **Knik Arm sediment**, like Eagle River sediment, would be mostly clean deposits and therefore was given a low hazard probability.

e. **Groundwater** as an exposure medium through percolation of WP already has been discussed as having a low probability. In addition, the distance to potable wells and the tidal influence give groundwater a low hazard probability.

5.8.3 Surface Water

Because of laboratory testing to date and the diversity of benthic organisms on ERF, the following exposure mediums of surface water contamination are considered to have a low hazard probability:

- Eagle River ponds
- Gullies
- Eagle River
- Knik Arm

5.8.4 Air/Smoke

The air route would be the likely exposure medium for direct contact with WP smoke. The unlikeness of this occurrence, however, warrants a low hazard probability.

5.9 Exposure Route

5.9.1 Unexploded Ordnance

The primary exposure route for UXO is the **direct contact** route. Activity in ERF warrants a classification of high hazard probability.

5.9.2 Sediment

a. **Ingestion** of sediment containing WP is the most likely cause of acute mortality in waterfowl. For this reason, ingestion is considered a high hazard probability as an exposure route.

b. **Direct contact** of WP by biota is possible; however, laboratory studies to date have not demonstrated acute toxicity. This route of exposure is considered to have a low hazard probability.

c. **Ingestion** through the **groundwater** route has been given a ranking of low hazard probability for reasons previously discussed in relation to percolation and availability of groundwater to humans in the area.

5.9.3 Surface Water

a. **Ingestion** of surface water containing WP is considered to have a low hazard probability because of the size of particles, insolubility of WP, and laboratory studies showing no acute effects.

b. **Direct contact** of surface water was also given a ranking of low hazard probability for the same reasons. In addition, the constant adjustment of water conditions from tidal and rainfall influences would minimize WP effects.

5.9.4 Air

Inhalation would be the likely exposure route for airborne contamination. Again, because of the limited likelihood of this occurring, inhalation was assigned a low hazard probability.

5.10 Primary Receptor

5.10.1 Unexploded Ordnance

Human receptors are considered to have a high hazard probability, for as long as there is human access to ERF.

The primary receptors for direct exposure to UXO would be **human and large terrestrial vertebrates** (for example, moose) likely to disturb and detonate ordnance. Because of the yearly incidence of duds in ERF, poor historical records of number and location of duds, the difficulty in locating ordnance among years of metal debris accumulation, and changing conditions from flooding tides, the presence of UXO must be considered very seriously. Therefore, human receptors are considered to have a high hazard probability, for as long as there is human access to ERF.

5.10.2 Sediment

5.10.2.1 Sediment Through the Ingestion Route

WP particles are similar in size to the seeds and larvae usable as duck food and are eaten by waterfowl mistakenly.

a. **Dabbling ducks** (included with swans) are considered to be the primary receptor in ERF. Pintails, green-winged teals, and mallards represent the greatest number of mortality among waterfowl (Racine *et al.*, 1992a), and are considered to have a high hazard probability. Although there are significant numbers of American wigeon and northern shovelers in ERF, the American wigeon and northern shovelers have had a relatively low mortality incidence because of feeding behavior that precludes or discriminates against the uptake of WP particles in the sediment (Reitsma and Steele, in Racine *et al.*, 1994).

   Sediments in ERF contain food items available to waterfowl. WP particles are similar in size to the seeds and larvae usable as duck food and are eaten by waterfowl mistakenly (Racine *et al.*, 1993).

b. Minimal **shorebird** deaths have been discovered during the years of mortality studies in ERF. Significant shorebird populations include greater and lesser yellowlegs, pectoral sandpipers, and dowitchers. Selective feeding behavior that limits WP uptake and the frequenting of habitat that periodically dries allow the WP to sublimate. Because occasional shorebirds are found dead in ERF, this receptor has been ranked as having a moderate hazard probability. Shorebirds were not assigned a high hazard probability, because none of the observed mortality has been attributed to WP exposure (Racine *et al.*, 1993, 1994). WP was not observed in any shorebird carcasses during 1994 studies. Further research was not performed to evaluate the cause of shorebird deaths once WP was eliminated (Sparling *et al.*, 1994).

c. **Bottom-feeding fish** have not been studied in ERF in great detail. Fish sampling in ponded areas in ERF was conducted in 1994, and stickleback was the only fish encountered. Of 86 fish and

invertebrates sampled, only four had detectable levels of WP (Bouwkamp, in Racine *et al.*, 1994). Therefore, fish are considered to have a moderate hazard probability as a primary receptor.

5.10.2.2 Sediment Through the Direct Contact Route

Studies during the past 10 years show little evidence of toxicity by direct contact for **aquatic invertebrates** or **aquatic plants** (Bouwkamp, in Racine *et al.*, 1994) because of sediments contaminated with WP. Therefore, these potential primary receptors have been given a low hazard probability. Similarly, observations in the field have not indicated acute toxicity by direct contact with **shorebirds** and **dabbling ducks**.

5.10.2.3 Sediment Through Percolation to Groundwater

Because of the limited ability of WP to reach groundwater and the distance to production wells, the **human receptor** is given a low hazard probability for exposure.

5.10.3 Surface Water

5.10.3.1 Surface Water Through Ingestion Route

Because of the findings from previously described laboratory and field studies, exposure to WP by ingestion of surface water is seen as a low hazard probability for the following potential primary receptors:

- **Terrestrial vertebrates**
- **Waterfowl**
- **Fish**

5.10.3.2 Surface Water Through Direct Contact Point

This route also is seen as having a low hazard probability for the following potential receptors:

- **Fish**
- **Plants**
- **Invertebrates**

5.10.4 Air

The likely receptors for this inhalation route would be humans and terrestrial vertebrates. The small likelihood of inhalation warrants a low hazard probability.

5.11 Secondary Receptors

Secondary **terrestrial receptors** would include predators such as the bald eagle, herring gull, raven, wolf, coyote and fox. **Aquatic receptors** would be waterfowl, fish, mink, and otter. All hazard

designations for primary receptors also would be applicable for secondary receptors shown in Figure 5-6, except those receptors discussed below.

The sediment source through the ingestion route to shorebirds would be reduced in hazard as the food chain ascends.

The sediment source through the ingestion route to shorebirds (primary receptor) would be reduced in hazard as the food chain ascends **(terrestrial scavengers and terrestrial and aquatic predators)**. Because of the relatively low levels of WP and the low percentage of the secondary receptor population surveyed showing WP in the body, the terrestrial and aquatic predators would be exposed to lower levels of WP. Therefore, a low hazard probability ranking is appropriate for those secondary receptors.

The sediment source through ingestion route from dabbling ducks (primary receptor) to **terrestrial predators and scavengers** would be reduced to a moderate hazard probability. Because of the limited potential for bioaccumulation and the low levels of WP remaining in waterfowl carcasses, the hazard to predators is reduced somewhat (Racine *et al.*, 1993).

SECTION 6

OB/OD Pad Investigation and Assessment

This section presents a summary of past operations at OB/OD Pad, also referred to as Demolition Area One or Demo 1, and results of the 1996 site investigation completed for this portion of OUC. Supporting documentation for this section, including laboratory analytical data, quality assurance reports, and completed monitoring well logs is included in Appendix E of this RI report.

Open burning and open detonation of explosives on Fort Richardson have historically been performed on a pad adjacent to ERF in the northwest sector of Fort Richardson, Alaska. The location of OB/OD Pad relative to ERF can be seen in Figure 2-2. The pad covers an area of approximately 4 ha. It served as an EOD site for Fort Richardson at least since 1956, according to aerial photography (Racine *et al.*, 1992a), and may have been used for OB/OD activities earlier.

OB/OD Pad, which was designated an SWMU under the RCRA, was scheduled for closure under Title 40 of the *Code of Federal Regulations* (CFR), Part 265, Subpart G. This area was included in OUC under the three-party FFA negotiated when Fort Richardson was added to the NPL under the CERCLA program. Therefore, pad closure will be addressed under the CERCLA program.

OB/OD Pad consists of a gravel pad, reported to be 2 m thick, that was placed as fill on the edge of the salt marsh (EMCON Alaska, Inc., [EMCON], 1993). The 1996 site investigation indicates that the pad may be thicker in several locations. Currently, the pad contains the remains of destroyed surplus and outdated munitions, along with assorted objects such as junked vehicles and rocket motor casings.

OB/OD Pad consists of a gravel pad placed as fill on the edge of the salt marsh.

Section 6.1 provides background of pad operations. Section 6.2 discusses the chemical releases from the site. Section 6.3 describes the site investigation plan, and Section 6.4 summarize the activities that occurred during the investigation. Section 6.5 provides the hydrogeological and chemical analytical results of the investigations. The results are compared to action levels for a clean closure presented in the *Demolition Area Number One Closure Guidelines, Fort Richardson, Alaska* (EMCON, 1993). The site investigation results are integrated into a CSM that is described in Section 6.6. Conclusions regarding clean closure of OB/OD Pad are presented in Section 6.7.

6.1 OB/OD Pad Operations

The primary sources of contaminants observed on OB/OD Pad are the explosive ordnance destroyed on the pad during the normal course of operation.

The primary sources of contaminants observed on OB/OD Pad are the explosive ordnance destroyed on the pad during the normal course of operation. Records on OB/OD activities before 1980 are not available for review. Because of the lack of written documentation, it is assumed that operations before 1980 were performed in various areas throughout the pad. Interviews with OB/OD staff on Fort Richardson indicate that ordnance disposal activities were confined to a 0.8 ha zone on the western side of the pad after 1980 (EMCON, 1993). According to these same sources and the *RCRA Facility Assessment Preliminary Review/Visual Site Inspection Report* (as referenced in EMCON, 1993), no OB/OD activities have been performed on OB/OD Pad since November 1988.

It is assumed that the types of material disposed of on the pad after 1980 are similar to those destroyed before 1980. Existing records indicate that a variety of explosive material, including propellants, were disposed of on OB/OD Pad. These explosive materials (as listed in EMCON, 1993a) included fuses, 105-mm and 40-mm high-explosive (HE) projectiles, smoke pots, mortar rounds, star clusters, flares, booby traps, blasting caps, detonation cord, mines, rocket motors, claymore C4, 40-pound shape charges, mine AP M16, PETN detonation cord, smoke grenades, hand grenades, incendiary box liners for safes, and thermite and propellant bags. On at least one occasion, military police requested destruction of a small quantity of potassium and sodium chlorate (EMCON, 1993).

Materials from nonmilitary sources occasionally destroyed on OB/OD Pad included dynamite, explosives, 105-mm projectiles, and various flammable solids.

Materials from nonmilitary sources occasionally destroyed on OB/OD Pad included dynamite (supplied by the Alaska State Troopers), explosives (supplied by an oil service company in Kenai), 105-mm projectiles (supplied by Alyeska Ski Resort), and various flammable solids, including sodium, red phosphorus, and yellow phosphorus (supplied by ADEC). In addition to the explosives and their breakdown products, it is possible that metals leaching could occur as a result of precipitation contacting numerous shell casings and pieces of shrapnel spread over the area.

Existing records and interviews with OB/OD personnel indicated that no liquids such as paint thinner or antifreeze were disposed of on OB/OD Pad (EMCON, 1993).

6.2 Releases

Disposal through burning was performed either on the ground surface or in excavated pits. During the 1960s, smaller pieces of ordnance were ignited on the ground surface by using diesel fuel (EMCON, 1993). Occasionally pits were excavated and small-arms ammunition was disposed of by covering with other material soaked in a small

volume of diesel fuel (typically about 19 L) and igniting. Once the ammunition was spent, the pit was covered and the refuse was buried in place.

The ordnance disposal by detonation would tend to spread shrapnel and explosives over adjacent areas on the pad surface. Subsurface explosion and burning would have introduced larger quantities of explosive residue in a smaller area that would have been held in place through subsequent burial. Isolated pockets of soil contamination extending deeper than 46 cm would be expected at the locations of past open-burning pits and at blast crater locations. The craters were created through a series of charge detonations. The resulting craters reached maximum depths of approximately 2.4 to 3.6 m and widths of up to 9.1 m. No attempt has been made to locate these filled depressions because of the potential hazards created by UXO.

Surface soil sampling in 1992 showed that contaminants were spread throughout the pad, with most contamination found at depths of less than 46 cm and predominantly on the western half of the pad.

Surface soil sampling conducted by USAEHA in 1992 showed that contaminants were spread throughout the pad, with most contamination found at depths of less than 46 cm and predominantly on the western half of the pad (USAEHA, 1993). The most commonly detected contaminant was 2,4-DNT. Sediment and surface water sampling performed as part of several studies between 1985 and 1989 found no evidence of explosives and slightly elevated levels of the following metals: aluminum, antimony, arsenic, barium, chromium, copper, iron, and zinc. The reference values against which the sample concentrations were compared were based on one sample collected adjacent to Eagle River near the Route Bravo bridge and one sample collected from the Palmer Hay Flats. Phosphate also was detected at levels that were slightly higher than the reference locations. None of the contaminants found at elevated concentrations were present at levels considered to be toxic to wildlife (Racine *et al.*, 1992b).

An additional study conducted in 1991 analyzed 128 sediment samples collected along transects extending from the edge of OB/OD Pad into ERF. Sixty-eight of those samples contained 2,4-DNT, with 11 percent at levels that exceeded 1 part per million (ppm) (dry weight).

In 1995, CRREL installed seven piezometers as part of a study to test remote drilling technologies. The piezometers were all installed to an approximate depth of 6 m below ground surface. No samples were collected for laboratory analysis (Racine *et al.*, 1996). However, some water elevations were measured as presented in the 1995 and 1996 CRREL reports.

6.3 Site Investigation Plan

A site investigation was conducted to collect data needed to evaluate closure requirements for OB/OD Pad (CH2M HILL, 1996b). To

achieve this purpose, specific objectives were defined that ultimately determined the scope and strategy of the fieldwork.

Very little data existed regarding the physical system of OB/OD Pad before the site investigation. Therefore, physical parameters such as thickness of OB/OD Pad and water table elevations were to be measured during the investigation. In addition, the pad, seven existing piezometers installed in 1995 by CRREL, and the newly installed monitoring wells were to be surveyed.

The following were objectives of this fieldwork:

Objectives of the fieldwork in 1996 were to assess potential pathways of subsurface migration of contaminants, delineate subsurface soil contamination, and install a series of monitoring wells.

- Assess potential pathways of subsurface migration of contaminants by evaluating the hydrogeologic properties of the gravel pad and the natural sediment. These properties include the presence of shallow soil stratigraphy, depth to groundwater, the groundwater flow direction, and groundwater flow gradients.
- Delineate subsurface soil contamination in areas where the greatest surface soil contamination was measured during the 1992 sampling event
- Install a series of monitoring wells that will be useful in evaluating the nature and extent of groundwater contamination and in future groundwater monitoring efforts

The scope of work for the OUC OB/OD Pad sampling effort included the following activities:

- Install and develop seven monitoring well clusters (one shallow and one deep well were installed at each cluster)
- Collect three soil samples from each of the seven monitoring well cluster locations during borehole advancement. The soil samples were to be analyzed for explosive compounds and explosive compound degradation products (Method 8330), total metals (Series 6000, 7000 metals), mercury (Method 7471/7470A), volatile organic compounds (Method 8020), and semivolatile organic compounds (Method 8270).
- Sample the newly installed monitoring wells and analyze the samples for the same parameters tested for in the soil analysis
- Measure depth to groundwater in each newly installed groundwater monitoring well
- Survey the pad to create a base map, and to locate existing piezometers and the newly installed monitoring wells

The methods were described in the work plan for these activities (CH2M HILL, 1996b).

6.4 Well Drilling and Sampling

Nine wells were drilled at OB/OD Pad between October 18, 1996, and October 27, 1996. The locations of the wells are shown in Figure 6-1. The well depth ranged from 4.05m in Well MW-1S to 11.7m in MW-6D. The work plan (CH2M HILL, 1996b) called for a cluster of wells at each site because it was believed an interface between the gravel pad and the underlying native soil existed (estimated at 2-m thick). The proposed deep wells would be advanced to approximately 1.5-m below the water table and completed with a 5-cm-diameter, 1.5-m-long prepacked screen at the bottom of the well. A second shallow well at each location would be advanced to just below the interface between the bottom of the gravel pad and expected underlying fine-grained sediments. The proposed shallow wells would be completed with a 1.5-m-long prepacked screen across the interface.

Clusters 1 and 5 were completed with both deep and shallow wells as proposed above. However, actual site physical conditions were different than expected in that there was no underlying fine-grained sediment below the pad. Therefore, shallow wells were not drilled at Locations 2, 3, 4, 6, and 7. Table 6-1 summarizes the sample locations and water table depth and elevation for each well.

A manually controlled inertial pump was used to develop, purge, and sample the groundwater monitoring wells. This collection method was designed to minimize turbidity in the sample and thus minimize the potential for contaminants sorbed onto fine particles present in the sample to be released during sample digestion. Development was

TABLE 6-1
Summary of Well Conditions

Well	Coordinates		Top of casing (m msl)	Depth of well (m bgs)	Screen Interval (m bgs)	Depth to Water (m below TOC)	Water Level Elevation (m msl)
	Northing (UTM meters)	Easting (UTM meters)					
MW-1S	6801019.1	355578.6	8.48	4.05	2.44 to 3.96	--	--
MW-1D	6801018.1	355576.1	8.16	7.41	5.79 to 7.32	6.31	1.85
MW-2D	6801073.7	355685.8	11.37	10.16	8.53 to 10.06	9.45	1.91
MW-3D	6801126.9	355684.1	11.57	10.36	8.14 to 9.66	9.63	1.93
MW-4D	6800942.4	355695.8	8.42	7.62	5.79 to 7.31	6.48	1.94
MW-5S	6801093.7	355790.6	12.68	8.23	4.42 to 5.94	--	--
MW-5D	6801091.6	355788.5	12.50	11.11	9.51 to 11.03	10.57	1.92
MW-6D	6801169.5	355782.0	12.94	11.68	10.05 to 11.58	10.97	1.96
MW-7D	6801033.4	355871.2	12.45	11.06	9.45 to 10.97	10.51	1.93

Note: -- = indicates no water level was measured. The screen interval of this shallow well was above the water table. Water levels were measured in November 1996.

stopped when the turbidity reached a maximum of 25 nephelometric turbidity units (NTU) or stabilized at higher NTUs in sediments that contained more materials than could effectively be removed by using low-flow methods. The same criteria were used for well purging before collecting groundwater samples for laboratory analysis. Because samples were not filtered, results for analyses of metals represent total metals.

The work plan also called for three soil samples to be collected at each proposed cluster: a surface sample, a sample at the interface between the OB/OD Pad and the native material, and a sample from halfway between the bottom of the pad and the water table. The absence of an interface changed the strategy for collecting a surface sample and a sample close to the top of groundwater. Samples were not homogenized in the field to prevent loss of volatiles.

Soil and groundwater samples were analyzed for the chemicals shown in Table 6-2.

6.5 Results

6.5.1 Hydrogeology

Samples collected during the 1996 site investigation drilling operations included sandy gravel with local intervals of gravelly sand, silty gravel, and silty sandy gravel, very similar to the glacial sediments present in road cuts leading to OB/OD Pad.

OB/OD Pad is a cleared flat area adjacent to ERF that has been routinely graded in the past by U.S. Army engineers to facilitate use and access. Grading of surface soils was conducted as recently as 1994 during construction of a dredge spoils retention basin. The hills adjacent to ERF are composed of glacial till. Samples collected during the 1996 site investigation drilling operations included sandy gravel with local intervals of gravelly sand, silty gravel, and silty sandy gravel. The recovered samples were very similar to the glacial sediments present in road cuts leading to OB/OD Pad. No interface was found between OB/OD Pad and underlying materials other than gradational variations in sediment where there were changes in the amount of sand-sized particles. Well logs with descriptions of collected samples are presented in Appendix E. Figure 6-1 provides a cross section of the subsurface environment based on logging performed during the October 1996 site investigation.

The water table isocontours measured in November 1996 are presented in Figure 6-2. On the basis of the one set of measurements collected, the water table appears generally flat with a small gradient between Wells MW-1D and MW-5D of 0.0004 to the southwest. It is believed that the groundwater movement patterns are strongly influenced by both the tides and the river. Seasonal water level measurements must be taken before a thorough hydrogeologic assessment can be made. Groundwater elevations were not measured from the existing piezometers installed in 1995 because they are screened above the water table and are dry.

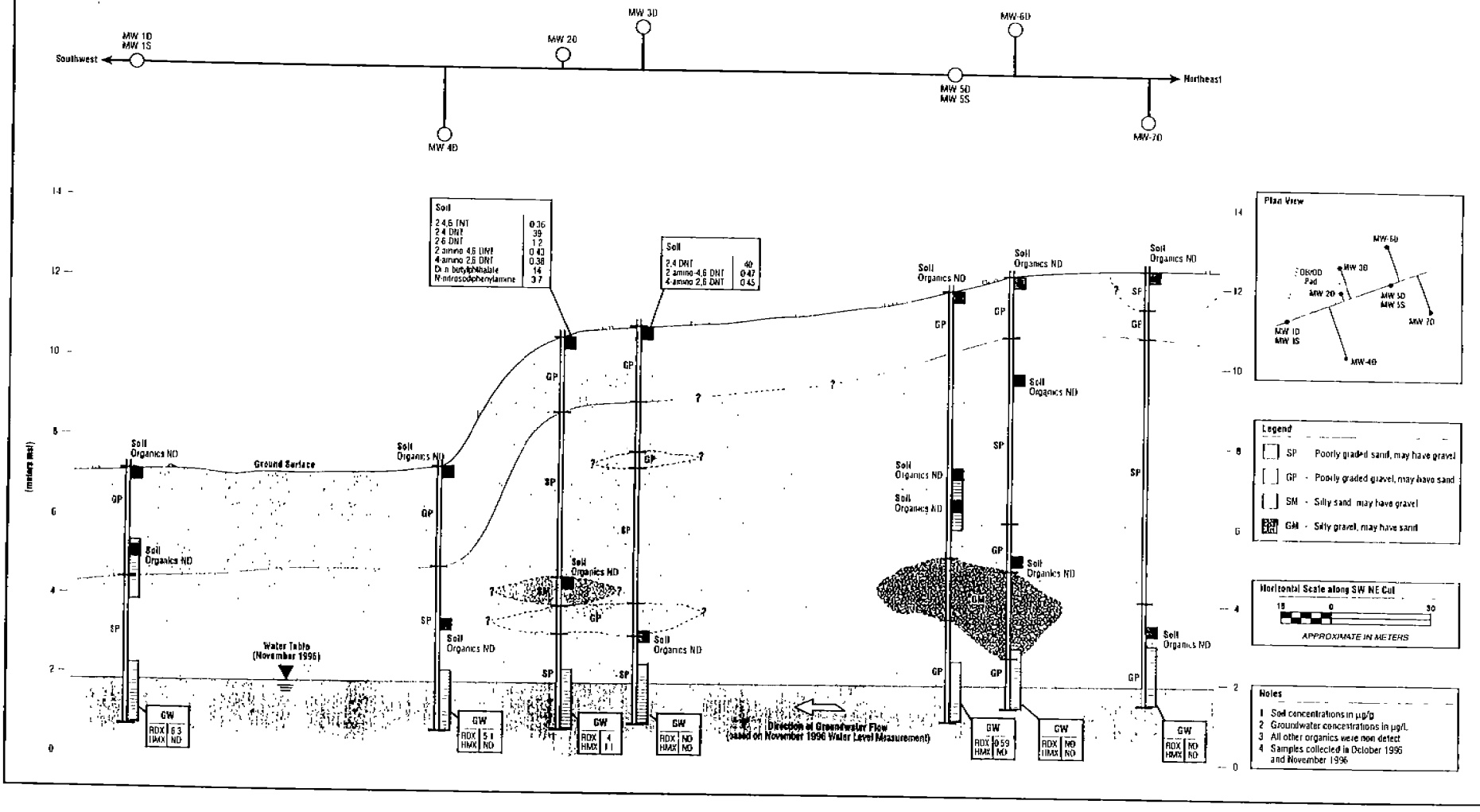


Figure 6-1

Lithologic Cross Section of OB/OD Pad

Operable Unit C, OB/OD Pad
Remedial Investigation
Fort Richardson, Alaska

CH2M HILL

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TABLE 6-2
Summary of Soil and Groundwater Chemical Analytes

VOCs	3-Nitroaniline
Benzene	4,6-Dinitro-2-methylphenol
Ethylbenzene	4-Bromophenyl phenyl ether
m,p-Xylene (Sum Of Isomers)	4-Chloro-3-methylphenol
o-Xylene	4-Chloroaniline
Toluene	4-Chlorophenyl phenyl ether
Explosives	4-Methylphenol (p-cresol)
1,3,5-Trinitrobenzene	4-Nitroaniline
1,3-Dinitrobenzene	4-Nitrophenol
2,4,6-Trinitrotoluene	Acenaphthene
2,4-Dinitrotoluene	Acenaphthylene
2,6-Dinitrotoluene	Anthracene
2-Amino-4,6-dinitrotoluene	Benzo(a)anthracene
2-Nitrotoluene	Benzo(a)pyrene
3-Nitrotoluene	Benzo(b)fluoranthene
4-Amino-2,6-dinitrotoluene	Benzo(g,h,i)perylene
4-Nitrotoluene	Benzo(k)fluoranthene
Hexahydro-1,3,5-trinitro-1,3,5-triazine	Benzoic acid
Methyl-2,4,6-trinitrophenylnitramine	Benzyl alcohol
Nitrobenzene	Benzyl butyl phthalate
Octahydro-1,3,5,7-tetranitro-1,3,5,7 tetrazocine	bis(2-chloroethoxy)methane
	bis(2-chloroethyl)ether
Metals	bis(2-chloroisopropyl)ether
Barium	bis(2-ethylhexyl)phthalate
Cadmium	Carbazole
Chromium	Chrysene
Silver	Di-n-butyl phthalate
Zinc	Di-n-octyl phthalate
Arsenic	Dibenzo(a,h)anthracene
Lead	Dibenzofuran
Mercury	Diethyl phthalate
SVOCs	Dimethyl phthalate
1,2,4-Trichlorobenzene	Fluoranthene
1,2-Dichlorobenzene	Fluorene
1,3-Dichlorobenzene	Hexachloro-1,3-butadiene
1,4-Dichlorobenzene	Hexachlorobenzene
2,4,5-Trichlorophenol	Hexachlorocyclopentadiene
2,4,6-Tribromophenol	Hexachloroethane
2,4-Dichlorophenol	Indeno(1,2,3-c,d)pyrene
2,4-Dimethylphenol	Isophorone
2,4-Dinitrophenol	N-nitrosodi-n-propylamine
2-Chloronaphthalene	N-nitrosodiphenylamine
2-Chlorophenol	Naphthalene
2-Methylnaphthalene	Nitrobenzene
2-Methylphenol (o-cresol)	Pentachlorophenol
2-Nitroaniline	Phenanthrene
2-Nitrophenol	Phenol
3,3'-Dichlorobenzidine	Pyrene

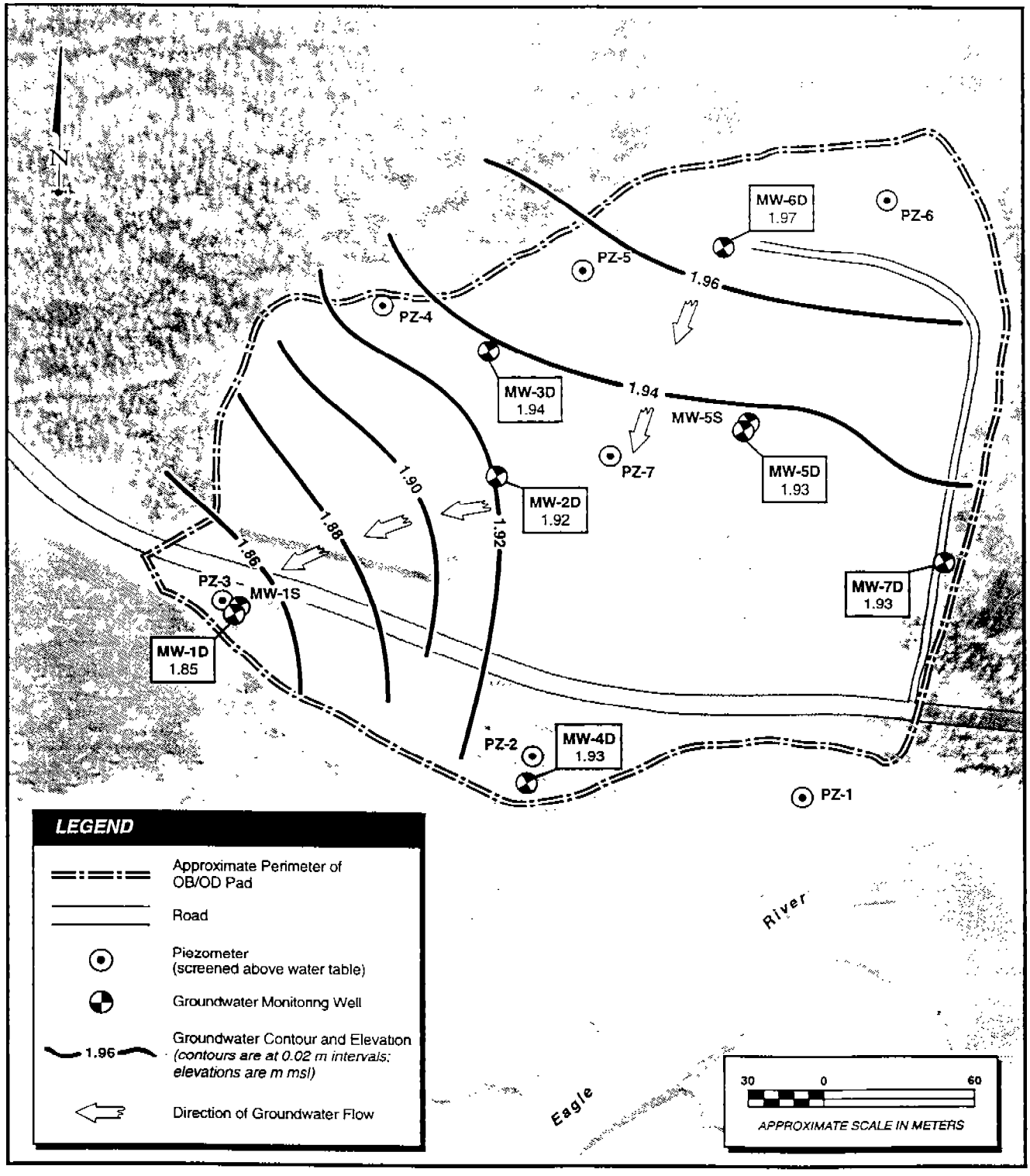


Figure 6-2

Groundwater Elevations During November 1996

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

CH2MHILL

138545 A2 40 Groundwater 05/13/97 ancjb

6.5.2 Environmental Samples

The soil and groundwater samples were analyzed according to the prescribed USEPA methods. A summary of the QC review is provided in the next section, which is followed by individual sections on the soil and groundwater results. Analytes are shown in Table 6-2.

6.5.2.1 Quality Control Review

The laboratory QC procedures for volatiles (Method 8020) and explosives (Method 8330) included five-point initial calibration, continuing calibration, laboratory control standards, surrogates, method blanks, matrix spikes, and matrix spike duplicates. For semivolatiles (Method 8270), QC procedures equivalent to USEPA Contract Laboratory Program (CLP) level of effort were maintained to include tuning, initial and continuing calibration, internal standards, surrogates, method blanks, and matrix spike/matrix spike duplicates. Laboratory-specific control limits were used. For total metals (Method 6010) and mercury (Method 7471/7470A), QC procedures equivalent to USEPA CLP were carried out to include initial and continuing calibration, initial calibration verification, calibration and method blanks, interference checks (for Method 6010), duplicates and spikes. The control limits were from CLP protocols. The project laboratory documented all QC data at a level equivalent to CLP documentation.

Soil samples were analyzed for volatile organic compounds, semivolatile organic compounds, inorganics (metals), and explosives. Most analytes were not detected in any samples. All detections were below the clean closure levels.

Data QA outside the laboratory was completed by the Department of Army, COE, North Pacific Division Laboratory. The associated chemical QA report is provided in Appendix D. The data QA process included review of the laboratory data as well as analysis of split samples by a QA laboratory, as detailed in Appendix D.

As described in Appendix D, semivolatiles, explosives, and metals data were found to be usable as reported by the laboratory. Volatiles data may be potentially biased low because of sample matrix effects noted in the report. Additional low bias for volatiles in soil samples also may have been introduced because of headspace noted in field containers. The headspace noted in the report is due to the nature of soil samples in the area of collection; mainly gravel samples were collected. Thus the headspace is representative of the natural site conditions. In addition, the low ambient temperatures present during soil sample collection may have minimized volatilization losses from sample media. Volatiles data were flagged "J" for qualitative usage.

6.5.2.2 Soils

Samples were analyzed for volatile organic compounds, semivolatile organic compounds, inorganics (metals), and explosives. Most analytes were not detected in any samples. A table of the complete analytical results is provided in Appendix E. Figures 6-3 and 6-4,

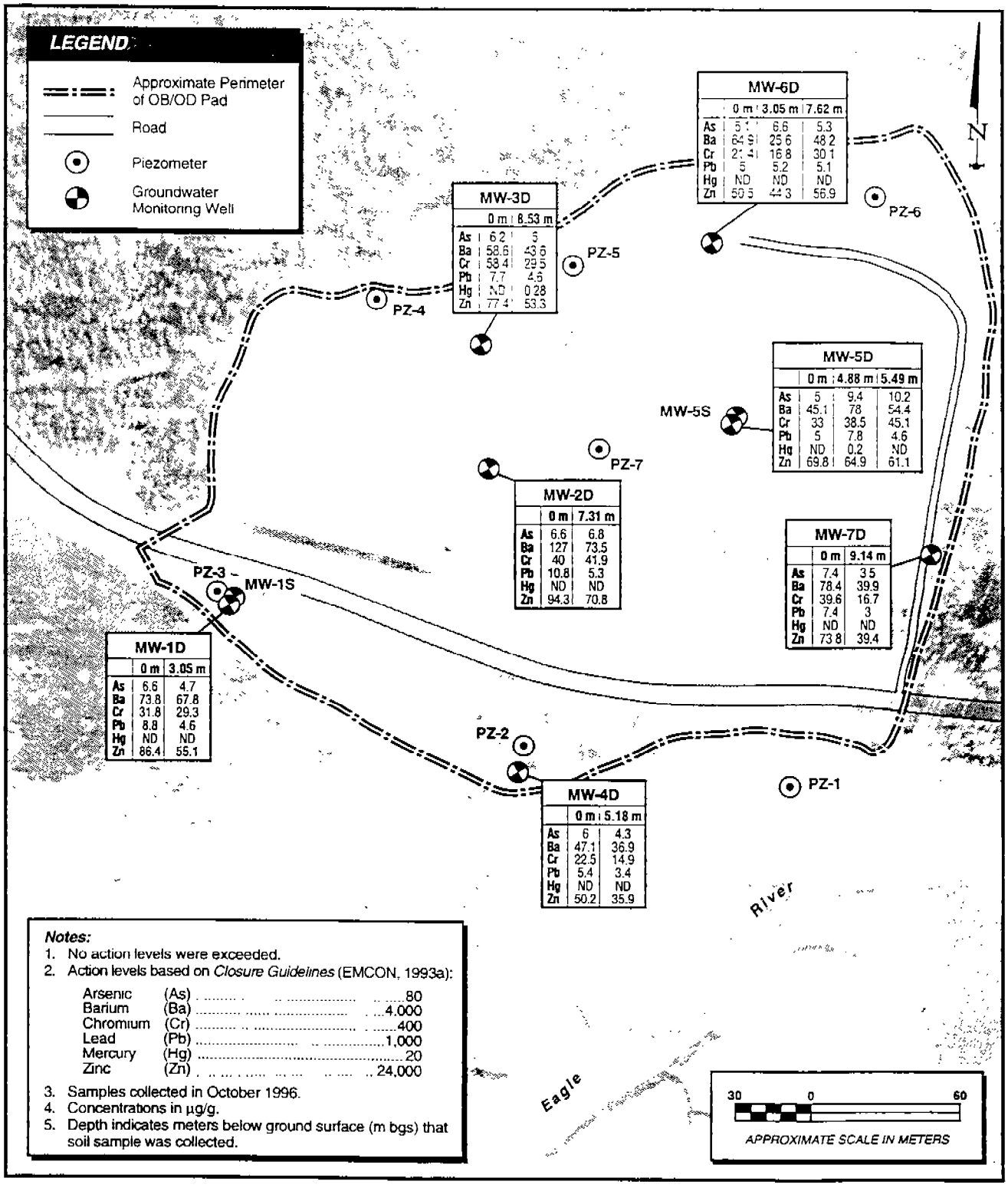


Figure 6-3

Metal Concentrations in Soil

Operable Unit C, OB/OD Pad
Remedial Investigation
Fort Richardson, Alaska

CH2MHILL

138545.A2.40 Metals 02/07/97 mcf/jp

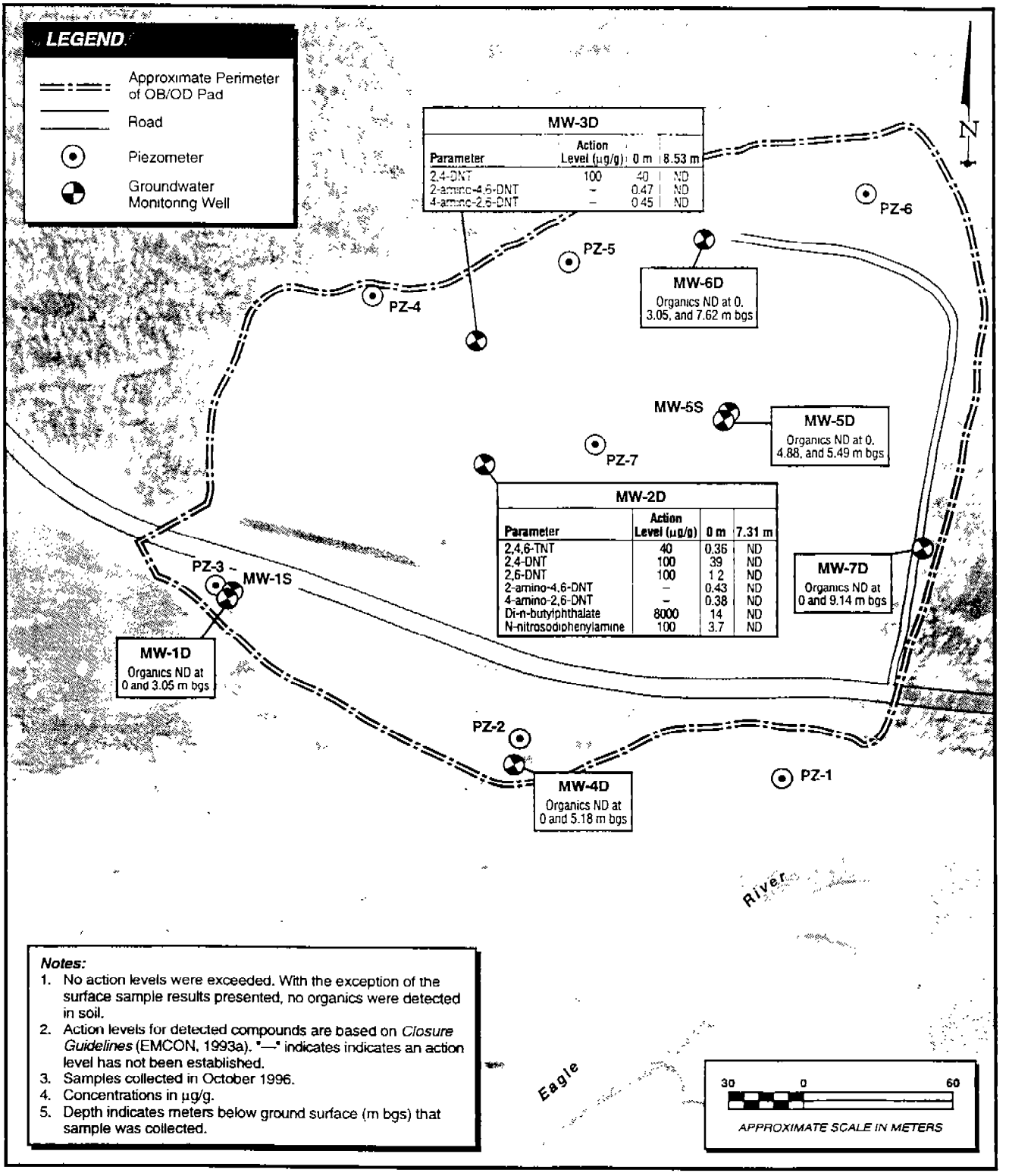


Figure 6-4

Organic Concentrations in Soil

Operable Unit C, OB/OD Pad
Remedial Investigation
Fort Richardson, Alaska

CH2MHILL

TABLE 6-3
Clean Closure Levels for Detected Chemicals in Soil

Parameter	Action Level[a] (µg/g)	Maximum Concentration in OB/OD Pad Samples (µg/g)	Number of Boreholes with Detected Constituents
2,4,6-TNT	40	0.36	1
2,4-DNT	100	40	2
2,6-DNT	100	1.20	1
2-Amino-4,6-DNT	none	0.47	2
4-Amino-2,6-DNT	none	0.45	2
Arsenic	80	10.2	7
Barium	4,000	127	7
Chromium	400	58.4	7
Lead	1,000	10.8	7
Mercury	20	0.28	2
Zinc	24,000[b]	86.4	7
Di-n-butylphthalate	8,000	14	1
N-nitrosodiphenylamine	100	3.7	1

[a]Source: EMCON, 1993.
[b]For zinc chloride (as total zinc).

respectively, summarize the detected inorganic and organic concentrations for each well. Table 6-3 summarizes the clean closure action levels compared to the maximum concentrations for the detected chemicals. The detected concentrations are considerably below the action levels for clean closure.

Several inorganics (metals) were found in the surface and subsurface soil samples. The detected concentrations of the inorganics are similar from well to well, and may represent a background condition for the type of material at the OB/OD Pad. Table 6-4 summarizes maximum metals concentrations from OB/OD Pad and representative values from reference areas in Alaska. The concentrations at OB/OD Pad are in the range of the reference values. Soil concentrations by sample are presented in Appendix E.

A few volatile and semivolatile organic compounds were detected in surface soil samples. As can be seen in Figure 6-4, the surface samples at Wells MW-2 and MW-3 contained a few compounds related to munitions. The 2,4-DNT detected in the explosives analysis (SW8330) was not confirmed in the semivolatiles analysis (SW8270) for Sample 96ED0200S2 collected at the borehole for Well MW-2D. In all cases, however, the detected concentrations were considerably below applicable clean closure action levels. No organic compounds were detected in subsurface samples collected during the site investigation.

TABLE 6-4
Sediment/Soil Concentrations from OB/OD Pad and Reference Areas (µg/g)

Chemical	Maximum in OB/OD Investigation	Fort Richardson and Elmendorf Mean Background[a]	Goose Bay Sediments[b]	Alaska Soils and Surficial Materials[c] (geometric mean, arithmetic mean)	Alaska Stream and Lake Sediments[c] (arithmetic mean)	Chugach Mountains[c] (geometric mean)	Average of Alaska Means[c] (geometric mean, arithmetic mean)	Arithmetic Mean of Eagle River Bridge and Cottonwood Slough Sediments[c]
Arsenic	10.2	5.46-7.2	15, 13	6.7, 9.6	17.3	--	6.7, 13	7
Barium	127	52.5-113.8	140, 110	595, 678	811	672	633, 744	190
Chromium	58.4	19.8-32	42, 21	50, 64	115	111	80, 89	56
Lead	10.8	5.3-10	12, 7.9	12, 14	12	25	18, 13	15
Mercury	0.28	--	<0.1, <0.1	--	--	--		0.097
Zinc	86.4	36.7-52.1	100, 86	70, 79	157	--	70, 118	133

[a]From Ecology and Environment, Inc., 1996.
[b]From Bouwkamp in Racine *et al.*, 1994.
[c]From ESE, 1990.

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6.5.2.3 Groundwater

Groundwater samples were analyzed for volatile organic compounds, semivolatile organic compounds, inorganics (metals), and explosives. Most of the analytes were not detected in any samples. A table of the complete analytical results can be found in Appendix E. Figures 6-5 and 6-6, respectively, summarize the detected inorganic and organic concentrations for each well.

In all cases, the detected concentrations of the inorganics are considerably below the groundwater action levels for clean closure. The metals concentrations also appear to be very similar to reference samples from Eagle River Valley.

Metals were detected in all monitoring wells, without much variation from well to well. Table 6-5 summarizes the maximum detected organic and inorganic concentrations and compares them with reference area values and the RCRA. In all cases, the detected concentrations of the inorganics are considerably below the groundwater action levels for clean closure (EMCON, 1993). With the possible exceptions of chromium and zinc, the metals concentrations also appear to be very similar to reference samples from Eagle River Valley.

During the November 1996 sampling event, metals analysis was not performed on groundwater from Well MW-6 because the sample bottle broke during shipment. The well was resampled and analyzed for metals in February 1997 following the same procedures outlined in the work plan. The analytical data are presented in Appendix E and Figure 6-5.

Only two organic compounds were detected in groundwater. RDX was detected in four of the seven wells, with a maximum concentration of 6.3 µg/L. This concentration is considerably below the RDX action level of 100 µg/L (shown in Figure 6-3). HMX was

TABLE 6-5
Detected Chemicals in Groundwater

	Concentration (µg/L)				
Parameter	Action Level[a]	Background[b]	Reference Area[c]	Maximum in OB/OD Pad Investigation	Number of Wells with Detects
RDX	100	–	none	6.3	4
HMX	2,000	–	none	1.1	1
Arsenic	50	1-9.9	5	5.4	3
Barium	2,000	0.50-510	42	49.5	6
Chromium	100	1-46	5	9.2	6
Lead	15	0.23-11,200	1	1	1
Mercury	2	0.10-0.64	2	0.2	1
Zinc	10,500[d]	1-1,300	6	16.3	6

[a]EMCON, 1993.
[b]Filtered metals Fort Richardson background concentrations, from Ecology and Environment, 1996.
[c]Eagle River Valley groundwater from ESE, 1990.
[d]For zinc chloride (as total zinc).

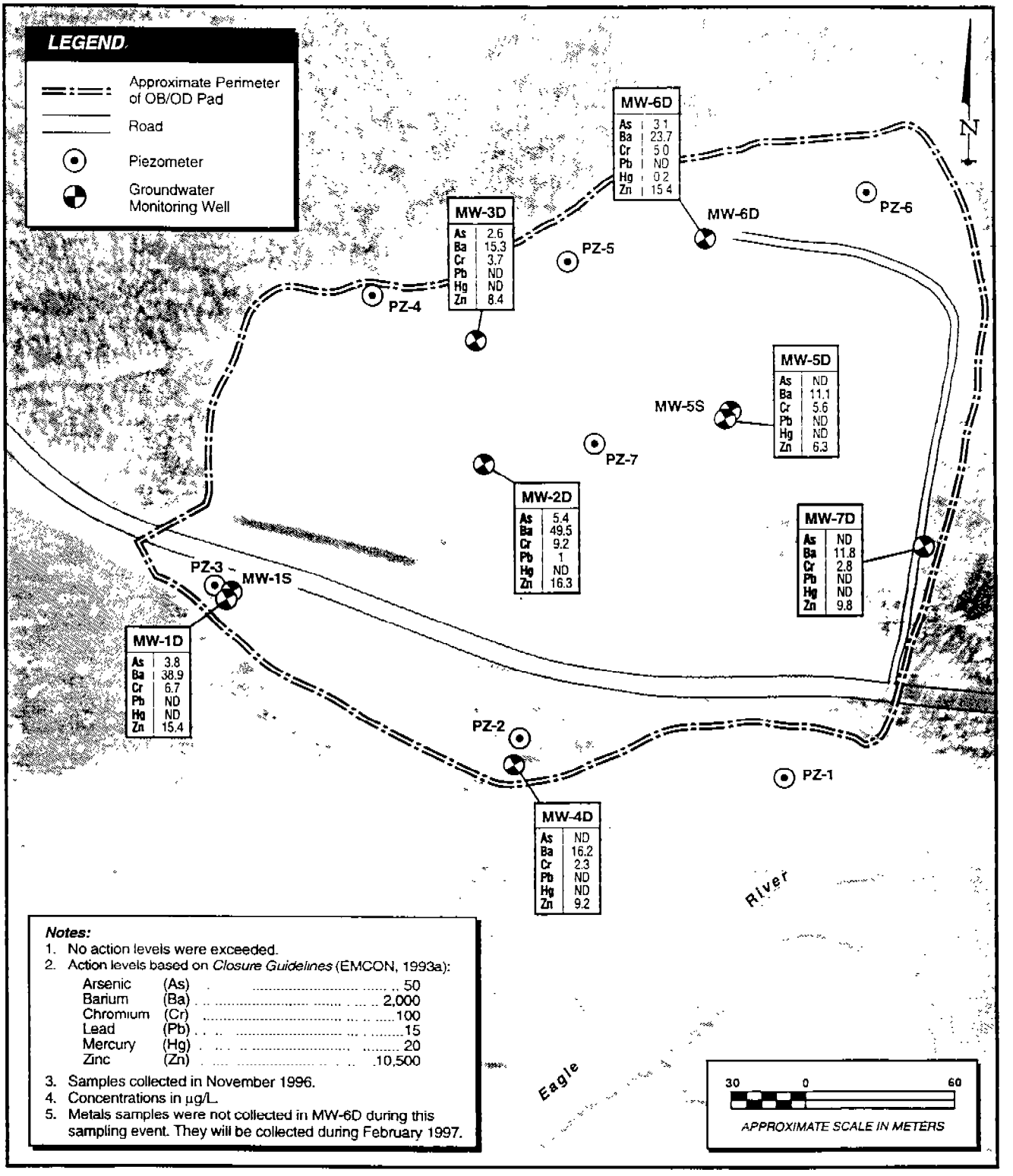


Figure 6-5

Metal Concentrations in Groundwater

Operable Unit C, OB/OD Pad
Remedial Investigation
Fort Richardson, Alaska

CH2M HILL

138545 A2 4D GW-Metals 05/23/97 anc/b

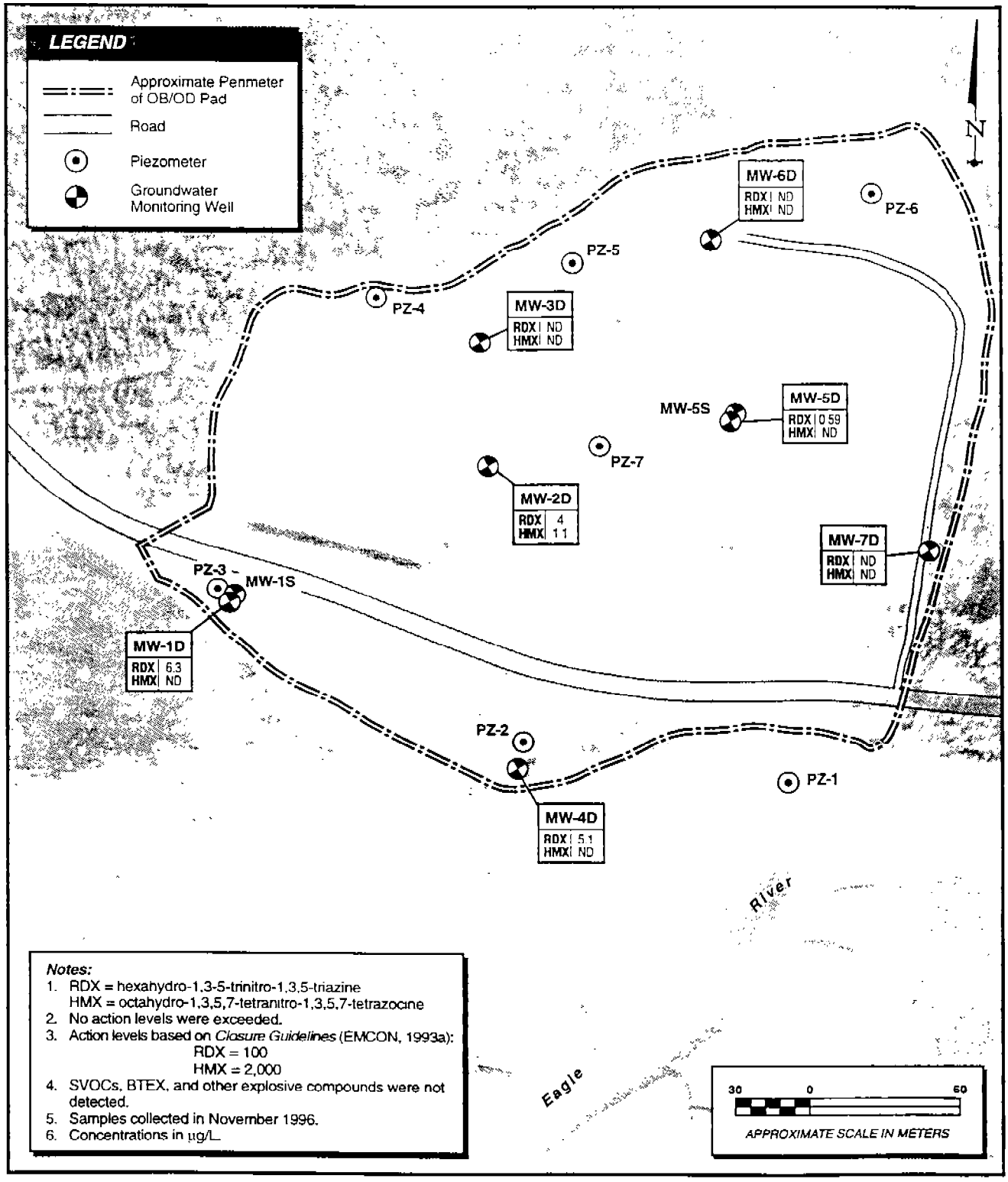


Figure 6-6

Organic Concentrations in Groundwater

Operable Unit C, OB/OD Pad
Remedial Investigation
Fort Richardson, Alaska

CH2MHILL

138545 A2.40 GW Organics 02/07/97 ancjb

detected only in Well MW-2D (natural and duplicate samples), and the maximum concentration was 1.1 µg/L. This concentration also is considerably below the action level of 2,000 µg/L.

The monitoring wells were assigned unique identification numbers by the COE for reference. The following identification numbers were assigned, and a metal plate with each identification number was affixed to each well at the conclusion of the site investigation:

Monitoring Well	COE Identification Number
MW-1S	AP 3763
MW-1D	AP 3764
MW-2D	AP 3765
MW-3D	AP 3766
MW-4D	AP 3767
MW-5S	AP 3768
MW-5D	AP 3769
MW-6D	AP 3770
MW-7D	AP 3771

6.6 Conceptual Site Model

OB/OD Pad is a graded clearing along ERF. It was engineered in glacial till composed of sandy gravel and gravelly sand. The apparent groundwater gradient, based on measurements from the site investigation, is very shallow.

During the well drilling in this study, coarse-grained material was observed in all borings. A layer of gravel, generally 2 to 4 m in depth, overlaid poorly graded sand where the groundwater monitoring wells were screened. Although the gravel was loose at the surface its density increased with depth. Gravel was observed both at the surface, and within the sand formation. The subsurface composition was a consistent sandy gravel material through the well depths drilled. The only gradational variations in sediment were changes in the amount of sand-sized particles from coarse to medium-coarse. Although no impervious layers were detected, silty gravel was observed at an elevation of approximately 4 m msl in three borings.

Organics were not detected in any other surface or subsurface samples, suggesting that surface contamination is very low and that contaminants are not being sorbed to soil.

The coarse-grained material suggests that precipitation infiltrates freely though the OB/OD Pad surface to the groundwater table. Low concentrations of organics, below action levels, were detected in two surface soil samples and four monitoring wells. Organics were not detected in any other surface or subsurface samples, suggesting the following:

- Surface contamination is very low. Contaminants are present below action levels.
- Contaminants are not being sorbed to soil. Very limited low plasticity material was observed in the subsurface.

It is likely that the limited presence and low concentrations of contaminants on the surface are the result of regular grading of OB/OD Pad.

Groundwater elevations ranged from about 1.85 to 1.96 m msl (6 m to 11 m below ground surface). On the basis of measurements from the site investigation, the apparent groundwater gradient is very shallow to the southwest.

The soil and groundwater samples were analyzed for volatiles, semivolatiles, metals, and explosives. There were very few detected chemicals, however. The metals in the soil and groundwater samples were reasonably consistent from well to well, and appeared to be similar to reference area concentrations, with the possible exception of chromium and zinc in groundwater. Although a few concentrations of munitions-related compounds were detected, all concentrations were below the action levels for clean closure.

6.7 Conclusions

Closure of OB/OD Pad will be conducted by Fort Richardson under the CERCLA program to meet or exceed the intent of the RCRA. The report *Demolition Area Number One Closure Guidelines, Fort Richardson, Alaska* (EMCON, 1993) describes actions that may be taken to close OB/OD Pad in accordance with RCRA. The guidelines were prepared to meet the requirements of 40 CFR 264, Subpart G, and 40 CFR 264, Subpart X. Procedures are included in the guidelines for demonstrating clean closure or closure with post-closure care. The 1996 site investigation was completed to determine whether clean closure can be demonstrated at OB/OD Pad or a post-closure care plan will need to be prepared to meet post-closure requirements contained in 40 CFR, Parts 264 and 270.

Analytical data for soil samples collected during the 1996 site investigation indicate that limited residual contamination exists in surface soil at levels below the action levels for clean closure presented in the guidelines.

The objective of the site investigation at OB/OD Pad was to characterize existing soil and groundwater contamination from wastes and constituents expected to be present at the unit as a result of past OB/OD activities. As discussed in Sections 6.5 and 6.6, analytical data for soil samples collected during the 1996 site investigation indicate that limited residual contamination exists in surface soil at levels below the action levels for clean closure presented in the guidelines. Levels of contaminants detected in groundwater also were below action levels for clean closure. As discussed in Section 8, the ecological and human health risks associated with OB/OD Pad are very low.

On the basis of results of the 1996 site investigation at OB/OD Pad and an evaluation of data collected during previous studies at this site, OB/OD Pad will meet clean closure according to the procedures outlined in the 1993 guidelines. These procedures include the following:

- Complete a sweep of the entire site by EOD personnel to identify and remove any unexploded ordnance present.
- Install a soil cap over the site to prevent direct contact with any residual surface contamination that may exist and to minimize wind and surface water transport of existing surface materials.
- Revegetate the cap to minimize potential wind and water erosion.
- Include engineering controls in the cap design and construction to prevent surface water run-on and runoff.

The closure guidelines include preliminary specifications for cap design for OB/OD Pad. Fort Richardson also may consider the use of the ERF dredge spoils currently contained within the retention basin at OB/OD Pad for use as cap cover material.

Section 5.2.11 of the closure guidelines includes notification, documentation, and record keeping requirements applicable to closure of OB/OD Pad. These activities will be conducted to complete the clean closure of OB/OD Pad in accordance with RCRA.

SECTION 7

Comparison of ARARs

7.1 Introduction

A preliminary ARARs evaluation was completed in 1994 as part of the *Eagle River Flats Comprehensive Evaluation Report* (CER) (CH2M HILL, 1994). Since publication of the CER, WP has been identified as the COC at ERF. Since publication of that document, COCs at ERF have been refined. In addition, Fort Richardson has been formally listed on the NPL and the ERF area has been incorporated into OUC along with the OB/OD Pad area.

Closure of OB/OD Pad under the CERCLA program and compliance with ARARs will be conducted to meet or exceed the intent of RCRA.

OB/OD Pad has been identified as an SWMU under the federal RCRA. A December 1993 document titled *Demolition Area Number One Closure Guidelines, Fort Richardson, Alaska* (EMCON, 1993), outlines investigations and documentation required for closure of OB/OD Pad in accordance with RCRA. The site investigation completed at OB/OD Pad was conducted to meet or exceed the intent of RCRA. Similarly, closure of OB/OD Pad under the CERCLA program and compliance with ARARs will be conducted to meet or exceed the intent of RCRA.

7.2 Potential ARARs

Remedial actions, removal actions, and IRAs conducted at a site must be designed to comply with federal, state, and local environmental laws, regulations, standards, requirements, criteria, and limits that are legally applicable or relevant and appropriate to the situation. Potential ARARs are identified in this document for selection of actual ARARs by the lead agencies working on the OUC process. As other requirements are identified during the selection of removal, remedial, or interim remedial actions, they will be included and the list refined.

Section 121 of SARA established four standards that govern selection of remedial action. USEPA is required to select a remedial action that accomplishes the following:

- Protects human health and the environment
- Is cost effective
- Uses permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable
- Attains, at the least, federal ARARs and more stringent state ARARs promulgated under state environmental or facility siting

laws for any material remaining onsite at the conclusion of remedial action

A requirement is applicable if the remedial action or circumstance at the site satisfies all jurisdictional prerequisites of that requirement.

ARARs are either applicable or relevant and appropriate. Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a particular CERCLA site. For a requirement to be applicable, the remedial action or the circumstance at the site must satisfy all jurisdictional prerequisites of that requirement. For example, the minimum technology requirement for hazardous waste landfills under the federal RCRA would apply only if a new hazardous waste landfill (or an expansion of an existing hazardous waste landfill) was built on a site.

For onsite activities at NPL sites, a distinction is made between substantive and administrative requirements. Onsite actions must comply with those substantive requirements that pertain directly to actions or conditions in the environment, but are exempt from administrative requirements such as permits and record keeping. Onsite actions, however, must be conducted according to the intent of such administrative requirements.

The relevance and appropriateness of a requirement can be judged by comparing factors such as the characteristics of the remedial action, the hazardous substances in question, and the physical characteristics of the site with those characteristics addressed by the requirement.

An ARAR is "relevant and appropriate" if, although it may not meet the definition of "applicable," it is promulgated under federal or state law and still addresses problems or situations sufficiently similar to those encountered at the CERCLA site so that use of the ARAR is well-suited to the particular area. The relevance and appropriateness of a requirement can be judged by comparing factors such as the characteristics of the remedial action, the hazardous substances in question, and the physical characteristics of the site with those characteristics addressed by the requirement. For example, RCRA management requirements for hazardous waste would not be applicable to wastes that could not be strictly classified as hazardous wastes. If those wastes are similar to hazardous wastes, however, the RCRA requirements could be relevant and appropriate to management of the wastes.

The USEPA has grouped potential ARARs into three categories:

- **Ambient or chemical-specific requirements**–numerical values or methodologies based on health or risk and technology that, when applied to site-specific conditions, establish an acceptable amount or concentration of contaminant that may be found in, or discharged to, the ambient environment
- **Location-specific requirements**–special requirements or standards that apply because of the site location

- **Performance, design, or other action-specific requirements**– limitations or requirements that apply to specific technologies or activities, particularly with respect to hazardous waste

ARARs are not the only factors that determine what happens at a contaminated site; they represent the minimum requirements for which an action must be taken. In some instances, for example, because of multiple contaminants or pathways, compliance with ARARs will not achieve an acceptable degree of protection. In such cases, nonpromulgated criteria, advisories, and other guidance need to be considered. Therefore, cleanup goals are defined by health-based risk levels of the contaminant, ARARs, environmental impacts, and, possibly, to-be-considered (TBC) criteria or guidelines. The health-based risk levels developed for cleanup goals must consider the potential future uses of the site. In most cases, for example, the most conservative future use of a contaminated site would be a civilian residential scenario. According to U.S. Army regulations, future uses of ERF and OB/OD Pad will remain restricted to ordnance-related activities; these regulations will also be considered, along with the ARARs and TBCs, for determining cleanup goals at OUC.

ARARs represent the minimum requirements for which an action must be taken.

7.2.1 Chemical-Specific ARARs

The first step in identifying chemical-specific ARARs is identifying the COCs. On the basis of all available information collected to date regarding the COCs associated with past activities in ERF, WP has been identified as the primary COC and is the focus of the current investigations and treatability studies in that area. Additional COCs for the OB/OD Pad area, based on information obtained from soil surface samples collected by AEHA in 1992 and results of the 1996 site investigation are included. If additional analytical data from future sampling investigations determine additional COCs are present in OUC and pose a risk to humans and ecological receptors, the list of COCs and the chemical-specific ARARs will be refined.

The first step in identifying chemical-specific ARARs is identifying the COCs.

Potential chemical-specific ARARs for the ERF and OB/OD Pad areas are listed in Table 7-1. Chemical-specific ARARs for ERF include only WP; the remaining ARARs listed address COCs at OB/OD Pad that were identified as a result of the 1996 site investigation and surface soil samples collected in 1992 by AEHA. The media of concern include both water and soil. Soil cleanup standards for individual chemical contaminants (from sources other than underground storage tanks) have not been promulgated under either federal or State of Alaska laws. Numerical drinking water and water quality standards are included in regulations for several COCs. On the basis of results of groundwater sampling at OB/OD Pad, concentrations of contaminants do not pose a risk to groundwater; therefore, chemical-specific drinking water and water quality standards for surface water only are included as ARARs for the OB/OD Pad. The ARARs list

TABLE 7-1
Chemical-Specific Potential Applicable or Relevant and Appropriate Requirements

Chemical Name	Potential ARARs					
	CWA Ambient Water Quality Criteria for Protection of Human Health		CWA Ambient Water Quality Criteria for Protection of Aquatic Life		SDWA	RCRA
	Water and Fish Ingestion (µg/L)[a]	Fish Consumption Only (µg/L)[a]	Freshwater Acute/Chronic (µg/L)[a]	Marine Acute/Chronic (µg/L)[a]	MCLs (µg/L)	TCLP for Hazardous Waste Identification (mg/L)
EBR ARARs						
White phosphorus	--	--	--		--	--
OB/OD Pad ARARs						
2-Amino-4,6-DNT	--	--	--	--	--	--
4-Amino-2,6-DNT	--	--	--	--	--	--
Arsenic	0.018	0.14	360/190	69/36	50[b]	5.0
Barium	--	--	--	--	2,000[c]	100.0
Chromium (III)	--	--	1,700/210	--	100[d]	5.0
Chromium (VI)	--	--	16/11	1100/50	100[d]	5.0
Di-n-butylphthalate	2,700	12,000	--	--	--	--
2,4-DNT	0.11	9.1	--	--	--	0.13
2,6-DNT	--	--	--	--	--	--
HMX	--	--	--	--	--	--
Lead	--	--	82+/3.2+	220/3.2	15*	5.0
Mercury	0.144	0.146	2.4/0.012	2.1/0.025	2.0[d]	0.2
N-nitrosodiphenylamine	--	--	--	--	--	--
RDX	--	--	--	--	--	--
2,4,6-TNT	--	--	--	--	--	--
Zinc	--	--	120[a]/110	95/86	5,000[e]	--

[a]57 FR 60847 (December 22, 1992); "Applicable Alaskan Receiving Water Quality Criteria That Include State-Adopted and Federally-Imposed Numbers" (ADEC, August 21, 1995)
[b]50 FR 46936 (November 13, 1985).
[c]56 FR 30266 (July 1, 1991).
[d]56 FR 3526 (January 30, 1991).
[e]Secondary MCL; 53 FR 31516 (August 18, 1988); 56 FR 3526 (January 30, 1992); 18 AAC 60; Rev. 6/91.

Notes:
* = Action level for lead is 15 µg/L; action level for copper is 1,300 µg/L
µg/L = Parts per billion.
-- = Not available.
+ = Hardness dependent criteria.

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established concentration limits by media for the hazardous substances, pollutants, or contaminants.

Concentration limits for potential chemical-based ARARs were compiled from the following sources:

- **Safe Drinking Water Act (SDWA) and the National Primary Drinking Water Regulations (40 CFR 141)**–These regulations establish enforceable maximum contaminant levels (MCLs) for inorganic and organic compounds in public drinking water systems. In addition, nonenforceable MCL goals have been set at the level at which no known or anticipated adverse health effects are expected, assuming an adequate margin of safety. Although the OUC area does not contain drinking water sources and groundwater contamination is not considered at risk for OB/OD Pad COCs, MCLs are often used as cleanup action levels for surface water contaminants and may be considered potential ARARs.

- **Resource Conservation and Recovery Act and RCRA Groundwater Protection Standards (40 CFR 260-270)**–RCRA waste characteristics, such as reactivity and the toxicity-characteristic leaching procedure (TCLP) concentration limits, are used in determining if waste generated on a site is hazardous, as defined in 40 CFR 261. Potential ARARs for the OB/OD Pad area COCs may include RCRA standards for identification and management of investigation-derived wastes or remediation wastes generated at the site. Additional potential RCRA ARARs for ordnance areas are included in 40 CFR 265.382 for the open burning of waste explosives.

- **Clean Water Act (CWA) Water Quality Criteria**–The applicability or relevance and appropriateness of water quality criteria as potential ARARs are dependent on the designated use or uses of the water. The water quality criteria for environmental protection may be ARARs for OUC because surface waters at ERF support migratory bird feeding and resting areas and fish species. Where available, ambient water quality criteria (AWQC) for human health and freshwater and saltwater organisms are cited, according to the most recent *Federal Register* (FR) updates and published ADEC water quality regulations (Title 18, *Alaska Administrative Code*, Chapter 70 [18 AAC 70]).

- **Alaska Drinking Water Regulations (18 AAC 80)**–These regulations establish maximum contaminant concentrations (MCCs) for organic and inorganic contaminants in public water systems. These concentrations are equivalent to, or more stringent than, the SDWA MCLs and, therefore, are potential ARARs. Although OUC does not contain a public water system and groundwater does not appear to be at risk from OB/OD Pad

COCs, the MCCs may be used as cleanup action levels and, therefore, are considered potential ARARs.

- **Alaska Water Quality Standards (18 AAC 70)**–These standards apply to groundwater and surface water and establish criteria for protected classes of water use. In addition, Alaska has adopted a nondegradation policy for waters of quality that is higher than quality in the criteria. General water-quality criteria potentially applicable to OUC are summarized in Table 7-2. Where water is used for more than one purpose, the most stringent water-quality criteria ARARs shall be used. Eagle River is protected for all water use classes. Specific criteria applicable to Eagle River will depend on the parameter being evaluated. In most cases the "Criteria for Growth, Propagation of Fish, Shellfish, other Aquatic Life and Wildlife" are the most stringent and, therefore, applicable to OUC.

- **Alaska Oil Pollution Regulations (18 AAC 75)**–These regulations set requirements for discharge reporting, cleanup, and disposal of hazardous substances for spills of hazardous substances to Alaska's land or water within specified time frames. ADEC's broad definition of "hazardous substance" includes constituents of explosives as well as oil and other petroleum products. To date, petroleum products have not been identified as primary COCs at OUC, although small quantities of diesel fuel were reported to be used during past OB/OD activities at OB/OD Pad. Onsite remedial activities may involve the use of equipment that uses fuel products, such as diesel. Discovery and cleanup of spills of oil or hazardous substances regulated by the State of Alaska that may result from onsite remedial activities at OUC will need to consider these regulations as ARARs.

- **Alaska Solid Waste Management Regulations (18 AAC 60)**–These regulations set requirements for the management of solid waste, including hazardous waste. Waste must be managed to prevent violation of the Alaska water quality standards (18 AAC 70).

- **Alaska Hazardous Waste Management Regulations (18 AAC 62)**–These regulations apply to hazardous waste generators, transporters, and owners or operators of treatment, storage, or disposal facilities. These regulations are potential ARARs for the offsite transportation, storage, and disposal of waste materials generated at the site. Alaska references the federal RCRA regulations as the state standards in 18 AAC 62.

Location-specific ARARs are restrictions developed on the basis of the concentration of hazardous substances or the conduct of activities in specific locations.

7.2.2 Location-Specific ARARs

Location-specific ARARs are restrictions developed on the basis of the concentration of hazardous substances or the conduct of activities in specific locations. These ARARs may restrict or preclude certain

TABLE 7-2
Alaska Water Quality Standards (18 AAC 70.020)

	Class (1)(A)(i) Water Supply (Drinking)	Class (1)(A)(ii) Water Supply (Agriculture)	Class (1)(B)(ii) Water Recreation (Secondary Recreation)	Class (1)(C) Aquatic Life and Wildlife
Fecal coliform (FC) bacteria	Surface mean shall not exceed 20 FC/100 mL with not more than 10% of the samples exceeding 40 FC/100 mL Groundwater mean shall be less than 1 FC/100 mL (MFT) or <3 FC/100 mL (MPN).	Mean shall not exceed 200 FC/100 mL with not more than 10% of the samples exceeding 400 FC/100 mL.	Same as Class (1)(A)(ii)	Not applicable
Dissolved oxygen (DO)	DO ≥ 4 mg/L (surface water only)	DO ≥ 3 mg/L (surface water only)	DO ≥ 4 mg/L	DO > 7 mg/L Total not to exceed 110% of saturation at any sampling point.
pH	6.0 ≤ pH ≤ 8.5 Shall not vary by more than 0.5 pH units from natural	5.0 ≤ pH ≤9.0	5.0 ≤ pH ≤ 9.0	6.5 ≤ pH ≤9.0 Shall not vary more than 0.5 pH units from natural.
Turbidity	Shall not exceed 5 NTU above natural when the natural <50 NTU and no more than 10% increase when the natural is >50 NTU, not to exceed a maximum increase of 25 NTU	Shall not cause detrimental effects	Shall not exceed 10 NTU above natural when the natural <50 NTU and no more than 20% increase when the natural is >50 NTU. Not to exceed an increase of 15 NTU.	Shall not exceed 25 NTU above natural conditions.
Temperature	Shall not exceed 15°C	Shall not exceed 30°C	Not applicable	Shall not exceed 20°C at any time; shall not exceed 15°C in migration routes or rearing areas; shall not exceed 13°C in spawning areas or egg and fry incubation.

TABLE 7-2
Alaska Water Quality Standards (18 AAC 70.020)

	Class (1)(A)(i) Water Supply (Drinking)	Class (1)(A)(ii) Water Supply (Agriculture)	Class (1)(B)(ii) Water Recreation (Secondary Recreation)	Class (1)(C) Aquatic Life and Wildlife
Dissolved inorganic substances	TDS shall not exceed 500 mg/L chlorides or sulfates shall not exceed 200 mg/L	TDS shall not exceed 1000 mg/L Sodium absorption ration <2.5 Sodium percentage less than 60% Residual carbonate <1.25 mg/L Boron <0.3 mg/L	Not applicable	TDS shall not exceed 1500 mg/L. Increase shall not exceed one-third of the natural.
Sediment	No measurable increase above natural	Shall not exceed 200 mg/L	Shall not pose hazards	Sediment loads shall not cause adverse effects on aquatic animal or plant life, their reproduction, or habitat
Toxic or deleterious substances	Shall not exceed Alaska MCCs or USEPA water quality criteria	Same as Class(1)(A)(i)	Shall not pose hazards	Individual substances shall not exceed applicable USEPA water quality criteria or ADEC MCCs; toxic effects on aquatic life prohibited; undesirable odor or taste to fish due to substances prohibited.
Petroleum hydrocarbons, oil, and grease	Shall not cause a visible sheen or impart odor or taste	Shall not cause a visible sheen on the surface	Shall not cause a film, sheen, or discoloration on the surface or floor of the water body or adjoining shoreline	Ta_qH in water column may not exceed 15 µg/L; TAH may not exceed 10 µg/L; no deleterious effects to aquatic life; no sheens or discoloration to surface waters.

Notes:
mL = Milliliter.
mg/L = Milligrams per liter.
NTU = Nephelometric turbidity units.
Ta_qH = Total aqueous hydrocarbon.
TAH = Total aromatic hydrocarbon.
TDS = Total dissolved solids.
µg/L = Micrograms per liter.

remedial actions, or they may apply only to certain portions of OUC. Location-specific factors that may add ARARs include sensitive habitats, floodplains, wetlands, endangered species habitat, fault locations, historic or archeological resources, and oceans, rivers, and coastlines.

Among significant potential requirements for remedial activities at OUC are floodplain, wetlands, and wildlife requirements.

The most significant of the potential requirements for remedial activities at OUC are the floodplain requirements under RCRA and Executive Order 11988, "Protection of Floodplains"; the wetlands requirements under Executive Order 11990, "Protection of Wetlands"; the Migratory Bird Treaty Act; the Bald Eagle and Golden Eagle Protection Act; and the Fish and Wildlife Coordination Act. ARARs for the protection of wetlands are included in Sections 401 and 404 of the federal CWA.

Under RCRA, any site that is located in a 100-year floodplain and can be classified as a hazardous waste disposal area will have to be closed in a manner that prevents washout of wastes during a 24-hour, 25-year flood event. Remedial actions that take place in a floodplain (100 year or otherwise) will be subject to Executive Order 11988, "Protection of Floodplains." This order requires that actions in floodplains avoid adverse effects, minimize potential harm, and restore and preserve natural and beneficial values.

Remedial actions that affect wetlands will have to comply with Executive Order 11990, "Protection of Wetlands." This order requires action to minimize the destruction, loss, or degradation of wetlands. No dredged or fill materials may be disposed of in wetlands without a CWA Section 404 permit from the COE. Section 401 of the CWA allows for state consistency determinations on the Section 404 permits; in Alaska, the ADEC is responsible for issuing the consistency determinations. Before Fort Richardson was included on the NPL, Nationwide Permit 38, issued by the COE, and an accompanying Jurisdictional Determination authorized the dredge and fill activities at ERF and OB/OD Pad associated with studies conducted in the ERF wetlands.

The Fish and Wildlife Coordination Act requires that USFWS and the National Marine Fisheries Service be consulted regarding any action that modifies a stream or river or other water of the United States. The intent of this regulation is to protect fish and wildlife that may be adversely affected by changes in the quality or quantity of water in a river, stream, or other water body. USFWS is currently a member of the Eagle River Flats Biological Technical Assistance Group and is an active participant in studies and decisions affecting ERF.

The *Fort Richardson Natural Resource Plan* (Gossweiler, 1984) and the *Draft Integrated Natural Resources Plan, 1997-2001, U.S. Army Alaska* Vol. 2, Fort Richardson (Center for Ecological Management of Military Lands and Gene Stout and Associates, 1996) were reviewed for

preliminary information pertaining to threatened or endangered species and habitat. No threatened or endangered plant or animal species are resident on Fort Richardson. In the *Draft Integrated Natural Resources Plan,* the U.S. Army identified avian species of special concern for wildlife management on Fort Richardson. These species are seen on Fort Richardson and include the American peregrine falcon, bald eagle, golden eagle, and trumpeter swan.

Table 7-3 summarizes potential location-specific ARARs identified for OUC.

7.2.3 Action-Specific ARARs

Action-specific ARARs indicate how a selected alternative must be achieved.

Action-specific ARARs are additional requirements that would apply to a specific remedial action. Different remedial ARARs are identified depending on the interim remedial actions or remedial actions discussed during the overall site remediation process. Action-specific requirements do not in themselves determine the remedial alternatives; they indicate how a selected alternative must be achieved. The action-specific ARARs identified during the remedial action feasibility process for Fort Richardson will need to be further refined during remedial design, when specific information becomes available. Because of the physical hazards of unexploded ordnance present at OUC, worker health and safety regulations are considered the most important ARARs for site work.

The OB/OD Pad area adjacent to Area C in ERF is a potential source of munitions residue leachate entering ERF. Because OB/OD Pad area is a regulated RCRA SWMU, remedial activities affecting that area will need to consider RCRA closure and corrective action regulations as potential ARARs.

USEPA has recently promulgated regulations specifically for hazardous waste generated from military munitions and for the transportation of these wastes for both military and nonmilitary properties. The regulations were finalized February 12, 1997, and are included in the action-specific ARARs for regulations cited in 40 CFR Parts 260-266 and 270.

Table 7-4 summarizes potential action-specific ARARs identified for OUC.

7.3 To Be Considered Criteria or Guidelines

Other types of information may be useful for designing remedies or may be necessary for determining what is protective at a specific contaminated area.

Although ARARs are promulgated, enforceable requirements, other types of information may be useful for designing remedies or may be necessary for determining what is protective at a specific contaminated area. In some instances, for example, because of multiple contaminants or pathways, compliance with ARARs will not achieve an acceptable degree of protection from the contaminants. In

TABLE 7-3
Potential Location-Specific Applicable or Relevant and Appropriate Requirements

Location	Requirement	Prerequisite	Citation
Wetlands[a]	Action to prohibit discharge or fill material without permit	Wetlands as defined in U.S. Army Corps of Engineers regulations	Clean Water Act Sections 401 and 404; 40 CFR 230, 33 CFR 320-330
	Action to avoid adverse effects, minimize potential harm, and preserve and enhance wetlands to the extent possible	Action involving construction of facilities or management of property in wetlands, as defined by 40 CFR 6, Appendix A, Section 4(j)	40 CFR 6, Appendix A
Within 100-year floodplain	Facility must be designed, constructed, operated, and maintained to avoid washout	RCRA hazardous waste; treatment, storage, or disposal	40 CFR 264.18(b) 18 AAC 63.040
Within floodplain	Action to avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values	Action that will occur in a floodplain, such as lowlands, and relative flat areas adjoining inland and coastal waters and other flood-prone areas	Protection of floodplains (40 CFR 6, Appendix A); Fish and Wildlife Coordination Act (16 USC 661 *et seq.*); 40 CFR 6.302 Executive Order 11988 Executive Order 11990
Area affecting stream or river	Action to protect fish or wildlife	Diversion, channeling, or other activity that modifies a stream or river and affects fish or wildlife	Fish and Wildlife Coordination Act (16 USC 661 *et seq.*) 40 CFR 6.302; Rivers and Harbors Act of 1899, Section 10 (33 USC 401-413) Protection of Fish and Game AS 16.05.870 5 AAC 95.010
Within area where action may cause irreparable harm, loss, or destruction of significant artifacts	Action to recover and preserve artifacts	Alteration of terrain that threatens significant scientific, prehistoric, historic, or archaeological data	Archaeological and Historic Preservation Act (16 USC 469); 36 CFR 65 40 CFR 6.301(c)
Historic project owned or controlled by federal agency	Action to preserve historic properties; planning of action to minimize harm to National Historic Landmarks	Property included in, or eligible for, the National Register of Historic Places	National Historical Preservation Act (16 USC 470); 36 CFR 800 40 CFR 6.301(b)
Federal facility	Action that may generate waste military munitions as hazardous waste; transportation of hazardous waste	Action located on military or nonmilitary property	40 CFR 260-266; 270

TABLE 7-3
Potential Location-Specific Applicable or Relevant and Appropriate Requirements

Location	Requirement	Prerequisite	Citation
Oceans and coastlines	Prevent or strictly limit the dumping into ocean waters of any material that would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities	Action that involves dumping materials into ocean	Marine Protection, Research and Sanctuaries Act (33 USC 1401)
	Ensure that federal actions are consistent with state management plans to protect and preserve the coastal zone	Action that will occur in coastal zone	Coastal Zone Management Act of 1972 (16 USC 1451) and relevant Alaska State Management Plans
	Protect all marine mammals	Action that affects marine mammals	Marine Mammal Protection Act of 1972 (16 USC 1361)
	Ensure protection for use, management, restoration, and enhancement of the overall quality of the coastal environment	Action occurs within Alaska Coastal Zone	Alaska Coastal Management Law (AS 46.40); Alaska Coastal Management Regulations (6 AAC 80, 85)
Bird migratory routes	Protect almost all species of native birds in U.S. from unregulated "take", which can include poisoning at waste sites	Action that affects migratory birds, including eagles.	Migratory Bird Treaty Act of 1972 (16 USC 703-712) 50 CFR Parts 10, 20, 21 Bald Eagle and Golden Eagle Protection Act (16 USC 668-668d)
Critical habitat upon which endangered species or threatened species depend	Action to conserve endangered species or threatened species, including consulting with the Department of the Interior	Determination of endangered or threatened species	Endangered Species Act (16 USC 1531 *et seq.*) 50 CFR Part 200; 50 CFR Part 402
Land air and water of State of Alaska	Provides for protection of the environment and response actions for pollution; permits required for solid waste or wastewater disposal	Action that may pollute; solid waste or wastewater disposal activity; degradation of a water body from operations or activities	Alaska Environmental Conservation Law AS 46.03 Alaska Administrative Procedures and Permit Regulations 18 AAC 15 Alaska Wastewater Disposal Regulations 18 AAC 72 Alaska Oil and Hazardous Substances Pollution Control Regulations and Law AS 46.04, AS 46.09 18 AAC 75 Alaska Water Quality Standards 18 AAC 70

[a] 40 CFR 6, Subpart A sets forth USEPA policy for carrying out the provisions of Executive Orders 11988 (Floodplain Management) and 11990 (Protection of Wetlands). Executive orders are binding on the level of government (federal or state) for which they are issued.

USC = United States Code.

TABLE 7-4
Potential Action-Specific ARARs

Activity	Standard Requirement, Criteria, or Limitation	Federal Citation	State Citation	
Clean Water Act		**33 USC Sec. 1251-1376**	**AS Title 46, Chapter 3**	
Hazardous waste identification, management, and transportation for military munitions	• Requirements for identification, onsite management, and transportation of military munitions	40 CFR 260 40 CFR 261 40 CFR 262 40 CFR 263 40 CFR 264 40 CFR 265 40 CFR 266 40 CFR 270		
Remedial action requiring point source discharge to U.S. waters or potential construction activities in navigable waters	• Permit required for outfall discharge: Federal National Pollution Discharge Elimination System (NPDES)	40 CFR 122 40 CFR 125	18 AAC 70	Alaska Water Quality Standards
			18 AAC 72	Alaska Wastewater Disposal Regulations
	• Standards and criteria for NPDES permits and operations that cause or contribute to degradation of water body	40 CFR 230 33 CFR 320-330	18 AAC 15	Alaska Administrative Procedures and Permit Regulations
	• Restrictions and regulations for dredge and fill activities for navigable waters			
Clean Air Act		**33 USC Sec. 1251-1376**	**AS Title 46, Chapter 3**	
Incineration Storage of POLs Air stripping Handling POL-contaminated soils Biodegradation Bioremediation	• Emission standards for hazardous air pollutants	40 CFR 61	18 AAC 50	Alaska Air Quality Control Regulations
	• Standards for ambient air quality to protect public health and welfare	40 CFR 50	18 AAC 15	Alaska Administrative Procedures and Permit Regulations
	• Classification of air pollution sources			

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TABLE 7-4
Potential Action-Specific ARARs

Activity	Standard Requirement, Criteria, or Limitation	Federal Citation	State Citation	
Solid Waste Disposal Act/Resource Conservation and Recovery Act		**42 USC Sec. 6901-6987**	**AS Title 46, Chapter 3**	
Landfilling	• Criteria for classification of solid waste disposal facilities and practices; permits	40 CFR 257	18 AAC 60	Alaska Solid Waste Regulations
	• Standards for management of hazardous waste for owners or operators of facilities that treat, store, or dispose of hazardous waste	40 CFR 264 49 CFR 265 40 CFR 266 40 CFR 268 40 CFR 270	18 AAC 62	Alaska Hazardous Waste Management Regulations (federal requirements with additional criteria and standards)
	• Restrictions on land disposal of specific types of hazardous waste based on levels achievable by current technology			
Closure of OB/OD Pad	• Requirements for closure/corrective action of RCRA solid-waste management unit (SWMU)	40 CFR 264	18 AAC 62	Alaska Hazardous Waste Regulations
Onsite generation of hazardous waste	• Identification and listing of hazardous waste	40 CFR 261 40 CFR 262	18 AAC 62	Alaska Hazardous Waste Regulations
	• Standards for generators of hazardous waste			
Transport of hazardous waste off site	• Standards for transporters of hazardous waste within the U.S.	40 CFR 263	18 AAC 62	Alaska Hazardous Waste Regulations
Recycling hazardous waste on site or off site	• Standards for recycling materials, recycling materials in a manner constituting disposal; and burning hazardous waste for energy recovery	40 CFR 266	18 AAC 62	Alaska Hazardous Waste Regulations
			18 AAC 63	Siting of Hazardous Waste Management Facilities
Onsite treatment or disposal of hazardous waste	• Requirements for acquiring state permit for hazardous waste management facility		18 AAC 62	Alaska Hazardous Waste Regulations
			18 AAC 63	Siting of Hazardous Waste Management Facilities

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TABLE 7-4
Potential Action-Specific ARARs

Activity	Standard Requirement, Criteria, or Limitation	Federal Citation	State Citation	
Occupational Safety and Health Act		**29 USC Sec. 657 and 667**	**AS Title 18, Chapter 60**	
All onsite remedial actions	• General standards for safety in the work place • Protection standards for workers at hazardous waste sites, and construction sites who are performing work under federal service contracts	29 CFR 1910 29 CFR 1926 29 CFR 1925	8 AAC 61	Alaska Occupational Safety and Health (Subchapter 10, Hazardous Waste Operations and Emergency Response Code)
Additional Activities Affecting Wildlife Handling or Collection				
Onsite actions involving handling or collection of live animals	• Requirements for handling and collecting live animals • Permit requirements for collection of migratory birds, bald eagles	9 CFR 50 CFR	AS 16.05.930(a)	Alaska Fish and Game Exempted Activities Regulations
Federal Insecticide, Fungicide, and Rodenticide Act		**7 USC Sec. 136, et seq.**	**AS Title 46, Chapter 3**	
Use of waterfowl repellents	• Registration requirements for chemicals, materials, or devices	40 CFR 160	18 AAC 75	Alaska Oil and Hazardous Substances Pollution Control Regulations
			18 AAC 90	Alaska Pesticide Control Regulations
State of Alaska, Oil Pollution Control Law			**AS Title 46, Chapters 3, 4, 9**	
Oil or hazardous substance discharge	• Permit requirements for discharge of oil or residual petroleum product • Approval required for cleanup of oil or hazardous substance discharge		18 AAC 75	Alaska Oil and Hazardous Substances Pollution Control Regulations

USC = United States Code
CFR = Code of Federal Regulations
AS = Alaska Statutes
AAC = Alaska Administrative Code

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such cases, nonpromulgated criteria, advisories, and other guidance need to be considered.

Examples of TBCs include chemical-specific health advisories and reference doses. In addition, other TBC materials, such as guidance or policy documents developed to implement regulations, may be considered and used as appropriate. If no ARARs address a particular situation identified during the contamination investigation and remediation process at OUC, or if existing ARARs do not provide protection, TBCs may be used to set cleanup targets.

The types of contaminants at ERF and OB/OD Pad areas include constituents of explosives and munitions that do not have promulgated cleanup standards or criteria for soil or water. Potential TBCs for remediation of these contaminants may include negotiated cleanup levels established at other sites where explosives and munitions have been used. The following table (Table 7-5) of soil and groundwater "clean closure" levels was developed for potential COCs at the OB/OD Pad area and was presented in *Demolition Area Number One Closure Guidelines* (EMCON, 1993a). These clean closure levels are additional TBCs available for OUC remedial actions. They were used to compare results of the 1996 site investigation at OB/OD pad (Section 6).

Results of acute and chronic toxicity studies may be used as TBCs.

Several acute and chronic toxicity studies have been conducted for waterfowl, aquatic organisms, and mammals as part of past investigations at ERF. Information obtained from these studies and others regarding the acute and chronic toxicity of chemicals used at ERF and OB/OD Pad areas may also be used as TBCs. For example, in 1991 the U.S. Army conducted a risk evaluation of chronic and acute exposure values for humans (70-kg adult) consuming WP-contaminated waterfowl. An acutely toxic dose of WP was equal to approximately 1.4 µg of WP per day for a 70-kg adult. An acute dose of 1.4 mg/kg of WP was presented in that study (USAEHA, 1991). The 1994 ERF studies included acute and chronic toxicity testing for WP in waterfowl; those studies indicated that a lethal dose for 50 percent of a sample population (LD_{50}) for pelletized WP is between 3 and 4 mg/kg. A lowest observable effects level (LOEL) for single doses in waterfowl was estimated to be approximately 1 to 2 mg/kg (Racine *et al.*, 1995). These values may be TBCs for determining a cleanup level for WP in ERF sediments.

Military activities are currently conducted at OUC; therefore, all future investigations, treatability studies, and remedial activities will need to be coordinated with local U.S. Army activities, such as ongoing operations with firings of test weapons and other related EOD practices and activities. Personnel access into the OUC areas is restricted by the U.S. Army because of active firing of munitions and the existence of old, unexploded ordnance. The status of ERF as an active firing range and the restricted entry to the OUC areas represent

TABLE 7-5
OB/OD Unit Soil and Groundwater Clean Closure Levels and Analytical Methods
Reproduced from *Demolition Area Number One Closure Guidelines* (EMCON, 1993)

Constituent	Groundwater Clean Closure Level (µg/L)	Soil Clean Closure Level (µg/g)	Analytical Method	Practical Quantitation Limit (µg/L or µg/g)
40 CFR 264, Appendix IX Constituents				
Dibutyl phthalate	4,000 (DWEL & RCRA CA/W)	8,000.0 (RCRA CA/S)	EPA 8270	10.0
2,4-DNT	100 (DWEL)	100.0	EPA 8270	10.0
n-Nitrosodiphenylamine	10 (7.0 RCRA CA/W)	100.0 (RCRA CA/S)	EPA 8270	10.0
Arsenic	50 (DW-MCL)	80.0 (RCRA CA/S)	EPA 7061	20.0
Barium	2,000 (DW-MCL)	4,000.0 (RCRA CA/S)	EPA 7080	1,000
Chromium	100 (DW-MCL)	400.0 (RCRA CA/S)	EPA 6010	70.0
Lead	15 (DW Action Level)	1,000.0 (CERCLA ROD)	EPA 7421	10.0
Mercury	2.0 (DW-MCL)	20.0 (RCRA CA/S)	EPA 7470	2.0
Other Constituents				
2,6-DNT	40 (DWEL)	100.0	EPA 8270	10.0
2,4,6-TNT	20 (DWEL)	40.0	USAEHA HPLC	1.0
RDX	100 (DWEL)	250.0	USAEHA HPLC	1.0
HMX	2,000 (DWEL)	4,000.0	USAEHA HPLC	1.0
Zinc chloride (as total Zn)	10,500 (DWEL)	24,000.0	EPA 7950	50.0
White phosphorus (as total P)	0.5 (DWEL)	1.2	EPA 365.1	

additional TBCs for the ERF site. The COE Nationwide Permit 38 includes additional TBCs for treatability studies conducted at OUC after inclusion of OUC on the NPL.

Table 7-6 summarizes potential TBCs for OUC areas.

7.4 Waiver of ARARs

Section 121 of CERCLA/SARA provides that under certain circumstances ARARs may be waived. These waivers apply only to meeting ARARs with respect to remedial actions at the contaminated area; other statutes requiring remedies that protect human health and the environment cannot be waived. A waiver must be invoked for each ARAR that will not be attained or achieved. Waivers of ARARs may include the following:

- **Interim measures**–The RA selected is only part of a total RA that will meet the ARAR when completed; it may apply to sites where a final remedy is divided into several smaller actions.
- **Greater risk**–Compliance with the ARAR will result in greater risk to human health or the environment; magnitude, duration, and reversibility of adverse impacts are considered.
- **Technically impracticable**–Compliance is technically impracticable from an engineering perspective; engineering feasibility and reliability are considered.
- **Equivalent to other standard**–The selected action would attain a standard of performance equivalent to the standard required by the ARAR; it may be used where the ARAR specifies design, or where operating standards by equivalent or better results are available from an alternative design or method of operation.
- **Inconsistent application**–The standard may not be applied consistently in similar circumstances; similarity of sites or response circumstances is considered.
- **Fund balancing**–For action under CERCLA Section 104, if the need to balance Trust Fund across many sites requires another remedy; consider cost of remedy, availability of Fund, and significant threats that may not be addressed if ARAR is met (USEPA, 1988).

Certain circumstances under which ARARs may be waived have been identified.

A complete discussion of the waivers provided by CERCLA Section 121(d)(4), circumstances under which each waiver might be invoked, and criteria for invoking the waivers is presented in the USEPA guidance document *CERCLA Compliance with Other Laws Manual, Part I* (1988).

TABLE 7-6
Potential Other Criteria or Guidelines to be Considered

Federal

- Drinking Water Health Advisories.
- Toxic Substances Control Act Chemical Advisories.
- USEPA Water Quality Advisories.
- USEPA Proposed Corrective Action Rule for Solid Waste Management Units, 55 Federal Register (FR) 30798, July 27, 1990.
- Applicable USEPA RCRA Guidance Documents
- DEMO 1 RCRA Closure Guidelines, December 1993
- U.S. Army Corps of Engineers Nationwide Permit 38
- Applicable U.S. Army internal policies, directives, and facility regulations for Fort Richardson
- Cooperative Agreement for Management of Fish and Wildlife Resources on Army Lands in Alaska (U.S. Army, 1986)

State of Alaska

- Alaska Department of Environmental Conservation. Guidance for Storage, Remediation, and Disposal of Non-UST Petroleum Contaminated Soils, July 29, 1991.
- Alaska Department of Environmental Conservation. Interim Guidance for Non-UST Contaminated Soil Cleanup Levels, July 17, 1991.
- Alaska Department of Environmental Conservation. Underground Storage Tanks Procedures Manual, September 22, 1995.
- Alaska Department of Environmental Conservation. Guidance for Storage, Remediation and Disposal of Petroleum Contaminated Soils (UST), March 15, 1991.
- Alaska Department of Environmental Conservation, Interim Guidance for Surface and Groundwater Cleanup Levels, September 26, 1990.
- Alaska Department of Environmental Conservation. Draft Water Quality Standards Revision and Oil and Hazardous Substances Cleanup Standards, December 18, 1996.

SECTION 8

Baseline Risk Assessment

8.1 Introduction

This section presents a summary of the baseline risk assessment for OUC. A baseline risk assessment is an analysis of the potential current and future adverse health and environmental effects caused by releases of, and exposure to, site-related chemicals. To develop a baseline risk assessment, it is assumed that no action is taken at the site to prevent exposure of ecological or human receptors to contamination. Therefore, the baseline risk assessment is an evaluation of the risks that could be present if the site is not remediated. The goal of the risk assessment process is to provide a consistent framework for remedial decisionmaking.

The goal of the risk assessment process is to provide a consistent framework for remedial decisionmaking.

The ecological and human risk assessments are provided in this RI report as Appendices A and B. The ecological risk assessment (EcoRA) addresses all biota in OUC, not just waterfowl, considering both chronic and acute effects of COCs. The human health risk assessment (HHRA) addresses the potential human health risks posed by chemicals and UXO in the OUC.

Following are the objectives of the baseline risk assessment:

- Evaluate, under a certain set of assumptions, the current and potential risks at OUC
- Document the magnitude and known causes of risks at OUC
- Provide a basis for developing risk-based remediation goals for both ecological and human receptors
- Provide a basis for evaluating the effectiveness of remedial activities at OUC

Both the EcoRA and HHRA use the site information presented in earlier sections of this RI report.

8.2 Ecological Risk Assessment

This EcoRA has been conducted in accordance with the following guidance and advisories:

- *Risk Assessment Guidance for Superfund,* Volume II, Environmental Evaluation Manual (USEPA, 1989a)
- *Ecological Assessment of Hazardous Waste Sites* (USEPA, 1989b)

- *Framework for Ecological Risk Assessment* (USEPA, 1992a)
- ECO Updates, Volume 1, Numbers 1 to 5 (USEPA, 1991b, 1991c, 1992b, 1992c, 1992d)
- ECO Updates, Volume 2, Numbers 3 and 4 (USEPA, 1994a, 1994b)
- ECO Updates, Volume 3, Numbers 1 and 2 (USEPA, 1996a, 1996b)
- *Risk Assessment Handbook,* Volume II (COE, 1995a)

Assumptions and information sources used in the baseline risk assessment are described in Sections 1.3 and 1.4 of Appendix A. Uncertainties associated with each component of the EcoRA are not repeated in this report.

Achievement of remedial objectives can be verified by comparing subsequent endpoint data to baseline conditions and established endpoint criteria. These comparisons are used to guide remedial decisionmaking.

8.2.1 Problem Formulation

Problem formulation is the first phase of EcoRA that establishes the goals, extent, and focus of the assessment (USEPA, 1992a). Assessment and measurement endpoints are identified on the basis of information presented in earlier sections of this report. The objective of the problem formulation section is to present a structure for assessing current and future impacts of contamination at ERF and OB/OD Pad. The structure is constructed from the CSMs (Sections 5 and 6), by using their characteristics and previous studies to define potential assessment and measurement endpoints. The result is a combination of biological and physical endpoints for use in evaluating remedial success across ERF over the long term. A series of physical measurements (pertaining to the physical endpoints) also can be used to evaluate site-specific remedial actions in the short term. Achievement of remedial objectives can be verified by comparing subsequent endpoint data to baseline conditions and established endpoint criteria. These comparisons are used to guide remedial decisionmaking.

The performance characteristics of the risk assessment structure are evaluated so that the structure can be modified and strengthened as needed.

The baseline risk assessment has a strong basis in the studies of the past several years and is supported by the quality of collected data, the successful transfer of data to the ERF GIS, and the application of the ERF GIS to remedial action decisions contained in the structure for the assessment. This baseline assessment represents an application of the analytical structure for the risk assessment to the available data. The performance characteristics of the risk assessment structure are evaluated so that the structure can be modified and strengthened as needed. The remedial action program will be adjusted or additional data will be collected during the 1997 field season to support improved performance.

The overall remediation objective is the protection of the animals, plants, and their habitat in ERF and nearby Knik Arm. Extensive investigations have been performed during the past 5 years to determine the toxic agent responsible for waterfowl mortality and its

consequences at ERF as reported in Racine *et al.* (1993, 1994, 1995) and CH2M HILL (1994). WP has been identified as the toxic agent, and several effects from WP exposure have been measured at ERF or in the laboratory. These past studies were used to develop the endpoints criteria for evaluating risk.

The overall remediation objective is the protection of the animals, plants, and their habitat in ERF and nearby Knik Arm.

A number of inorganic and organic contaminants were detected in surface soils and groundwater at OB/OD Pad, as summarized in Section 6 (Tables 6-4 and 6-5). The soil and groundwater contaminants were observed at relatively low levels in samples collected from recently installed monitoring wells on OB/OD Pad. All detected inorganic and organic contaminants were below clean closure criteria established by the RPMs. Groundwater contaminants would be diluted even further as groundwater discharged into and mixed with surface waters of ERF. Therefore, none of the detected contaminants in groundwater was retained as a COPEC for OB/OD Pad.

Inorganic and organic surface soil contaminants were screened to determine whether any of these chemicals should be considered as a COPEC for OB/OD Pad. Table 8-1 shows that the maximum detected inorganic concentrations from recent soil samples were similar to or below corresponding background levels. Therefore, none of the inorganic chemicals was retained as a COPEC.

Information on critical toxicity values (CTVs) for use in screening the detected organic contaminants was very limited for plants and soil invertebrates; however, it was possible to derive soil CTVs for small mammals by using the methods described by Opresko *et al.* (1996) and USEPA (1993). Table 8-2 shows that the maximum detected soil values for organic contaminants at OB/OD Pad were below or similar to corresponding CTVs for the deer mouse, a representative small mammal. Therefore, none of the organic soil contaminants detected at OB/OD Pad was retained as a COPEC.

The areas of potential ecological concern have been based on physical characteristics that correspond with maximum exposure of waterfowl to WP.

8.2.1.1 Selection of Areas of Potential Ecological Concern

The areas of potential ecological concern (AOPECs) have been based on physical characteristics that correspond with maximum exposure of waterfowl to WP. Other chemicals were investigated and eliminated as potential causes of elevated waterfowl mortality at ERF (Racine *et al.*, 1993). Therefore, the criteria used to define the AOPECs should be consistent with characteristics that create waterfowl exposure to WP.

Ponded areas were determined to be AOPECs because they are preferred feeding habitat for dabbling waterfowl. On the basis of earlier studies, these areas include sedge marsh, permanent ponds, and intermittent ponds. The geographical areas of highest potential ecological concern are Area C, Bread Truck, and Racine Island, as determined by past studies on the frequency and concentrations of WP. (See Section 4.5.)

TABLE 8-1
Ecological Assessment of Inorganic Soil Contamination at OB/OB Pad

Inorganic	Concentration (µg/g) Maximum Detected OB/OD Pad Value	Background Range[a]	COPEC ?[b]	Basis
As	7.4	6.7 to 9.6	No	Similar to background
Ba	127	190 to 678	No	Less than background
Cr	58.4	50 to 64	No	Similar to background
Pb	10.8	12 to 15	No	Less than background
Hg	0.12U	0.097	No	Similar to background
Zn	94.3	70 to 133	No	Similar to background

[a] Background range from Table 6-4 of the RI report is range of mean values (geometric and arithmetic) for Alaska soils and superficial materials (ESE, 1990) and the Eagle River Bridge/Cottonwood Slough sediments.
[b] Chemical of Potential Ecological Concern
Note: U = Flagged by laboratory as estimated value.

TABLE 8-2
Critical Toxicity Values for Organic Soil Contamination at OB/OD Pad[a]

Organic	Maximum Reported OB/OD Pad Value (µg/g)	Deer Mouse[b] Soil CTV	COPEC ?[c]
2,4,6-TNT	0.36	2	No
2,4-DNT	39	10	No[e]
2,6-DNT	3.9U	199	No
2-amino-4,6-DNT	0.47	103	No
4-amino-2,6-DNT	0.45	103	No
Di-n-butylpthalate[d]	14	3,718	No
N-nitrosodiphenylamine	4.2	251	No

[a] CTV derived as described in Opresko *et al.*(1996) and *Wildlife Exposure Factors Handbook* (USEPA, 1993).
[b] Deer mouse considered to represent small mammal receptors at site.
[c] Chemical of potential ecological concern
[d] Suter *et al.*(1993) estimate a no observed effect concentration (NOEC) for plants at 200 µg/g that represents a soil CTV for plants.
[e] CTV is a conservative extrapolation that assumes plant concentration in mouse diet is equal to soil concentration. The deer mouse soil CTV is derived from data from dog toxicity studies that increases uncertainty in the value.
Note: U = Flagged by laboratory as estimated value.

Area C/D also was considered as an AOPEC because of its proximity to Area C and Bread Truck. Although the presence of high concentrations of WP in sediments was not confirmed by the limited sampling, it was considered likely that WP could be found in some of the small ponds within the Area C/D sedge marshes, a preferred waterfowl feeding habitat. Area A also could be considered as an AOPEC because based on 1996 telemetry, it was heavily used. However, it was not as heavily used during previous telemetry studies. Despite the lack of data to indicate high concentrations of WP in sediments, all three preferred feeding habitats (permanent ponds, intermittent ponds, and sedge marsh) are present in this area and waterfowl mortality has been documented.

Inorganic surface soil contaminants were detected at levels similar to or lower than background concentrations (Table 8-1). Organic soil contaminant concentrations were below estimated CTVs for a small mammal (deer mouse). None of the detected contaminants in the OB/OD Pad surface soil and groundwater samples was retained as a COPEC. Therefore, this area is not considered to be an AOPEC.

Mallard, northern pintail, and green-winged teal, which accounted for 97 percent of all bird mortality, are considered to be primary ecological receptors that feed mainly in shallow ponds.

8.2.1.2 Selection of Exposure Pathways, Exposure Routes, and Ecological Receptors

As discussed in the CSM for ERF (Section 5), the primary exposure pathway is by incidental ingestion of WP particles contained within pond sediments by dabbling ducks during the course of feeding in shallow ponds. In deeper ponds, swans are exposed to WP in a similar manner. Direct ingestion of the WP particles occurs because birds regularly feed in habitats where WP is found. These birds either confuse the WP particles with their natural food items (such as invertebrate larvae or plant seeds) or accidentally ingest the particles along with pond sediments.

The ecological receptors of primary importance to this EcoRA are ducks and swans. Of all bird species observed at ERF, three species of dabbling ducks (mallard, northern pintail, and green-winged teal) have accounted for nearly 97 percent of all bird mortality. These three duck species are considered to be primary ecological receptors that feed mainly in shallow ponds. Swans feed in deeper water habitats than those used by the dabbling ducks and also are considered to be primary ecological receptors.

Minimal shorebird deaths have been discovered during the years of mortality studies in ERF. Shorebird populations include species such as greater and lesser yellowlegs, pectoral sandpipers, and dowitchers. Selective feeding behavior that limits WP uptake and the frequenting of habitat that periodically dries (allowing the WP to sublimate) likely reduce shorebird exposure. Because occasional shorebirds are found dead in ERF, this receptor has been ranked as having a moderate hazard probability. Shorebirds were not assigned a high hazard

probability because none of the observed mortality has been attributed to WP exposure (Racine *et al.*, 1993, 1994). WP was not observed in any shorebird carcasses during 1994 studies. Further research was not performed to evaluate the cause of shorebird deaths once WP was eliminated (Sparling *et al.*, 1994).

The detected contaminants from recent sampling at OB/OD Pad do not occur at levels that would constitute significant contaminant sources. In fact, all detected contaminants were found at levels well below the cleanup action levels established by the RPMs for OB/OD Pad.

Risk to ecological receptors at OB/OD Pad was assessed by comparing maximum concentrations of detected chemicals to available data or derived CTVs. Inorganic chemicals in surface soils at OB/OD Pad were detected at levels similar to or less than background concentrations (Table 8-1). Organic chemicals were compared to soil CTVs derived for a small mammal, the deer mouse, considered to be representative of small rodents at OB/OD Pad (Table 8-2). Larger mammals were not expected to derive a significant proportion of their diet on the limited pad area (about 4 ha).

Risk to plants at OB/OD Pad was estimated for a single organic compound, di-n-butylphthalate, detected at 14 µg/g. A no observed effect concentration (NOEC) for plants was estimated at 200 µg/g by Suter *et al.* (1993). Soil CTVs for plants were not found for any of the other detected organic compounds. Significant uptake and bioaccumulation of the detected explosive residues or semivolatile organic compounds is not expected. There are three reasons for this judgment:

- These compounds would only be significantly translocated into plant roots by diffusion if there was a high concentration gradient (that is, high concentrations in the soil). The low concentrations detected in soil were probably not high enough for significant diffusion into the roots to take place.

- The compounds could be actively translocated across the root cell membranes if the plant expended energy. Because these compounds are not normally linked to plant metabolism, active transport by the plant is not likely.

- Nitrosamines in general can be taken up by plants from nutrient solution and soil but the concentration in plants is rapidly decreased by either chemical vaporization or metabolic breakdown (Bell, 1992).

No available soil CTVs for terrestrial invertebrates were found for any of the organic compounds detected at OB/OD Pad.

Overall use of OB/OD Pad by ducks, as indicated by telemetry, was very low (about 1 percent of all observations). Waterfowl were not

evaluated as potential ecological receptors because their preferred feeding habitat, ponds and marshes, were not present at OB/OD Pad.

8.2.2 Exposure Assessment

The exposure assessment uses site-specific information to estimate the nature, extent, and magnitude of potential exposure to ecological receptors. Information used to evaluate potential ecological exposures at ERF includes characterization of the ecosystem, evaluation of tissue concentrations of WP in biota collected at ERF, and analysis of potential exposure to WP in environmental media collected from the different areas at ERF. These topics are discussed in Section 3.1 of Appendix A. Relevant portions not presented elsewhere in this RI report are summarized below.

The exposure assessment uses site-specific information to estimate the nature, extent, and magnitude of potential exposure to ecological receptors.

8.2.2.1 Ecosystem Characterization

The ecosystem consists of physical and biological components significant to the current assessment, as described in Section 2 of this report. The potential receptors that were considered for ERF included aquatic vegetation, aquatic invertebrates, fish, and birds, as well as their consumers. Walsh (in Racine *et al.*, 1994) determined that aquatic plants growing within contaminated sediments contained low levels of WP. The author concluded, however, that the risk to grazing animals from plant consumption was very low when compared to incidental ingestion of the sediment containing WP particles. Low mortality of waterfowl that feed mainly on vegetation (such as geese and wigeons) supports this conclusion.

WP impacts to aquatic invertebrates and fish were investigated in separate studies by Bouwkamp (in Racine *et al.*, 1994, 1995) and Sparling (in Racine *et al.*, 1994). In general, the population diversity of benthic macroinvertebrates was not significantly different between areas with or without WP contamination (Bouwkamp, in Racine *et al.*, 1994). Sediment toxicity tests with the use of aquatic amphipods and midge larvae indicate that these organisms were sensitive to WP. Sampling and analysis of ERF macroinvertebrates and fish did not reveal significant accumulations of WP (Sparling, in Racine *et al.*, 1994; Bouwkamp, in Racine *et al*, 1995). It was concluded that WP in fish and aquatic invertebrates would not constitute a significant risk for birds or mammals who eat them, and that WP was not affecting invertebrates under field conditions.

Bird populations in ERF have been studied by aerial census and ground observation.

The above studies of various ERF biological components have shown that the most significant WP impacts are occurring to bird populations. Bird populations in ERF have been studied by aerial census and ground observation. Aerial census data have been collected with the use of fixed-wing aircraft from April to October from 1988 through 1995 (Eldridge, 1990, 1991, 1992; Eldridge, in Racine *et al.*, 1994, 1995; in Walsh *et al.*, 1997). These aerial surveys

represent the most complete bird population data for ERF. In addition, a similar population survey was performed during the 1995 field season for other marshes around UCI (Eldridge, in Walsh *et al.*, 1997). This survey was intended to allow comparison of bird use between ERF and other marshes in the area.

Ground observation duck counts made during the spring and fall of 1994 and 1995 (included in the ERF GIS) were compared with aerial survey population estimates on those days when both surveys were conducted. The comparison indicated similar bird counts for spring surveys but higher aerial survey counts for fall surveys. The correlation coefficients for the 1994 and 1995 surveys were 0.31 and 0.52, respectively.

The potential for WP impacts to secondary receptors indicated by laboratory studies have not been confirmed to have direct effects by the field studies.

Secondary receptors include predators and scavengers such as the bald eagle, herring gull, raven, wolf, coyote, and fox. Studies of activities and potential risks related to scavengers and predators were reported by Reitsma and Steele (in Racine *et al.*, 1995), Cummings *et al.* (in Racine *et al.*, 1995), and Roebuck (1995). The laboratory studies indicated a potential for WP impacts to secondary receptors, but direct effects were not confirmed by the field studies.

8.2.2.2 White Phosphorus Tissue Analysis

Tissue samples from various species of plants and animals were collected from ERF for analysis of WP concentrations. In addition, laboratory bioaccumulation (WP-feeding) studies were conducted on prey and predator species representative of those found at ERF. Biota samples collected from different areas of ERF include waterfowl (pintail, green-winged teal, mallard, and tundra swan), other bird species (northern phalarope, lesser yellowlegs, greater yellowlegs, arctic tern, mew gull, dowitcher, sandhill crane, and eagle), mammals (coyote), plants (sedge, bulrush, and arrowgrass), fish (stickleback and mixed species), and invertebrates (chironomid, damselfly, dragonfly, and mixed invertebrate species). Species used in laboratory bioaccumulation studies include mallards, chickens, and kestrels.

Tissue samples from various species of plants and animals were collected from ERF for analysis of WP concentrations.

This section provides a brief summary of WP tissue concentrations found in field-collected biota and from WP feeding studies. Results of the different tissue analyses are presented in Table 3-3 (birds and mammals), Table 3-4 (fish and invertebrates), and Table 3-5 (plants) of Appendix A.

WP was measured in the gizzard contents, liver, fat, or skin of field collected ducks (mallards, pintails, and teal) and swans that had been exposed to in situ WP. The WP concentration in the same tissues of mallards in toxicological feeding studies varied according to the dose and form of WP administered (dissolved in oil or in pelletized form).

An eagle found dead in ERF had measurable WP concentrations in its fat tissues. Consequently, American kestrels were examined during a

toxicological study in which they were fed WP-contaminated poultry chicks. The WP concentrations were measured in the kestrels' fat and in whole gizzards to evaluate the effects of WP poisoning in secondary receptors. Although the uptake of WP by predators is rapid, the potential for bioaccumulation in the food chain may be limited because of its rapid loss upon reduction of dose. Bioaccumulation and toxicity could be significant if the ingested dosage exceeds the degradation rate of the receptor.

Only one tissue sample from mammals was analyzed. Nondetectable levels of WP were found in the leg muscle of a coyote collected from behind the Canoe Point tower in the woods close to ERF (Roebuck, 1995).

Fish samples were taken from ERF and a reference location at Goose Bay across Knik Arm from ERF (USAEHA, 1994, 1995). More than 75 fish samples from ERF were analyzed. Although detection limits varied, WP was seldom detected in the ERF fish samples. Two fish samples from Racine Island area were found to have WP concentrations of 24.1 micrograms per kilogram (µg/kg) wet weight (ww) and 82.3 µg/kg ww.

Similarly, samples of *Chironomus* (invertebrates) collected from Areas A, B, and C; the Bread Truck area; and Goose Bay did not have measurable concentrations of WP (USAEHA, 1995). Dragonfly and damselfly samples, as well as other invertebrates, were collected from sample sites, with whole organisms being blended and analyzed. A sample of damselflies also was collected at Fire Creek, a reference location away from ERF. Most invertebrate samples did not have measurable concentrations of WP, except one sample from Racine Island that had a detected WP concentration of 67.6 µg/kg ww.

In most plant samples from ERF, WP was not found in detectable levels.

Numerous plant samples from ERF were analyzed for WP. Only three of the plant samples had detectable levels of WP as follows: a sample of *Zannichellia palustris* taken from Miller's Hole in Area C showed a concentration of WP in tissue of 160 µg/kg ww; the roots of a sedge (*Carex lyngbyei*) sample, taken from Site 110 in Area C, had a WP concentration of 2,270 µg/kg ww; and a bulrush (*Scirpus paludosus*) rhizome collected from Site 615 in Area C, had a WP concentration of 110 µg/kg ww.

8.2.3 Ecological Effects Assessment

The ecological effects assessment evaluates cause and effect relationships between COPECs and ecological receptors. A relationship between cause and effect is established through evaluation of field studies, laboratory studies, and toxicity tests conducted at OUC as well as literature on the ecological effects of COPECs.

8.2.3.1 Field Studies

Field studies to count and tabulate the species of bird carcasses have been used to assess mortality rates.

The high mortality rate of waterfowl in ERF was first recognized in 1978, and investigations of the problem began in 1982. Dabbling ducks, such as northern pintails, mallards, and green-winged teal, and swans (trumpeter and tundra) are the most affected species. Mortality of dabbling ducks has been concentrated in four areas of ERF where suitable pond habitat is located. (See Figure 3-8 in Appendix A.)

Attempts to count and tabulate the species of bird carcasses in various parts of ERF have been made since 1983. Many of the early mortality counts were made in conjunction with the collection of carcasses by USFWS for necropsy by the National Wildlife Health Research Center (NWHRC). Reitsma and Steele (in Racine *et al.*, 1993) included feather piles and carcasses as indicators of mortality.

These studies assessed the rate of waterfowl mortality to detect year-to-year changes as WP exposure decreased through remediation efforts. Feather piles and carcasses were counted in sample areas of ERF and in the surrounding woods to more accurately estimate total mortality and detect potential new areas of high mortality. Observation of waterfowl and remains of dead waterfowl from 1991 to 1993 indicates that spring staging differs from autumn staging (Reitsma and Steele, in Racine *et al.*, 1993). During spring migration, almost all dead or near-dead ducks are eaten by predators or scavengers, primarily bald eagles. Some are consumed where they are captured, and some are carried to other locations (Reitsma and Steele, in Racine *et al.*, 1993). Eagle predation and scavenging of carcasses is much more prevalent in spring than in fall.

Transects were established to detect changes in mortality.

To detect changes in mortality between years, duck carcasses were counted along permanent transects that were established in 1992 (Figure 3-7 in Appendix A). Transect counts of carcasses were supplemented with counts of feather piles on a transect within ERF, in a 1-ha quadrat in the forest immediately adjacent to Area C and along transects extending into the forest from the edge of ERF (Figure 3-10 in Appendix A).

Changes in mortality were assessed between 1992 and 1995 by Steele and Reitsma (in Racine *et al.*, 1996) (as summarized in Table 3-9 in Appendix A). The mortality rate is summarized as the ratio of duck carcasses found divided by the number of ducks counted near the mortality transects. The spring mortality rate dropped from 1992 to 1994. Although mortality appeared to remain low in 1995, the low exposure rate precludes strong conclusions about the mortality rate in 1995.

In fall 1993, mortality dropped. The fall mortality rate remained low in 1994 and dropped slightly in 1995, despite higher duck use of the flats (Reitsma and Steele in Racine *et al.*, 1995). Three possible reasons for the lower mortality in fall are (1) implementation of hazing in the most

contaminated areas; (2) lack of suitable foraging habitat; and (3) reduction of available WP. Mortality transects were not evaluated during the 1996 field season because of health and safety concerns (Steele *et al.*, in Walsh *et al.*, 1997). For this reason, it was not possible to evaluate the trend in duck mortality affected by the lack of hazing.

Radiotelemetry was used to study waterfowl distribution and movement in ERF. Mortality also was tracked.

Mortality also was studied between 1993 and 1996 field seasons by Cummings *et al.* (in Racine *et al.*, 1994, 1995, 1996; in Walsh *et al.*, 1997) by using radio telemetry. As part of their study of waterfowl distribution and movement in ERF, they recorded the mortality of ducks equipped with radio transmitters in ERF. These birds were tracked from stations or by helicopter to determine location and movement. Mortality results during these studies are found in Tables 3-11 through 3-14 of Appendix A.

To evaluate habitat use, radio-equipped ducks were monitored in ERF to determine daily movements, turnover rates, and site-specific exposure during 1993 to 1996 (Cummings, in Racine *et al.*, 1994, 1995, 1996; in Walsh *et al.*, 1997). Within this period, 163 mallards, 57 northern pintails, 36 green-winged teals, and 7 other ducks were fitted with radio transmitters. In 1994 and 1995, 31 bald eagles also were monitored for mortality and movements.

Bird telemetry studies conducted from 1993 to 1996 were used to describe duck habitat preference.

As part of their telemetry study of eagles and waterfowl, Cummings *et al.* (in Racine *et al.*, 1994, 1995, 1996; in Walsh *et al.*, 1997) calculated the daily turnover rate of birds fitted with transmitters in ERF by dividing the number of radio-instrumented ducks that departed ERF each day by the total (by species) instrumented. The daily turnover rate was used to determine the relative WP risk to birds using ERF.

Bird telemetry studies conducted from 1993 to 1996 were used to describe duck habitat preference. These studies were done by using the ERF GIS to overlay the observation locations with the ERF landcover to determine which habitat was being used at the time of each observation. Only observations that were made during nonhazing periods were used to simulate normal use patterns for bird habitat. The studies indicated that sedge marshes (28.7 percent) and the permanent ponds (11.4 percent) were the two most commonly used habitats by ERF ducks. Various meadow types (Ramenski's sedge [10.0 percent], halophytic herb [7.5 percent], and interior sedge [9.0 percent]) had lower duck use percentages. Intermittent ponds were used by ERF ducks in approximately 7.4 percent of observations. Approximately 7.8 percent of ERF duck observations were not classified according to habitat type.

Sedge marshes and permanent ponds were identified as the two most common habitats of ERF ducks.

Other results of the telemetry study are summarized in Tables 3-15 through 3-18 of Appendix A. Briefly, the study provided the following information:

- During fall 1993, 11 of 39 radio-tagged ducks died during the monitoring period.
- Turnover rate among the ducks was high; average length of stay in ERF was 12.5 days.
- During spring of 1994, 9 of 34 radio-tagged ducks died during the monitoring period.
- During fall of 1995, 7 of 54 ducks died during the monitoring period.
- During fall of 1996, 37 of 107 mallards died during the monitoring period.
- During fall of 1996, mortality rate of mallards exceeded proportional area use in ERF Areas C and C/D, Racine Island, and Bread Truck Pond.
- None of the 31 bald eagles died from WP exposure during spring 1994, fall 1995, or fall 1996 study periods.
- Turnover rates for waterfowl in 1995 and 1996 were lower than in 1993 or 1994.

Ongoing bird studies by USFWS have included aerial bird population surveys.

USFWS conducted aerial bird population surveys of ERF during spring, summer, and fall (April through October) from 1989 through 1996 as part of ongoing waterbird studies. The objective of these surveys was to monitor bird abundance and distribution in ERF during spring, summer, and, fall (Eldridge, 1990, 1991, 1992; Eldridge, in Racine *et al.*, 1994; Eldridge and Robertson, in Racine *et al.*, 1996). Waterfowl were counted or estimated and recorded by species or species group. Results of these 8 years of study were presented in Section 3.1.1 of Appendix A.

8.2.3.2 Laboratory and Field Toxicity Tests

Birds. Laboratory and field toxicity tests of birds (primarily mallards) and aquatic macroinvertebrates have been conducted to determine acute and chronic toxicity as well as potential effects to secondary receptors. The results of these studies are summarized below; they are discussed in more detail in Section 3.2.2 of Appendix A.

Establishment of a target WP concentration in sediment at ERF was not done for the following reasons: Because WP occurs in particulate form in ERF, its uneven distribution as the result of deposition by munition rounds creates considerable uncertainty for sampling and quantification. Actual dosage to waterfowl from sediment is affected by the suitability of the feeding habitat (such as water depth) and the

relative efficiency of each species in locating and ingesting WP particles of different sizes during feeding. If particulate WP is present in the sediment and the sediment is accessible to waterfowl, a potential for lethal or sublethal WP exposure to occur exists.

Toxicity tests were useful in determining the lowest dose of WP resulting in mortality and for recognizing signs of WP toxicity.

Various types of toxicity tests were conducted by Sparling *et al.* (in Racine *et al.*, 1994, 1995) and by Roebuck and Nam (in Racine *et al.*, 1995). The tests included acute toxicity of WP to juvenile and adult male and female mallards, acute toxicity of WP dissolved in oil, acute toxicity of WP in a pelletized form, acute toxicity of different sizes of particulate WP as opposed to dissolved WP, identification of acute biomarkers of WP exposure, and comparison of organ damage observed in laboratory toxicity tests versus field conditions. These studies were useful in determining the lowest dose of WP resulting in mortality (5.2 mg/kg body weight [bw]) and the lethal dose for 50 percent of a sample population (LD_{50}) (6.4 mg/kg bw) for mallards, in comparing dissolved and pelletized WP, and for describing the signs of WP toxicity. Histopathological changes also were observed for each dose group. In general, damage was observed in the liver, spleen, heart, and duodenum (small intestine) in birds treated with WP at 5.2 mg/kg bw or greater.

Toxicity tests with pelletized WP in one study (Sparling *et al.*, in Racine *et al.*, 1995) indicated that pelletized WP was more toxic than WP dissolved in oil. However, in another study (Roebuck and Nam, in Racine *et al.*, 1995), there was no indication that the form of WP (either dissolved or particulate) significantly affected toxicity in mallards and that the acute LD_{50} estimates made from other studies of WP either dissolved in oil or in pelletized form would be predictive of toxicity to ducks in the field.

Studies also were conducted to determine bioindicators of WP exposure.

Studies also were conducted to determine bioindicators of WP exposure (Sparling *et al.*, in Racine *et al.*, 1995). Blood chemistry results (including, for example, blood urea nitrogen, potassium, lactate dehydrogenase, glucose, hematocrit, and hemoglobin) indicated both toxicity and a dose-response relationship. These parameters diagnosed changes in liver or kidney function or in general blood characteristics, and were not solely indicative of WP exposure. However, the combination of changes in some indicators (such as reduced hematocrit and hemoglobin) could be used as an indicator of WP exposure.

Toxicological effects in birds tested under laboratory conditions were also compared to those observed in the field (Sparling *et al.*, in Racine *et al.*, 1994). Farm-raised mallards with no previous exposure to WP were placed in pens in C Pond for 6 hours, then collected and evaluated for histopathologic effects. Thirty percent of exposed birds died within 24 hours of exposure and many others had signs of sublethal exposure similar to those observed in laboratory tests.

Toxicological effects in birds tested under laboratory conditions were also compared to those observed in the field.

Subchronic and chronic toxicity tests conducted by Sparling *et al.* (in Racine *et al.*, 1994, 1995) included subchronic toxicity tests, chronic toxicity tests, and preliminary mallard reproductive studies. Results indicated no mortality and no significant damage to liver, kidneys, or heart tissue at any of the tested concentrations, but one bird treated at 2.6 mg/kg-bw/day and two birds treated at 3.7 mg/kg-bw/day developed liver foci (a sign of sublethal exposure). An acute LOEL based on mortality was estimated for WP dissolved in oil to be about 4 mg/kg-bw/day, and a LOEL based on sublethal effects would be less than 2 mg/kg-bw/day.

The effects of repeated subchronic exposures were tested in adult male and female mallards treated with WP doses of 3.7, 4.8, 5.3, and 5.7 mg/kg-bw/day for 4 days (Sparling *et al.*, in Racine *et al.*, 1994). Results of these tests indicate that mortality and histopathologic effects (liver and kidney damage) from repeated subchronic exposures were consistent with acute exposures from single doses at similar concentrations.

Chronic toxicity tests were conducted with pelletized WP given at doses of 2.4 and 3.4 mg/kg-bw/day for 10 days to adult male mallards (Sparling *et al.*, in Racine *et al.*, 1995). Birds treated with 2.4 mg/kg-bw/day exhibited liver and kidney damage. Birds treated with 3.4 mg/kg-bw/day also exhibited liver and kidney damage or significant weight loss. From this study, a LOEL could not be identified because death occurred at the lowest dose tested. However, it was estimated that a LOEL based on an endpoint of mortality would range between 1.5 and 2.0 mg/kg-bw/day. LOELs based on other effects, such as reproduction, probably would be much lower.

Studies of secondary receptors showed that the greatest risk was through ingestion of portions of the digestive tract that contained pelletized WP.

Preliminary reproductive studies were conducted with mallard hens dosed with 2.6 mg/kg-bw/day or 1.3 mg/kg-bw/day of pelletized WP in water for 5 days (Sparling *et al.*, in Racine *et al.*, 1995). The study results indicate that hens exposed to sublethal levels of WP have reduced reproductive output and embryos with teratogenic deformities, including scoliosis, lordosis, submandibular edema, microphthalmia, and spina bifida.

Toxicity of WP to secondary receptors (birds that prey on dead or dying ducks) was studied by Sparling *et al.* (in Racine *et al.*, 1995), Nam *et al.* (1994), and Roebuck *et al.* (1994b). The first two studies were conducted with American kestrels as a surrogate species for bald eagles, herring gulls, and common ravens, which have been observed feeding on dead or dying ducks at ERF. The final study modeled the potential risks to bald eagles feeding on WP-contaminated ducks, based on WP concentrations in ducks from WP-contaminated areas of ERF. The results of the secondary receptor studies indicated the following:

- The greatest risk to secondary receptors was through ingestion of portions of the digestive tract that contained pelletized WP.
- Although the uptake of WP by predators is rapid, the potential for bioaccumulation in the food chain may be limited because of the rapid loss upon reduction of dose.
- Bioaccumulation and toxicity could be significant if the ingested dosage exceeds the degradation rate of the receptor.
- Ingestion of a WP-contaminated duck's gizzard could result in a dose to the predator that could be more than 100 times the dose received from ingestion of tissues alone.

In studies conducted by Roebuck *et al.* (1994b), WP concentrations were analyzed from tissues of 27 ducks that were collected from a WP-affected area of ERF in which predation by eagles, herring gulls and ravens had been observed (Area C). Tissues analyzed for WP included fat, skin, breast muscle, wing tissue, and gizzard contents. The potential risk of ingestion of WP by an eagle was then estimated by using the maximum tissue concentrations from the ducks collected. For ingestion of gizzard contents, the corresponding daily dose to an eagle would be 1.76 mg/kg bw. For ingestion of tissues, including fat, skin, and muscle, the corresponding daily dose to an eagle would be 0.09 mg/kg bw. A single daily dose of waterfall gizzard and tissues could provide an eagle or other predatory bird with almost half of the estimated LD_{50} (1 to 2 mg/kg bw). This indicates that predators could be exposed to harmful doses of WP. In addition, exposure to lower levels could result in sublethal effects such as decreased reproductivity or survival.

Exposure of predators to harmful doses of WP could result in sublethal effects such as decreased reproductivity or survival.

Laboratory toxicity tests and field studies of aquatic biota were conducted to determine acute toxicity (LC_{50}) and chronic toxicity (no observed effect level [NOEL]) of WP present in sediment, as well as impacts on benthic macroinvertebrate community structure, as described in Section 3.2.2 of Appendix A.

It was concluded that the sediment toxicity tests needed to be refined to more closely imitate conditions found in the field at ERF.

Initial 30-day sediment toxicity studies were conducted in 1993 (Bouwkamp, in Racine *et al.*, 1994). The toxicity test used sediment collected from Racine Island tested with the amphipod *Hyalella azteca* and the midge *Chironomus riparius*. A NOEL could not be established based on the results of the toxicity test because all test organisms in all dilutions died before the end of the test. Furthermore, the concentrations of total and dissolved WP in the overlying surface water were more than 1,000 times greater than those measured in the field over equally contaminated sediments. From this information, it was concluded that the sediment toxicity tests needed to be refined to more closely imitate conditions found in the field at ERF.

A second set of sediment toxicity tests was conducted in 1994 (Bouwkamp, in Racine *et al.*, 1995; USAEHA, 1995) to refine the

methodology used in the 1993 studies and determine a sediment LC_{50} and NOEL for WP. Thirty-day toxicity tests of sediment collected from Racine Island were conducted with *H. azteca* and *C. riparius* under the following treatment scenarios:

- Overlying water was renewed two times per week.
- Overlying water was not renewed and sediment was disturbed to mimic feeding ducks.

Two additional treatment scenarios were used for *C. riparius*:

- Sediments were spiked with 1 microliter (µL) of WP particles equivalent to 5 mg/kg (1.85 mg of WP per 372 g sediment).
- Sediments were spiked with 3 µL of WP particles equivalent to 14.25 mg/kg (5.3 mg of WP per 374 g sediment).

Studies showed that is unlikely that WP was adversely affecting the aquatic community.

An LC_{50}, a NOEL, and an LOEL were calculated by using results of the toxicity tests for each treatment scenario and test species. Results were similar to those found in the 1993 study in that sediments from Racine Island were not toxic to organisms living in them in the field, but were toxic to laboratory organisms at diluted concentrations. *C. riparius* was more sensitive to WP than *H. azteca*, and the lowest NOELs were 26 µg/kg and 1,500 µg/kg, respectively.

The macroinvertebrate community structure of ERF was evaluated to determine whether sediment or surface water concentrations of WP were affecting the aquatic food chain (Bouwkamp, in Racine *et al.*, 1994). Benthic macroinvertebrates were collected from 23 sites, including 14 ponded areas in ERF and Goose Bay, 7 from distributaries, and 2 from Eagle River (upstream and downstream of ERF). Results indicate that the number of species and species diversity were not significantly different among the WP contaminated sites. The number of organisms per unit area was significantly different at WP contaminated sites versus noncontaminated sites, but the number of organisms increased with higher concentrations of sediment WP. From these results, it seems unlikely that WP was adversely affecting the aquatic community.

There is no evidence that WP was adversely affecting benthic macroinvertebrate communities at ERF.

A similar macroinvertebrate community survey was conducted in 1994 (Bouwkamp, in Racine *et al.*, 1995). Macroinvertebrates were collected from 42 sites and analyzed for species density, diversity, and number of organisms per unit area. Results indicate that the macroinvertebrate community structure at WP contaminated areas was not significantly different from reference locations for any parameter. From these results, it was concluded that there is no evidence that WP was adversely affecting benthic macroinvertebrate communities at ERF.

8.2.3.3 Literature

Toxicological information on the effects of WP on birds and other wildlife is limited. Much of the research on toxicity of WP has been conducted in conjunction with CRREL at Fort Richardson. Results of those studies, some of which also reappear in the open literature, were presented in Section 3 of this report and are in Section 3.2.3 of Appendix A. Additional information from the open literature is summarized in the baseline risk assessment; it is not repeated here.

8.2.4 Risk Characterization

In this section, the likelihood of adverse ecological effects occurring as a result of exposure to WP in ERF is evaluated. In the first part of risk characterization, the exposure assessment (Section 8.2.2) and the ecological effects assessment (stressor-response profile in Section 8.2.3) are integrated. The second part of risk characterization is the risk description, in which ecological risks are summarized and an interpretation of the ecological significance of the risk is provided (USEPA, 1992a).

8.2.4.1 Risk Estimation

Risk estimation consists of comparing the exposure and ecological effects assessment. For this EcoRA, waterfowl mortality is considered to be the only significant effect of WP on ecological resources.

Waterfowl mortality is considered to be the only significant effect of WP on ecological resources.

Physical characteristics associated with exposure were integrated in the hot area analysis (refer to discussion in Section 10). Characteristics such as habitat (vegetation, landform, pond), WP concentrations, and duck use were combined in the GIS system to identify areas where all these factors exist together (overlapped). The figure shows that hot areas have been identified in the intermittent and permanent ponds and in sedge marshes of Area C, Bread Truck, and Racine Island. The sedge marshes of Area C/D also have been included as a potential hot area because of proximity to Area C and Bread Truck. Although the presence of high concentrations of WP in sediments was not confirmed by the limited sampling, it was considered likely that WP could be found in some of the Area C/D sedge marshes, a preferred waterfowl feeding habitat. Area A also could be considered as an AOPEC because it receives the highest proportion of bird use at ERF, as indicated by telemetry studies. Despite the lack of data to indicate high concentrations of WP in sediments, all three preferred feeding habitats (permanent ponds, intermittent ponds, and sedge marsh) are present in this area and waterfowl mortality has been documented.

To estimate risk, each area of ERF was evaluated to answer the following questions (see Tables 4-1 and 4-2 of Appendix A):

- If bird mortality was observed, how many dead birds were found and what were the WP levels in bird tissue (fat, gizzard)?

- Were bird tissue levels in excess of those associated with lethal dose levels from laboratory studies?
- What percentage of time did birds use the area (as indicated by telemetry studies)?
- How many birds are estimated to use the area on an annual basis?

The hot areas were evaluated to answer the following set of questions (see Table 4-3 of Appendix A):

Evaluation of hot areas examined habitat, area of habitat, percentage of time birds use the habitat, numbers of birds using the habitat, and percentage of time birds use the particular habitat within a hot area.

- What is the type of the hot area habitat?
- How much area does the hot area habitat include? What proportion of the total ERF habitat type is represented?
- What percentage of time did birds use the habitat type (as indicated by telemetry studies)?
- How many birds are estimated to use the habitat type on an annual basis?
- What percentage of time would birds use the hot area type of habitat?

This evaluation shows that mallard, northern pintail, and green-winged teal carcasses or dying ducks were collected from Areas A and C, Bread Truck, and Racine Island. Mallard carcasses or dying ducks also were collected from Area C/D. WP was detected in various tissues of these duck samples. In Areas C and C/D and Racine Island, WP levels in fat and/or skin samples were higher than the corresponding maximum tissue concentrations for mallard WP toxicity studies. These levels indicate that the ducks ingested enough WP in ERF to result in mortality. The maximum tissue levels from toxicological tests provide a conservative comparison for WP bird tissue levels.

Fish and invertebrate sampling and analysis for WP from surface waters was conducted in Areas A, B, C, and C/D, as well as Bread Truck and Racine Island. Positive WP results were noted for fish samples from Area A and Racine Island. Positive WP results were observed for invertebrate samples from Racine Island. WP was not observed above the detection limits in the other areas. Plants sampled in Area C did not show uptake of WP.

Duck mortality studies show that the largest proportions of ERF dead or dying ducks were observed in Area C (37 percent), Racine Island (22 percent), Area A (22 percent), Bread Truck (12 percent), and Area C/D (6 percent). Of these areas, only Area A did not contain WP exposure hot areas. No observations of dead or dying birds in the coastal areas (east or west) were recorded in the GIS database. Dead

swans also were observed in Area C (44 percent), Areas A and D (25 percent), and Area C/D (6 percent).

The mortality ratio for ducks was calculated as the number of carcasses observed along transect divided by an estimate of the bird exposure rate from ground surveys of bird populations (Steele and Reitsma, in Racine *et al.*, 1996). The results show that the mortality ratios appear to have declined from 1992 to 1995. These studies were not conducted during the 1996 field season because of heightened health and safety restrictions by the Army; therefore, mortality changes from the cessation of bird hazing at ERF could not be evaluated (Steele *et al.*, 1997).

Mortality ratios of ducks appear to have declined from 1992 to 1995.

Duck use of the various areas was estimated by using the telemetry observations during periods when hazing was not occurring. The results of these analyses indicate the following relative use by ducks: Area C (22 percent), Coastal East (16 percent), Area C/D (14 percent), Area B (10 percent), Bread Truck (7 percent), Area A (7 percent), Coastal West (5 percent), Area D (4 percent), and Racine Island (3 percent). Comparison of duck mortality to duck use indicates that highest mortality occurs in Area C, Bread Truck, and Racine Island.

The hot areas in Areas C and C/D, Bread Truck, and Racine Island represented the following percentage of total ERF area for the corresponding habitat types: permanent ponds (29 percent), intermittent ponds (19 percent), and sedge marsh (51 percent). The actual percentage of bird use of these hot areas based on the corresponding habitat use was calculated from telemetry observations during nonhazing periods as follows: permanent ponds (47 percent), intermittent ponds (31 percent), and sedge marsh (54 percent). In general, this distribution indicates that bird use of the hot areas is higher than would be indicated by bird use based on the proportional area of the corresponding habitat. The percentage of bird use of hot areas was much lower when compared to overall ERF use: permanent ponds (5.4 percent), intermittent ponds (2.3 percent), and sedge marsh (16 percent) (Cummings *et al.*, in Racine *et al.*, 1994, 1995, 1996; Walsh *et al.*, 1997).

Aerial surveys of birds compared bird use of ERF with overall bird use of UCI marshes.

Eldridge (in Walsh *et al.*, 1997) also estimated duck preference for a limited number of landform types in ERF. For the fall period (representing about 86 percent of all ducks counted in 1996), aerial surveys estimated duck use of ponds at 72 percent of the total. Telemetry studies (Cummings *et al.*, in Walsh *et al.*, 1997) estimated duck use of ponds (permanent and intermittent) at 16 percent during the corresponding time period. The difference in duck use and preference of ponds was attributed to limitations or biases of the respective survey methods.

Comparison of bird use of ERF with overall bird use of UCI marshes (Eldridge, in Walsh *et al.*, 1997) was based on aerial surveys of bird

populations conducted during the 1995 field season. In general, about 3 to 5 percent of waterfowl (swans, geese, and ducks) in UCI were found in ERF wetlands. Higher percentages of eagles (between 9 and 52 percent) were found to use ERF. Because this comparison was based on a single field season, the relative proportions of birds would be expected to vary from year to year.

Although field studies have not established a reliable estimate of bird mortality in the reference areas of UCI, the mortality rate in ERF is likely much higher than the background mortality rate in reference areas (Steele and Reitsma, in Racine *et al.*, 1996). According to the mortality of ducks studied by Cummings *et al.* in bird telemetry studies between 1993 and 1995 (in Racine *et al.*, 1994, 1995, 1996; Walsh, *et al.*, 1997), 19 out of 120 radioed ducks were found dead in ERF. This represents a mortality rate of about 16 percent for ducks in ERF. However, the 1996 telemetry studies were conducted on a larger sample of birds (N = 107 mallards) and without hazing (Cummings *et al.*, in Walsh, *et al.*, 1997). The mortality rate from this study was 35 percent, a value that is probably more indicative of current risk at ERF without remediation. If it is assumed that about 5 percent of UCI ducks use ERF, the percentage of UCI ducks potentially affected (killed) by WP in ERF would be about 2 percent.

For this baseline EcoRA, the risk description is focused on waterfowl mortality from WP ingestion.

8.2.4.2 Risk Description

Risk description consists of two primary elements: the ecological risk summary and an interpretation of ecological significance (USEPA, 1992a). For this baseline EcoRA, the risk description is focused on waterfowl mortality from WP ingestion.

Ecological Risk Summary. The weight of evidence indicates that ingestion of WP particles by ducks and swans is the cause of elevated waterfowl mortality in ERF. WP has been identified at elevated levels in the sediment of three areas of ERF: Area C, Bread Truck, and Racine Island. Area C/D is adjacent to these areas and also could have high levels of WP that were not detected because of the limited sediment sampling. Area A also may be ecologically sensitive because of its heavy use by waterfowl and documented duck mortality.

Waterfowl found dead or dying in ERF have tested positive for WP in their tissues. The detected WP levels in bird tissues have been higher than corresponding WP levels in tissues from lethally dosed mallards in toxicity studies. For example, the highest tissue WP concentrations for lethally dosed mallards was 0.463 µg/g (ww) for skin and 0.940 µg/g (ww) for liver tissue. Field-collected mallards had WP concentrations up to 20.5 µg/g (ww) in skin tissue and up to 21.4 µg/g (ww) in liver tissue. Other field-collected waterfowl samples also had tissue concentrations that exceeded the corresponding tissue concentrations from the mallard toxicity studies. Field-collected teal had WP concentrations up to 6.34 µg/g (ww) in skin tissue and up to

2.70 µg/g (ww) in liver tissue. Field-collected pintail samples had WP concentrations in skin tissue up to 2.64 µg/g (ww). This information suggests that waterfowl can ingest sufficient quantities of WP in ERF to result in mortality.

Bird population studies have provided useful insights into natural variation in bird populations that use ERF, although the variation has not been quantified. Some data from population ground surveys have been used in conjunction with mortality transect data to develop a mortality ratio for ducks. This index was used to normalize observed mortality on the transect to the number of ducks with the corresponding area of ERF. It has been suggested that the falling mortality ratio in advance of full-scale remedial activities provides evidence that natural processes are occurring in some parts of ERF that are reducing WP exposure levels (Steele and Reitsma, in Racine *et al.*, 1996). The effect of bird hazing activities on ERF waterfowl exposure is another possible explanation for the falling mortality ratios.

Bird population studies have provided useful insights into natural variation in bird populations that use ERF, although the variation has not been quantified.

Activities at ERF that cause disruption to waterfowl also make it difficult (if not impossible) to determine whether falling mortality ratios can be attributed to natural reductions in WP exposure levels (through attenuation or sedimentation). Bird hazing, walking transects, the heavy use of helicopters, dredging activities, and the duck pen studies all have altered behavior of the ducks and swans. These activities appear to have had a lesser effect on resident waterfowl than on transients.

Thus, at a minimum, bird hazing should be stopped while assessments of bird populations and mortality along transects are being conducted. This information would be used to establish the baseline ERF mortality ratio. The baseline ERF mortality ratio then could be used to assess the success of future remedial activities or natural reductions in exposure.

Reduced bird exposure levels from sediment deposition over the WP-contaminated sediments may provide a short- and long-term reduction in waterfowl mortality. It is also possible that these sediments may become subsequently re-exposed by the processes of water or ice erosion.

Interpretation of Ecological Significance. The significance of waterfowl mortality at ERF is given perspective by providing an estimate of the proportion of UCI waterfowl that are using ERF. As indicated in Section 8.2.4.1, only a small percentage of UCI waterfowl (3 to 5 percent) may be using ERF (based on 1 year of surveys). The estimated in-ERF mortality rate from instrumented birds in the telemetry studies during 1993 to 1995 indicates that approximately 16 percent of the ducks died in ERF, presumably from WP poisoning or subsequent immobilization and predation.

When hot area use was compared to overall use of the habitat type in ERF, the hot area use represented 47 percent of permanent pond use, 31 percent of intermittent pond use, and 54 percent of sedge marsh use.

However, the 1996 telemetry studies were conducted on a larger sample of birds (N = 107 mallards) and without hazing. (Cummings *et al.*, in Walsh *et al.*, 1997). The mortality rate from this study was 35 percent, a value that is probably more indicative of current risk at ERF without remediation. If it is assumed that approximately 5 percent of UCI waterfowl use ERF, the estimated percentage of UCI waterfowl affected by WP in ERF would be about 2 percent.

Field studies have not established a reliable estimate of bird mortality in reference UCI marshes; however, mortality in ERF is much higher than background mortality in the reference areas (Steele and Reitsma, in Racine *et al.*, 1996).

The hot areas identified with the GIS database represent a large proportion of areas used by ducks, as indicated by telemetry studies from 1993 to 1995. Overall duck use of permanent ponds (13.1 percent), intermittent ponds (7.4 percent), and sedge marsh (26.4 percent) accounts for a total of 46.9 percent of duck observations made within ERF.

When hot area use was compared to overall use of the habitat type in ERF, the hot area use represented 47 percent of permanent pond use, 31 percent of intermittent pond use, and 54 percent of sedge marsh use. Overall duck use of the hot areas represented approximately 23 percent of all duck observations within ERF. This indicates that the hot area represent significant habitat resources for ducks in ERF.

The nature of studies used to characterize the ecosystem, estimate WP concentrations in ERF biota tissues, and characterize exposure of ERF biota to WP contamination contributes to uncertainties in exposure assessment.

8.2.5 Uncertainties

Detailed discussions of the uncertainties associated with the risk assessment are provided in Sections 3.3 and 4.1.2 of Appendix A. The uncertainty discussions pertain to the various studies associated with the exposure assessment, ecological effects, assessment, and the risk characterization.

Exposure assessment uncertainties stem from the nature of the studies used to characterize the ecosystem, to estimate WP concentrations in ERF biota tissues, and to characterize exposure of ERF biota to WP contamination. Limitations on estimating bird populations by aerial and ground survey methods contribute to the uncertainty associated with the ecosystem characterization. In addition, the actual cause of telemetry bird death, especially during hunting season, is another uncertainty. Studies to estimate WP concentrations in tissue samples had a number of factors that contributed uncertainty such as live versus dead bird samples, uneven distribution of sample locations, lack of predator tissue samples, lack of tissue sample information, and variations in the tissues analyzed and the WP analytical methods. Uncertainty in the exposure analysis was due to difficulties in sampling and quantification of WP in ERF because of danger from

UXO. The uncertainty stems from a lack of sampling for WP in some areas and the irregular distribution of WP at ERF.

Uncertainties about ecological effects arise from problems with the previously mentioned field studies and with the laboratory studies. The effects of researchers in the field and bird hazing activities on bird behavior and habitat use were not quantified. Equipment errors associated with the telemetry studies also could affect results.

Estimates of uncertainty (or confidence intervals) were not provided by either Eldridge or Cummings *et al.* in their reports. To quantify uncertainty from their studies would require that the original study data be collected in a way that would permit the estimation of confidence intervals. Uncertainties associated with the laboratory tests include intra- and inter-study variations, limitations of study design, and the ability to match laboratory conditions to those observed in the field.

Risk characterization represents the integration of the exposure and the ecological effects assessments.

Risk characterization represents the integration of the exposure and the ecological effects assessments. For this reason, the risk characterization uncertainties are affected by the previously mentioned uncertainties. Additional uncertainties include the limitations of the bird mortality studies, such as the assumption that birds do not travel a significant distance after exposure before dying, the uneven distribution of mortality transects, and the accuracy of the ground survey counts used in calculating the mortality ratio. In addition, studies of WP levels in fish and invertebrates may have had minimum detection limits that were too high to detect levels found at ERF. The single largest source of error associated with comparison of ERF bird use to that of the UCI marshes was that the comparison was based on a single field season. Considerable variation from year to year already has been demonstrated in the ERF population studies.

8.3 Human Health Risk Assessment

Offsite hunter and onsite recreation were considered as potential exposure scenarios.

Previous HHRAs for the human consumption of contaminated ducks from ERF, prepared in 1991 by the U.S. Army and the Alaska State Epidemiologist, concluded that there is a very low human health risk. This study was designed to determine the current and potential human health risks based on the latest information available for ERF. This baseline assessment assumes that no remedial action will be performed.

Initially, several different current and potential exposure scenarios were considered, including onsite and offsite activities. Although hunting on ERF is banned, the offsite hunter scenario was addressed quantitatively because of the current level of hunting in nearby areas and the potential for contaminated ducks to fly to those areas. In addition, because no physical barriers prevent access to ERF from

Knik Arm or Eagle River, an onsite recreation scenario was considered.

This offsite hunter scenario was developed from ADFG information to estimate that a very active hunter might consume 23 ducks during a year. This estimate was adjusted considering the probability that a harvested duck would be contaminated with WP from ERF, which was estimated as 0.005 based on (1) the proportion of ducks in ERF compared to other areas of Cook Inlet and (2) data on the mortality rate from WP exposure and the proportion of time ducks from ERF spend offsite. Duck meal portion sizes (112 and 90 grams for an adult and child, respectively) were estimated by using guidance from USEPA. An average concentration of 0.12 µg/g of WP for the duck portion was estimated by using field and laboratory studies. The chronic oral reference dose developed by USEPA (2×10^{-5} mg/kg-bw/day) and standard risk assessment equations also were used. The calculated hazard quotients were 0.005 and 0.003, respectively, for the child and adult consumers in the scenario. This is considerably below the value of one, indicating that the likelihood for significant chronic effects from the consumption of contaminated ducks in the offsite hunter scenario is very low.

For the recreational scenario on the OB/OD Pad, the calculated cancer risks and hazard indices were below the levels of concern.

On the basis of assumptions of the scenario, an adult would have to consume between 20 and 39 contaminated ducks each year, depending on the portion size consumed at each meal, before the USEPA oral reference dose for WP would be exceeded. Because the ducks at the ERF represent a small fraction of the total ducks in Cook Inlet, this event appears to have very low likelihood.

For the recreational scenario in ERF, it is believed that the greatest risk to human health comes from the potential explosion of UXO. Very few trespassers have been observed. For an upper-bound risk assessment for exposure to WP, it was assumed that intruders, a child and an adult, enter ERF for a few hours on each of 10 days in the summer, are exposed to an average WP concentration of 10 µg/g (which exceeds the mean values for all areas except Racine Island, as shown in Table 4-1), and ingests 200 and 100 mg of sediment, respectively, at each visit. With these assumptions, the calculated hazard quotients are 0.08 and 0.02, respectively, which are much less than 1, the value of concern.

For the recreational scenario in OB/OD Pad, an upper-bound risk assessment for exposure to the surface soil was performed. As with this scenario at ERF, it was assumed that child and adult intruders are on OB/OD Pad for a few hours on each of 10 days in the summer. Hazard indices and cancer risks were calculated for the detected chemicals at each sampling location. With these assumptions, the calculated cancer risks were about 10^{-7} for the child and adult, and the largest calculated hazard indices were 0.01 and 0.003 for the child and adult, respectively. As discussed in Section 6, the concentrations of

arsenic and chromium are similar to those at nearby reference areas. If these chemicals are excluded from the risk calculations, the cancer risks and hazard indices decrease because these metals are significant contributors. EPA has used a cancer risk level of 1×10^{-6} and a hazard index of 1 as levels of concern, and the calculated risks for the recreational scenario are substantially less than these levels of concern.

Although there are a number of uncertainties, it is unlikely that reasonable combinations of exposure factors for WP exposure in either the offsite hunter or the onsite recreation scenarios could lead to a hazard quotient of one, which is the level of concern. The greatest potential for harm is from exposure to unexploded ordnance in the recreation scenario.

Uncertainties are present in this assessment, including future human activities in the area, probability and magnitude of UXO detonation, environmental concentrations, appropriate exposure factors for the scenarios, and toxicity factors. Because the calculated hazard quotients are so small, it is unlikely that other reasonable combinations of exposure factors could result in a hazard quotient for WP exposure greater than 1 for the scenarios. It is likely that the greatest risk in the recreational scenarios come from potential explosions from UXO.

SECTION 9

Conclusions and Recommendations

OUC on Fort Richardson, Alaska, consists of the ERF, an estuarine salt march, and OB/OD Pad, a former EOD site. This report provides results of the OUC RI.

ERF is an active impact area owned and operated by the USARAK. It also is an important resting area for thousands of water birds during the annual spring and fall migrations. Efforts to characterize the site for investigating elevated mortality in ERF have shown that it is a diverse ecosystem supporting many species of birds, fish, mammals, and macroinvertebrates and a wide variety of plants. WP associated with munitions discharged into ERF has been shown to cause elevated mortality in dabbling ducks and swans. WP comes from smoke shells used by artillery units in association with training conducted in ERF. The WP has been shown to be persistent in wetland sediments where dabbling waterfowl, the primary receptors of concern, ingest it. No current direct threat to humans by WP has been identified as part of this investigation.

Efforts to characterize the site for investigating elevated mortality in ERF have shown that it is a diverse ecosystem supporting many species of birds, fish, mammals, and macroinvertebrates and a wide variety of plants.

The very low solubility in water and heterogeneous distribution of this contaminant make detailed characterization through sampling very difficult and expensive. The risk to site workers posed by the UXO further complicates characterization efforts. The existing WP data and the frequency of craters formed by munitions have been used in combination with data collected on bird mortality and behavior to identify hot ponds that will be targeted for initial remedial action. Future intrusive sampling for WP should be minimized because of the risk to humans of the UXO and the heterogeneity of WP in ERF. Future monitoring programs will help determine any shifts in duck use and confirm assumptions while measuring remedial success.

The primary remedial objective is to reduce waterfowl mortality. It is anticipated that efforts to reduce mortality also will prevent exposure of secondary receptors, such as predators and scavengers, to this contaminant and eventually reduce the ecological threat of WP in ERF to tolerable levels. Because ERF covers a large area, prioritizing areas through the identification of hot ponds enables funds to be expended where the greatest effect can be realized.

The primary remedial objective is to reduce waterfowl mortality.

The study results documented in this RI report for ERF were accumulated over nearly 15 years. Because most of this work was performed before Fort Richardson was added to the NPL, information was collected before the CERCLA process was initiated at OUC. The extensive data set that has been compiled as a result of these studies has been archived in the ERF GIS database used to support this RI

report. Many specific issues have been addressed during the course of these investigations. Conclusions have been drawn regarding the physical setting, contaminant, and receptors investigated. These conclusions are listed in the following section, followed by a strategy for pursuing remedial action in ERF.

All detected chemicals at OB/OD Pad had concentrations considerably below their action levels for clean closure.

Open burning and open detonation of explosive materials historically have occurred on a gravel pad adjacent to ERF. Materials have included fuses, HE projectiles, smoke pots, mortar rounds, star clusters, flares, mines, rocket motors, shape charges, detonation cord, dynamite, and some flammable solids. Existing records indicate that no liquids were disposed there. Disposal was either on the surface or in an excavated pit.

A site investigation of the soil and groundwater at OB/OD Pad was completed in 1996. Surface and subsurface soils were sampled. Nine monitoring wells were installed and developed, and groundwater samples were taken. The depth to groundwater was 6 to 11 m below the ground surface. Water table elevations indicate a shallow groundwater gradient to the southwest, toward ERF. It is believed that the groundwater movement is strongly influenced by both the tides and the river. Soil and groundwater samples were analyzed for an extensive list of volatile and semivolatile organic chemicals and metals. Very few chemicals were detected in either the soil or the groundwater. All detected chemicals at OB/OD Pad had concentrations considerably below their action levels for clean closure. In addition, the ecological and human health risk assessments indicate that the risks are very low.

9.1 Conclusions

On the basis of a review of the data collected in ERF since the mid-1980s, several conclusions are made for ERF:

Conclusions for ERF reflect data collected since the mid-1980s.

1. **WP is the primary cause of waterfowl mortality.** Symptoms exhibited by exposed ducks in ERF are similar to those observed in ducks dosed with WP in the laboratory. WP also was detected in tissue samples collected from duck carcasses found in ERF.

2. **WP was deposited in the sediment primarily during range firing activities.** WP smoke munitions were used during training activities in ERF for several decades. Rounds were fired onto the flats and detonated, dispersing WP particles over large areas. Further distribution of the particles likely occurred when HE rounds exploded in WP-contaminated soil and sediment.

3. **Craters in ERF potentially indicate the level of range firing activity.** Detonation of HE munitions generally creates a crater at the point of impact. Although WP munitions do not form craters

upon detonation, they typically have been used in conjunction with HE training activities. By applying a cause-and-effect approach, it can be deduced that the more craters in an area, the more munitions that have likely been fired there, and thus the higher probability of WP contamination.

4. **WP particles are not homogeneous throughout ERF.** WP particles are dispersed after munitions containing WP are detonated. Particle sizes vary because of the nature of an explosive release. Particle size, dispersion pattern, and ultimate resting location also depend on whether the munitions were detonated on land or over water. Even within small areas, the particle density can vary substantially.

The detection frequencies and concentrations for WP in sediment are highest in Area C, Bread Truck, and Racine Island.

5. **The detection frequencies and concentrations for WP in sediment are highest in Area C, Bread Truck, and Racine Island.** Sixty-three percent of the overall ERF sampling locations had nondetectable concentrations, but at least 45 percent of the locations in each of these three areas had detectable concentrations. The highest concentration, 3,071 µg/g, was found on Racine Island.

6. **WP particles can break down (sublimate) when exposed to air, but are long lasting in water-saturated media.** WP particles are readily oxidized when exposed to air at temperatures exceeding 20°C. Because they dissolve so slowly, particles have an indefinite life when quenched in the water and allowed to settle into pond or marsh bottom sediments.

7. **Waterfowl are exposed to WP from the sediment of ponds and sedge marshes while they are feeding.** Some WP particles match the size of food (such as seeds and macroinvertebrates) sought by dabbling ducks and swans. As the waterfowl forage for food in pond and marsh bottom sediments, it is possible that they cannot differentiate between WP and their normal food source.

8. **Dabbling ducks and swans are the primary receptors of WP.** Dabbling ducks and swans both forage for food in pond and marsh bottom sediments. In addition, mortality rates of dabbling ducks have been observed to be significantly higher than mortality rates of other waterfowl in ERF as well as other UCI marshes. Telemetry data in 1996 suggest that the mortality rate among mallards was about 35 percent.

Predation and human exposure to WP by consumption are not high-level concerns at present.

9. **Predation and human exposure to WP by consumption are not high-level concerns at present.** There has been no verified mortality resulting from predators feeding on WP-contaminated waterfowl carcasses. Although a dead eagle has been found with WP contamination, current predator mortality appears low. In

addition, the results of analyses of tissue collected from dabbling ducks taken by hunters near ERF do not indicate a threat to humans ingesting the meat.

Twenty-two permanent ponds with a total area of 23 hectares already have been identified as the likely areas of most significant exposure.

10. **Permanent ponds and associated sedge with confirmed presence of WP and/or moderate to high crater density and observed moderate to high dabbling duck and/or swan use are the most significant exposure areas (hot ponds).** According to the CSM, the areas of greatest concern are where there is a source (WP-contaminated sediment), a receptor (dabbling duck or swan), and a potential for exposure (foraging for food). Twenty-two hot ponds, which include a total area of 23 hectares, have been identified in these areas: A, C, C/D, Bread Truck, and Racine Island (discussed in Section 10).

11. **The movement of WP through Eagle River to Knik Arm appears to be minimal.** WP has been detected in the sediments traveling through the gullies, but no sediment and water samples in the river have detected any WP.

The following are major conclusions for OB/OD Pad:

1. **The groundwater is at a depth of 6 to 11 m below the surface, and the gradient is shallow, with groundwater moving toward the southwest, toward ERF.** Groundwater movement patterns are likely influenced by the tides and the river.

2. **The site investigation detected only a limited number of organic chemicals and metals in the soil and groundwater.** In many cases, observed soil concentrations were similar to reference area values.

3. **The OB/OD Pad will meet clean closure requirements.** The detected chemicals were all considerably below their clean closure action levels.

4. **The ecological and human health risk assessments found very low risks associated with exposures to these chemicals at the measured concentrations.**

The OB/OD Pad will meet clean closure requirements.

9.2 Recommendations

The results compiled to date have been used to identify several hot ponds that appear to be areas of both greatest exposure to WP and greatest mortality in ERF. Although previous characterization efforts have not completely defined the nature and extent of contamination in all areas of ERF, the existing data are sufficient to identify the likely areas of greatest exposure for dabbling waterfowl to WP. Therefore,

the following recommendations are proposed to constitute a general remediation strategy for ERF:

- The USARAK should initiate remedial action in the hot ponds identified in Section 10 of this report.
- A monitoring program designed to assess the short- and long-term effects of remediation and confirm assumptions should be developed and implemented in 1997 (see Section 10.3).
- Each remedial action should be implemented with an associated monitoring task that will provide the data needed to demonstrate that the action has achieved the site-specific remedial objective.
- It is possible that additional site characterization may be required at some locations to refine remedial planning. It is recommended that such efforts be limited to the activities required to meet site-specific remedial objectives. Additional site characterization on an ERF-wide basis is not considered necessary.

The following are recommendations for OB/OD Pad:

- The USARAK can proceed with clean closure, which includes removing unexploded ordnance, installing a soil cap, revegetating, and designing engineering control to prevent water run-on and runoff. Section 5.2.11 of the closure guidelines (40 CFR 264) includes several other activities applicable to closure in accordance with RCRA.
- The USARAK may consider the use of the ERF dredge spoils as cap material.

SECTION 10

OUC Preliminary Remediation Goals

The overall remediation goal at ERF is the protection of the environment and human health.

The overall remediation goal at a CERCLA site is the protection of the environment and human health. At OUC, preliminary remediation goals (PRGs) have been developed to support this overall goal for ERF. This section describes these goals and how their achievement will be monitored. Additional monitoring needs also are identified. The section ends with a brief summary of the proposed monitoring strategy for ERF.

No PRGs are described for OB/OD Pad. It is not discussed in this section because the environmental and human health risks were low, and the monitoring results found no chemical with a concentration that exceeded its action level for clean closure.

10.1 Preliminary Remediation Goals for ERF

The results of the risk assessment demonstrate that the greatest known risks are those associated with acute mortality of waterfowl. The effects on other species, including man, are not as significant or easily observable. The studies discussed in the earlier sections also have demonstrated that WP is the toxic agent for the waterfowl acute toxicity.

Several types of preliminary remediation goals were considered.

Several types of PRGs were considered:

- **Reduction in exposure concentrations.** This approach is consistent with that used at most CERCLA sites. In the case of a single toxic chemical, the cleanup level is the estimated highest concentration in an environmental medium (such as sediment) that would not lead to an unacceptable effect under a defined exposure scenario. The medium is then remediated until the environmental concentration is below that cleanup level. The PRG is achieved by reducing the area associated with concentrations that exceed the cleanup level.
- **Reduction of hot zones.** This approach is used most frequently when areas of relatively high environmental or human health risk ("hot zones") are surrounded by areas of relatively low risk. The identification of these hot zones focuses the remediation on the areas that should provide the most cost-effective remediation. The PRG is to reduce the area of the hot zones.
- **Reduction in waterfowl acute effects.** In this approach, the PRG is set as an absolute value of an acceptable level of waterfowl acute

effect, a reduction compared to the current level, or some combination of both.

- **Reduction in waterfowl chronic effects.** In this approach, the PRG is set as an absolute value of an acceptable level of waterfowl chronic effect, a reduction compared to the current level, or some combination of both.
- **Reduction in effects in other species.** In this approach, the PRG is set as an absolute value of an acceptable level of some effect in other species, a reduction compared to the current level, or some combination of both.

The advantages and disadvantages of each type are summarized in Table 10-1.

The "cleanup level" type has been rejected for ERF because the particulate nature of the WP and the high local heterogeneity of the WP contamination have not allowed a reliable estimate of the maximum WP concentration that could remain in sediment without causing harmful effects. Chronic and other effects have not been included as PRGs at this time because acute duck mortality has been the most obvious effect of the WP contamination, there is a high degree of difficulty in reliably estimating the levels of the chronic and

TABLE 10-1
Comparison of Preliminary Remediation Goal Types

Types	Advantages	Disadvantages
Cleanup level	Approach consistent with other CERCLA sites	Heterogeneity of WP in sediments makes concentration type very difficult to apply. Rate of particle ingestion by waterfowl is unknown.
Hot zones	Uses additional data (such as bird use) that is not dependent on the uncertainties of concentration measurements. Effects of remedial technology can be measured relatively quickly.	Hot zone criteria may not be perfectly correlated with waterfowl mortality. Therefore, reduction in hot zones may not reduce mortality.
Waterfowl acute effect (mortality)	Consistent with major concern at ERF	Variability probably requires measurement over several years to detect effect. Difficult to measure as an absolute quantity. Potential confounding factors.
Waterfowl chronic effects	Addresses effects other than acute toxicity	Few detected chronic effects are diagnostic for WP toxicity. Potential confounding factors.
Other effects	Covers larger range of potentially affected species and effects	Only waterfowl showed existing large effects. Other effects will require much larger population and/or different monitoring strategy. Few detected effects are diagnostic for WP toxicity. Potential confounding factors.

other effects, and reduction in acute mortality will be used as an indicator of reduced chronic effects. Other species and effects, including habitat alteration, will be examined following achievement of the principal biological PRG.

Figure 10-1 summarizes the two PRGs and the monitoring strategy for their assessment. The two PRGs proposed for ERF are described below.

The two PRGs for ERF include reduction of mortality and reduction of WP hot zones.

1. **Reduction of acute waterfowl effects (mortality).** This PRG sets both short-term and long-term goals for reducing waterfowl mortality. Because dabbling ducks have been the most affected, their mortality will be specifically assessed. The specific goal in 5 years is to reduce mortality as measured by telemetry by 50 percent of the value in 1996. The goal in 20 years is to reduce the measured mortality to no more than 1 percent above the reference value. The reduction in mortality may result from the elimination of the WP source within ERF and/or the elimination or reduction of WP exposure to waterfowl. Successful implementation of remedial technologies that are chosen to eliminate WP and WP exposure to waterfowl will be monitored to provide an indication that this PRG is being met. In addition, data on overall population, use, and mortality of waterfowl within ERF will be necessary to determine if this PRG is being met. Measurement methods for changes in waterfowl populations, use, and mortality throughout ERF are described in Section 10.2.1.

2. **Reduction of hot zones within ERF.** This PRG sets short-term and long-term goals to reduce the total hectares of WP hot zones. The goal will be to reduce hot zone areas by 50 percent in 5 years and by 99 percent in 20 years. A discussion of the criteria that have been developed and evaluated to determine WP hot zones and the hot zones that have been identified to date within ERF are included in Section 10.2.2. Remedial technologies that are chosen to reduce hot zones by source (WP) removal or elimination of exposure pathway will be monitored to help determine the success of this PRG.

Examples of remedial technologies that may be applied at ERF include dredging, pond draining, natural attenuation, AquaBlok™, and geosynthetics. Hazing also may be used as an interim remedial technology or in combination with other technologies. Figure 10-1 lists treatment options that are currently under consideration for achieving reduction in waterfowl mortality and WP hot zones. Measurements of success for the treatment options will be described in the feasibility study.

Because the birds have unrestricted access to ERF and occupy large areas over time, the measure of mortality provides feedback at the scale of the overall ERF, but it may take a few years to resolve whether

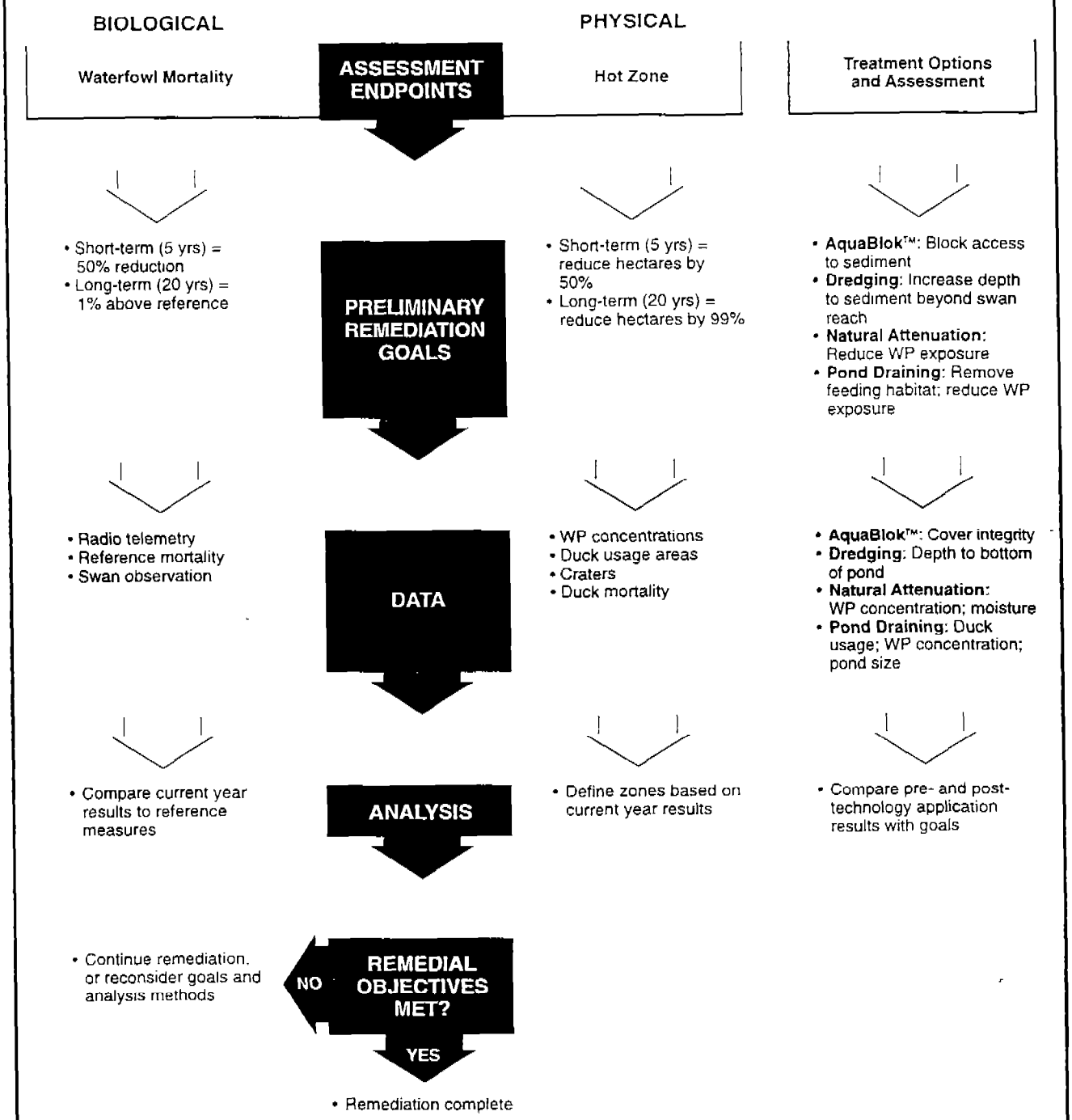


Figure 10-1

Preliminary Remediation Goals and Assessment Methods

Operable Unit C
Remedial Investigation
Fort Richardson, Alaska

CH2MHILL

the goal is met. The hot zone assessment integrates the remedial actions not only across ERF but also across individual smaller areas, such as Area C or Bread Truck Pond. Its timescale of resolution is probably only a few months, because several remedial actions may occur over the course of a field season. These two interrelated PRGs are being used at ERF because no single approach can be expected to provide adequate feedback on the remedial success of the actions.

10.2 Measurement Methods

10.2.1 Mortality

The achievement of the preliminary remedial goal for duck acute mortality will be measured by using radio telemetry of duck activity, based on the methods and conditions previously discussed (Cummings *et al.*, in Walsh *et al.*, 1997). Mallards have been chosen as the indicator species because they are one of the dominant species of dabbling ducks during the fall and are susceptible to WP toxicity.

The monitoring for the duck mortality PRG will include aerial surveys and telemetry for mallard mortality.

Radio telemetry devices will be attached to 100 to 150 mallards during the fall migration season. Depending on the specific study objectives that year, some telemetry devices will record only mortality; others also may be used to record daily movements of the birds. The birds will be released in the same areas in which they were captured. The bird positions will be recorded each day, or only as needed for those with the mortality transmitters.

The mortality rate will be determined by dividing the number of mallards that died during the measurement interval (typically about 2 months) by the number of mallards that were tracked for mortality (which may include birds tracked daily).

The current estimates of the ERF WP and reference mortality rates are 35 and 3 percent, respectively. The confidence limit on the mortality rate is about ±8 percentage points. These values may be revised in the future as new data become available.

Aerial surveys will be continued at ERF to provide a broader view of duck activities in and around ERF. To coincide with the telemetry study, the aerial surveys will focus on the fall migration season.

Because the mortality rate may be highly variable by year, an annual change may or may not be significant. Several years of data may be necessary to detect a significant effect. Trends and appropriate statistical analyses will be necessary to determine whether any changes are significant. Ducks are susceptible to other diseases, which also may cause a high mortality rate. Necropsy and laboratory analyses, if needed, can provide the confirmation of the cause of death.

10.2.2 Hot Zones

A method for identifying hot zones has been developed with the use of mortality, WP concentrations, duck usage, and crater density data.

Table 10-2 summarizes the total surface areas of ERF and the permanent and intermittent ponds in each ERF area. Permanent ponds are brackish to freshwater ponds, 25 to 50 cm deep, which do not usually dry out between flooding tides. Intermittent ponds are usually mud flat areas that flood with 10 to 20 cm of water during spring tides and then dry out by evaporation during occasional summer periods without flooding tides, low precipitation, and hot dry weather (Racine and Brouillette, in Racine *et al.*, 1995). Table 10-2 shows the maximum area in ERF used by waterfowl which may contain concentrations of WP that are toxic to water birds.

It is believed that there are smaller zones that contribute more than others to the observed mortality. Geographical priorities for these zones have been developed in a two-stage process. In the first stage, ERF areas were screened with the ERF GIS to identify the most likely areas where ducks are exposed to lethal quantities of WP (called "hot areas" in this report). In the second stage, the assessment focused on even smaller geographical areas, the ponds. Ponds (called "hot ponds") that are believed to be most likely to contribute the lethal doses of WP to the ducks based on the screening criteria are the product of this screening step. The two stages in the identification of these areas are discussed in the following two sections.

10.2.2.1 Identification of Hot Areas

The objective of this stage is to identify the broad geographical areas that most likely contain the lethal quantities of WP. Because

TABLE 10-2
Summary of ERF Ponds

		Permanent Ponds		Intermittent Ponds	
ERF Area	Total Area (ha)	Number	Area (ha)	Number	Area (ha)
A	188	54	7.8	44	16
B	18	36	8.8	3	0.4
C	108	21	10	15	10
C/D	30	47	4.7	0	
D	28	25	11	0	
Bread Truck	52	7	3.5	14	7.2
Coastal East	82	27	2.5	11	8.6
Coastal West	156	9	2.5	22	13
Racine Island	7	8	1.3	1	0.1
Total	809	234	52	110	55

Note: Pond number is double-counted if a pond is in two areas. Base period is early 1995.

established ERF areas (for example, Area A and Bread Truck) have been used for a number of years to characterize ERF, these areas comprise the geographical scale chosen for the first stage of developing geographical priorities. Screening criteria included the following:

Hot areas were identified by using four screening criteria: mortality, WP concentrations, duck usage, and crater counts.

- **Mortality–criterion indicates primary effect of concern.** Carcasses and feather piles have been counted for several years in ERF. The results of the 1995 transects were used in the mortality assessment. A criterion level of at least five carcasses was used to distinguish an area as "high." The following areas met the high level: A, C, C/D, Bread Truck, and Racine Island. The 1995 and 1996 telemetry data also were used. In 1995, the four dead ducks with radio collars recovered in ERF were found in Areas A, B, and C/D (Cummings *et al.*, in Racine *et al.*, 1996). In 1996, areas where more than 5 dead ducks with radio collars were found included A, C, C/D, and Racine Island (Cummings *et al.*, in Walsh *et al.*, 1997). This mortality level was called high. The other areas had either zero (D, Coastal East, and Coastal West) or only two (B and Bread Truck) ducks found. The main pond in Bread Truck (Pond 109) was drained in early 1996, which explains the low observed duck usage and mortality. Areas that were consistently high in mortality were labeled with a "yes" in the mortality column in Table 10-3.

- **WP concentrations–criterion indicates level of stressor.** WP concentrations provide direct evidence of the presence of environmental contamination. Table 4-2 shows a distinct break among areas with and without WP concentrations greater than 1 µg/g. Only three areas, Bread Truck, Area C, and Racine Island, had concentrations that exceeded this level. This criterion level also was chosen because a duck would have to consume a large quantity of sediment to obtain a lethal dose if the concentration were much below this level (Racine, in Racine *et al.*, 1995). Thus the screening criterion for this factor was set at an area with one or more samples with a concentration greater than 1 µg/g.

- **Duck usage–criterion indicates duck exposure.** It has been shown that ducks are feeding much of the time during the day (Reitsma and Steele, in Racine *et al.*, 1995). Information was available from the telemetry studies from the no-hazing period during fall 1995 and from fall 1996 when there was no hazing at all. The 1995 and 1996 fall aerial surveys also were used (Eldridge, in Racine *et al.*, 1996; in Walsh *et al.*, 1997). A screening level of high usage was defined in areas where at least 10 percent of the measured duck locations were found during the telemetry coverage in 1996 or during the no-hazing period of 1995. High usage also was defined where mean values of at least 100 duck groups were found during the fall aerial surveys. These screening levels were chosen because

TABLE 10-3
Summary of Area Screening

Area	White Phosphorus	Duck Usage	Craters	Mortality	Conclusion
A	Widespread, but not detected above 1 µg/g.	*Telemetry:* High in 1996. *Survey:* High in 1995 and 1996.	Several hectares with high crater density.	Yes	Included because of widespread WP, observed duck mortality, high crater density, and high duck usage.
B	None above detection limit.	*Telemetry:* High in 1995 and 1996. *Survey:* High in 1995 and 1996.	Low crater density.	No	Excluded because of the absence of WP, craters, and mortality.
C	Widespread and several samples above 1 µg/g.	*Telemetry:* High in 1995 and 1996. *Survey:* Low in 1995 and high in 1996.	Several hectares with high crater density.	Yes	Included because of widespread WP, observed duck mortality, high crater density, and high duck usage.
C/D	Limited sampling, and a few above detection limit.	*Telemetry:* High in 1995 and low in 1996. *Survey:* High in 1995 and 1996.	Craters are not visible.	Yes	Included because of similarity to nearby Bread Truck and Area C, observed duck mortality, inability to see craters, and WP concentrations above the detection limit.
D	None above detection limit.	*Telemetry:* Low in 1995 and 1996. *Survey:* Low in 1995 and high in 1996.	Craters are not visible.	No	Excluded because of low WP, low duck usage, and little mortality observed.
Bread Truck	Several samples above 1 µg/g.	*Telemetry:* High in 1995 and low in 1996. *Survey:* Low in 1995 and 1996.	Several hectares with high crater density.	Yes	Included because of widespread WP, observed duck mortality, high crater density.
Coastal East and West	Several samples and only one above detection limit.	*Telemetry:* High in 1995 and low in 1996. *Survey:* High in 1995 and 1996.	A few hectares with high crater density.	No	Excluded because of low mortality and WP concentrations.
Racine Island	Several samples above 1 µg/g.	*Telemetry:* Low in 1995 and 1996. *Survey:* Low in 1995 and 1996.	A few hectares with high crater density.	Yes	Included because of high WP, observed duck mortality, and high crater density.

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the values appeared to distinguish the areas from those with very little usage.

- **Craters–because crater density was used as a surrogate for WP, this criterion indicates a level of stressor.** Craters are particularly valuable as an indicator for areas where WP samples are not available. The screening level for high was at least 71 observed craters per hectare, which was the minimum level of the highest category when the observed crater densities were divided into five categories.

Identified hot areas include A, C, C/D, Bread Truck, and Racine Island.

The above screening criteria were applied as indicated in Figure 10-2. Table 10-3 summarizes the analysis to determine which areas pass the screening, and are included in the next screening stage. In summary, the following hot areas are carried forward to the next stage: A, C, C/D, Bread Truck, and Racine Island.

Table 10-4 summarizes the number of permanent and intermittent ponds and their surface areas in each of the hot areas. It should be noted that Pond 285 at Racine Island had AquaBlok™ applied in 1995 and the large permanent pond (Pond 109) in the Bread Truck area was drained in early 1996. Both still are counted as permanent ponds in this analysis. Pond numbers were obtained from the coverage ALLPONDS in the ERF GIS.

Criteria for hot pond screening include pond type, WP concentrations, and duck usage. Twenty-two ponds have been identified.

10.2.2.2 Identification of Hot Ponds

To obtain more focused zones, ponds were screened by using the following criteria:

- **Pond type.** The focus is on permanent ponds under the assumption that intermittent ponds are at least occasionally dry and therefore may undergo natural attenuation during the

TABLE 10-4
Summary of Ponds in Hot Areas

		Permanent Ponds		Intermittent Ponds	
Area	Total Area (ha)	Number	Area (ha)	Number	Area (ha)
A	188	54	7.8	44	16
C	108	21	10	15	10
C/D	30	47	4.7	0	
Bread Truck	52	7	3.5	14	6.8
Racine Island	7	8	1.3	1	0.1
Total	385	137	27	74	33

Notes:
Area characteristics met the decision schematic in Figure 10-2.
Pond number is counted twice if a pond is in two areas.

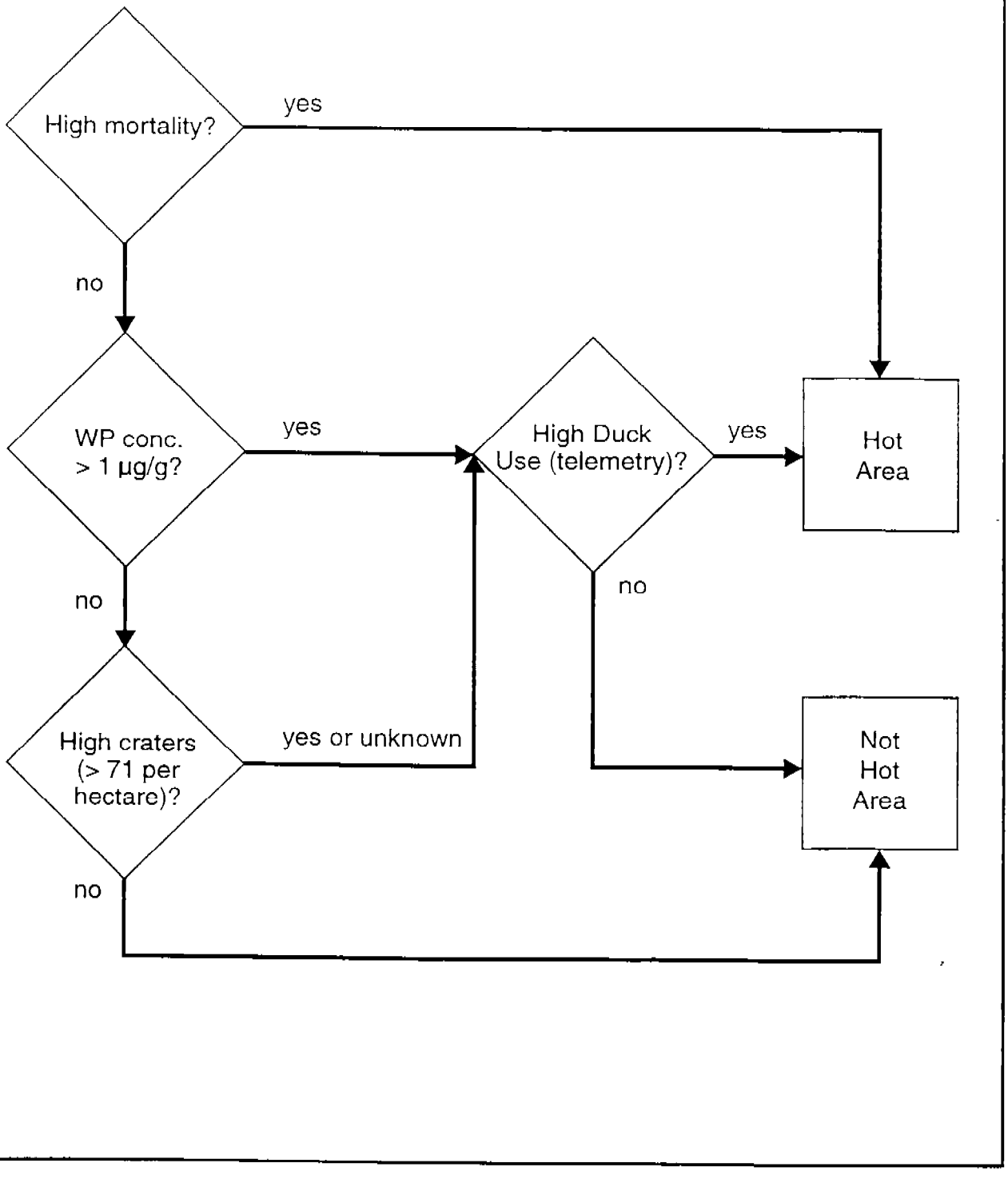


Figure 10-2

Decision Diagram for Determining Hot Areas

Operable Unit C
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Fort Richardson, Alaska

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summer periods between flooding tides. This assumption will be examined by additional monitoring, as discussed in Section 10.3.

- **WP concentrations.** The decision criterion was whether at least one sample had a detected WP concentration.
- **Duck usage.** The decision criterion was those ponds with duck usage greater than 1 percent of the measured duck locations in either the 1995 (no hazing) or 1996 telemetry studies. The criterion level in the aerial survey was ponds having at least 2 percent duck usage in fall 1996 (Eldridge, in Walsh *et al.*, 1997). The 1995 aerial survey did not identify duck usage in areas as specific as ponds.

Table 10-5 summarizes the results of the analysis and includes all ponds that met at least one criterion. The requirement that only one criterion be met for inclusion in the list of hot ponds was made in recognition that not all ponds have been sampled for WP at the same density. Further, it is unclear at this time whether a typical pattern in bird usage is best represented by the 1995 or 1996 data, or some combination. These hot ponds are shown in Figure 10-3.

A few of the 22 ponds already have undergone some treatment with AquaBlok™, draining, or dredging.

As can be seen in the comment column of Table 10-5, a few of the 22 ponds already have undergone some treatment. With the use of early 1995 as the base period, the total area of hot ponds is 23 ha. The total area of the ponds treated with AquaBlok™ at Racine Island (0.4 ha), drained at Bread Truck (3.3 ha), and dredged at the Area C Pond (0.3 ha) is about 4 ha. Although treatment verification studies have not been performed at some of these ponds, if full credit is given to these treatment efforts, treatment actions taken since early 1995 may have reduced the area of the hot ponds by 17 percent.

Some intermittent ponds met the WP concentration and duck usage criteria discussed in this section. If they have not undergone natural attenuation during the drying periods since the WP concentrations were measured (generally 1991 through 1993), they also may contribute significant risks of WP toxicity to water birds. These ponds are summarized in Table 10-6, and may be priority candidates for the confirmation monitoring discussed in Section 10.3.

10.2.2.3 Implications of Uncertainty

Continued monitoring will help reduce the potential for errors.

Screening processes such as those described above are subject to two types of errors. In this case, the errors are (1) including ponds that are not significant contributors to the toxicity to water birds and (2) failing to include ponds that are significant contributors to the toxicity. These errors result from the uncertainty in the available data, the criteria, and the decision scheme in estimating risk. Not all ponds have received the same level of WP sampling. WP sampling and telemetry studies may not represent actual conditions, because any sampling can only approximate those conditions. The transects used to count carcasses and feather piles were not in all areas, and may not have

TABLE 10-5
Summary of Permanent Pond Screening

Area	Pond	Area (ha)	White Phosphorus	Duck Usage			Comments
				Telemetry		Aerial Survey	
				1995	1996	1996	
A	138	0.9			✓		
	208	0.8			✓		
	226	0.5	✓		✓		
	228	0.7			✓		
	246	0.8			✓		
	256	0.4	✓				
	258	1.7	✓		✓	✓	
	290	0.9	✓		✓	✓	
C	129	0.3		✓			
	145	0.1		✓			
	146	5.5	✓	✓	✓		Part of pond dredged during 1994-96.
	155	0.4	✓				Lawson's Pond
	183	2.9	✓	✓		✓	
C/D	40	1.8	✓	✓		✓	
	49	0.4				✓	
	85	0.4		✓			
	93	0.09			✓		
	112	0.2		✓			
Bread Truck	109	3.3	✓	✓		✓	Pond drained in 1996. Now an intermittent pond.
Racine Island	285	0.4	✓				AquaBlok™ in 1995
	293	0.6	✓				
	297	0.03	✓				
Total	22 ponds	23					

Notes: ✓ = Met screening criterion: WP was detected, telemetry found at least 1 percent of the measured duck locations in the pond, or duck use was at least 2 percent in the fall aerial survey.

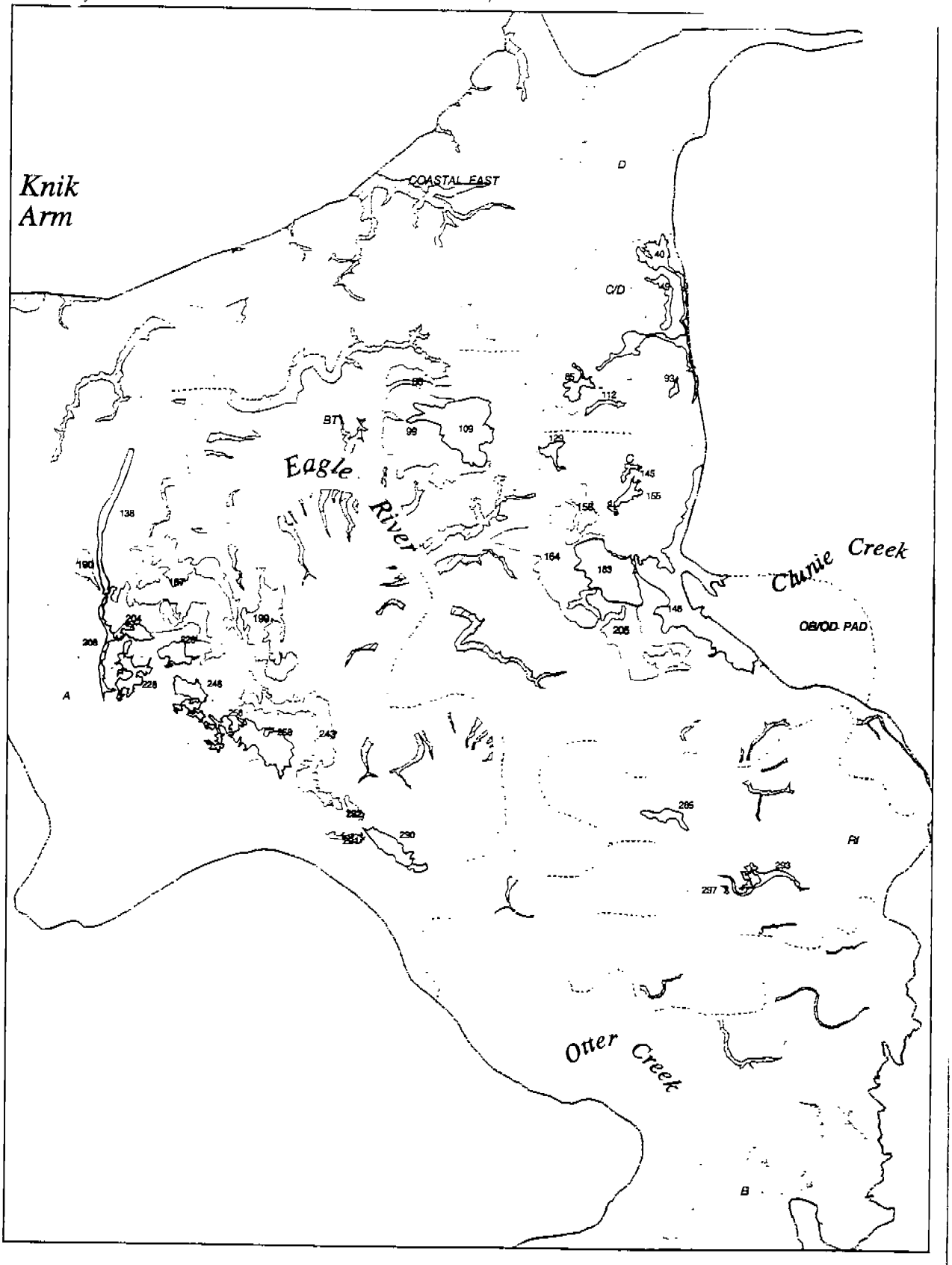


Figure 10-3

Identified ERF Hot Ponds

N

Scale 1:12000
1 cm = 120 m

0 meters 360

Mapping and database sources: CRREL, 1996.

49 Pond Number
Intermittent Pond
Permanent Pond

Priority Intermittent Pond Boundary
Hot Pond Boundary (Permanent)
Gully
River/Creek
Area Boundary
OUC Site Boundary

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been representative in the areas they were in. It is not possible to quantify the uncertainty of all these characteristics.

The error rates in the determination of hot ponds cannot be currently estimated. One design consideration, however, was an attempt to err on the side of too many hot ponds, rather than exclude some prematurely. The potential for these errors is one of the major reasons why continued monitoring is proposed in ERF (see Section 10.3). The errors can be identified and the error rates reduced by comparing the results of this screening to the results of future monitoring.

10.3 Summary of ERF Monitoring Strategy

The key elements that characterize a monitoring strategy are goals, assessment method(s), objectives, decision criteria, geographical test areas, levels of tolerable uncertainty, data types, schedule, and test methods. The proposed monitoring of ERF will include the PRGs and measurement methods discussed in Section 10.2, monitoring for successful implementation of remedial technologies, and monitoring

TABLE 10-6
Characteristics of Intermittent Ponds

				Duck Usage		
				Telemetry		Aerial Survey
Area	Pond	Area (ha)	White Phosphorus	1995	1996	1996
A	187	2.7			✓	
	190	0.55			✓	
	199	2.5			✓	
	204	2.9	✓		✓	
	243	3.2	✓		✓	
	282	0.2			✓	
	291	0.2			✓	
C	158	0.7	✓	✓		
	164	5.5	✓	✓		✓
	205	3.3	✓	✓		
Bread Truck	88	0.71	✓			
	99	5.4	✓	✓		✓
Total	12 ponds	28				

Notes: ✓ = Met screening criterion: WP was detected, telemetry found at least 1 percent of the measured duck locations in the pond, or duck use was at least 2 percent in the fall aerial survey.

for other effects such as ERF habitat alteration. Some of these key strategy elements are summarized in Table 10-7.

One type of monitoring shown in Table 10-7, but not discussed above, is the baseline monitoring. There are considerable data available for this project, but as mentioned before in previous sections, uncertainty remains about several issues. Although uncertainty is not unexpected in dealing with a site as unique, large, and complex as this one, it does appropriately produce caution in the strength of conclusions about site conditions and the expectations for remedial technologies. Baseline sampling will be conducted before initiation of a remedial action. The two monitoring strategies of baseline sampling and treatment verification will confirm whether a chosen remedial action is successful in achieving final remedial goals. Baseline sampling will test whether certain key assumptions about the site and the response to technology are adequate to conclude that the risk of water bird mortality is declining, ultimately achieving the biological PRG.

Details of the monitoring strategy will be presented in the FS.

Details of the ERF monitoring strategy will be presented in the FS because the characteristics of the preferred remedial technologies will significantly influence parts of the monitoring strategy.

TABLE 10-7
Elements of the ERF Monitoring Strategy

Type	Objective	Geographical Area	Assessment Method	Schedule	Data	Test Method
Mallard mortality	50% mortality reduction in 5 years. 1% above reference mortality in 20 years.	ERF	Aerial survey. Telemetry.	Every fall	Area and pond duck populations. Mortality.	Aerial surveys show duck populations. Telemetry shows lack of movement and radio collar recovered from a carcass or feather pile.
Hot ponds	50% reduction of area in 5 years and 99% reduction in 20 years	Hot ponds	WP quantity, duck usage	Every fall	WP particles, and duck usage	WP sampling Telemetry Aerial surveys
Baseline sampling	Potential WP risk to water birds	Ponds not treated	To be developed	To be developed	To be developed	To be developed
Treatment verification	Achieve technology-specific treatment goals	Treated area	Compare conditions before and after treatment	Before and after treatment application	Varies with treatment technology	Varies with treatment technology
Other impacts	Potential WP risk to other species, habitat alteration	To be developed	To be developed	To be developed	To be developed	To be developed

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SECTION 11

Works Cited

Alaska Environmental Information Data Center (AEIDC). *Alaska Climate Summaries.* Alaska Climate Center Technical Note 5, 2nd ed. University of Alaska Anchorage. 1989.

Bell, R.M. *Higher Plant Accumulation of Organic Pollutants from Soils.* EPA/600/R-92/138. June 1992.

Bouwkamp, C.A. Comment to Draft Remedial Investigation Report. July 1996.

Bouwkamp, C.A. *Protocol. Receiving Water Biological Study No. 32-34-HIZV-93, Water, Sediment, Macroinvertebrate, and Fish Sampling, Eagle River Flats, Fort Richardson, Alaska.* U.S. Army Environmental Hygiene Agency. July 1993.

Brown, J.M., K.J. Crossen, and J. Holzman. *A Field Guide to the Geologic Hazards of Anchorage and Turnagain Arm, Alaska.* Alaska Geological Society. Guidebook for Geologic Hazards Symposium. May 12-15, 1987. (as cited in Racine et al., 1993).

Center for Ecological Management of Military Lands, Colorado State University; and Gene Stout and Associates. *Draft Integrated Natural Resources Management Plan, 1997-2001, U.S. Army Alaska.* Vol. 2, Fort Richardson. 1996.

CH2M HILL. *Eagle River Flats Comprehensive Evaluation Report.* Prepared for U.S. Army Garrison, Alaska, Department of Public Works, and Department of the Army, U.S. Army Engineer District Alaska. July 1994.

CH2M HILL. *Operable Unit C Final Remedial Investigation/Feasibility Study Management Plan.* Prepared for U.S. Army, Alaska, Department of Public Works. April 1996a.

CH2M HILL. *Operable Unit C OB/OD Pad, Fort Richardson, Alaska, Site Investigation Work Plan.* Prepared for Department of the Army, U.S. Army Engineer District, Alaska. 1996b.

Chichowicz, J.J. *Programmatic Life Cycle Environmental Assessment for Smoke/Obscurants–HC Smoke.* Volume 4 of 5. Prepared for Project Manager for Smoke/Obscurants. U.S. Army Armament, Munitions and Chemical Command, Environmental Technology Division. July 1983.

Coburn, D.R., J.B. DeWitt, V.J. Derby, and E. Ediger. "Phosphorus Poisoning in Waterfowl." *J. Am. Pharm. Assoc.* 39:151-158. 1950.

Ecology and Environment, Inc. *Background Data Analysis Report, Fort Richardson, Alaska.* Prepared for U.S. Army Corps of Engineers, Alaska District, and U.S. Department of the Army, U.S. Army Alaska Public Works. January 1996.

Eldridge, W.D. U.S. Fish and Wildlife Service. Personal communication. 1994.

Eldridge, W.D. *Waterbird Utilization of Eagle River Flats–April-October 1990.* U.S. Fish and Wildlife Service, Anchorage, Alaska. December 1990.

Eldridge, W.D. *Waterbird Utilization of Eagle River Flats–April-October 1991.* U.S. Fish and Wildlife Service, Anchorage, Alaska. December 9, 1991.

Eldridge, W.D. *Waterbird Utilization of Eagle River Flats–April-October 1992.* U.S. Fish and Wildlife Service, Anchorage, Alaska. 1992.

EMCON Alaska, Inc. *Demolition Area Number One Closure Guidelines, Fort Richardson, Alaska.* Prepared for Department of the Army, U.S. Army Engineer District, Alaska. December 1993.

Environmental Science and Engineering, Inc. (ESE). *Eagle River Flats Expanded Site Investigation. Fort Richardson, Alaska.* Final Technical Report. Data Item A011. Prepared for USATHAMA Installation Restoration Division. Aberdeen Proving Ground, Maryland. June 1990.

Garrett, Ron. U.S. Fish and Wildlife Service. Personal communication. 1991. (as cited in Quirk, 1991.)

Gossweiler, W.A. *Fort Richardson Natural Resource Plan.* U.S. Army. 1984.

Gossweiler, W.A. Memorandum for the Record: Beluga Whale Sightings in Eagle River Flats. U.S. Army. Undated.

Hanson, H.C. "Characteristics of Some Grassland, Marsh, and Other Plant Communities in Western Alaska. *Ecol. Monogr.* Vol. 21, pp. 317-378. 1951. (as cited in Racine et al., 1994).

Lawson, D.E., and B.E. Brockett. *Preliminary Assessment of Sedimentation and Erosion in Eagle River Flats, Southcentral Alaska.* Report 93-23. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). 1993.

Lawson, D.E., L.E. Hunter, and S.R. Bigl. *Physical System Analyses of Natural Attenuation and Intrinsic Remediation of White Phosphorous Contamination, Eagle River Flats, Fort Richardson, Alaska.* U.S. Army Cold Regions Research and Engineering Laboratory. Prepared for U.S. Army Engineer District, Fort Richardson, Alaska. 1996.

Muhly, R.L. *Programmatic Life Cycle Environmental Assessment for Smoke/Obscurants–Fog Oil, Diesel Fuels, and Polyethylene Glycol (PEG 200).* Vol. 1 of 5. Prepared for Project Manager for Smoke/Obscurants. U.S. Army Armament, Munitions and Chemical Command, Environmental Technology Division. July 1983.

Municipality of Anchorage (MOA). *Chugiak-Eagle River Comprehensive Plan.* Physical Planning Division, Department of Community Planning and Development. January 12, 1993.

Nam, S.I., B.D. Roebuck, and M.E. Walsh. Uptake and Loss of White Phosphorus in American Kestrels. *Environ. Toxicol. Chem.* Vol. 13. 1994. pp. 637-641.

Neiland, B.J. *Survey of Vegetational and Environmental Patterns of the Chickaloon Flats, Kenai Peninsula, Alaska.* Report to Kenai National Moose Range. 1971. (as cited in Racine et al., 1994).

Opresko, D.M., B.E. Sample, and G.W. Suter. Toxicological Benchmarks for Wildlife. Electronic Database VI.5, U.S. Department of Energy, Office of Environmental Restoration and Waste Management, Oak Ridge National Laboratory. 1996.

Quimby, R. Waterbird Habitat and Use of Chickaloon Flats. M.S. Thesis. University of Fairbanks. 1972. (as cited in Racine et al., 1994).

Quirk, W.A. *Environmental Assessment for Resumption of Firing in the Eagle River Flats Impact Area, Fort Richardson, Alaska.* Department of the Army Headquarters, 6th Infantry Division (Light) and U.S. Army Garrison, Alaska, Fort Richardson, Alaska. December 31, 1991.

Racine, C.H., M.E. Walsh, C.M. Collins, S. Taylor, B.D. Roebuck, L. Reitsma, and B. Steele. *Remedial Investigation Report: White Phosphorus Contamination of Salt Marsh Sediments at Eagle River Flats, Alaska.* Report No. CETHA-IR-CR92004. Prepared for U.S. Army Toxic and Hazardous Materials Agency. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). March 1992a.

Racine, C.H., M.E. Walsh, C.M. Collins, D.J. Calkins, B.D. Roebuck, and L. Reitsma. *Waterfowl Mortality in Eagle River Flats, Alaska: The Role of Munition Residues.* Report 92-5. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). May 1992b.

Racine, C.H., M.E. Walsh, C.M. Collins, D. Lawson, K. Henry, L. Reitsma, B. Steele, R. Harris, and S.T. Bird. *White Phosphorus Contamination of Salt Marsh Sediments at Eagle River Flats, Alaska. Report I. Remedial Investigations. Report II, Treatability Studies.* U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). November 1993.

Racine, C.H., M.E. Walsh, C.M. Collins, D. Lawson, S. Bigl, K. Henry, C. Bouwkamp, J. Cummings, L. Clark, J. Davis, P. Pochop, P. O'Neil, C. Rossi, D. Sparling, R. Grove, L. Comerci, W. Eldridge, L. Reitsma, B. Steele, and S. Burson. *Interagency Expanded Site Investigation Evaluation of White Phosphorous Contamination and Potential Treatability at Eagle River Flats, Alaska.* Fiscal Year 1993 Final Report. C.H. Racine, ed. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). May 1994.

Racine, C.H., M.E. Walsh, C. Collins, D. Lawson, S. Bigl, B. Nadeau, L. Hunter, J. Bodette, E. Chacho, R. Haugen, K. Henry, M.R. Walsh, E. Chamberlain, D. Garfield, P. Weyrick, M. Brouillette, C. Bouwkamp, J. Cummings, L. Clark, J. Davis, P. Pochop, C. Yoder, R. Johnson, K. Gruver, K. Tope, J. Bourassa, R. Phillips, C. Rossi, D. Sparling, R. Grove, E. Hall, M. Gustafson, P. Klein, W. Eldridge, L. Reitsma, B. Steele, S. Burson, B. Roebuck, and S. Nam. *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination at Eagle River Flats, Alaska.* Fiscal Year 1994 Final Report. C.H. Racine and D. Cate, eds. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). May 1995.

Racine, C., M.E. Walsh, C. Collins, D. Lawson, S. Bigl, L. Hunter, E. Chacho, R. Haugen, M.R. Walsh, P. Robinson, R. Bailey, J. Mullen, J. Cummings, J. Davis, P. Pochop, C. Yoder, R. Johnson, K. Gruver, K. Tope, C. Rossi, W. Eldridge, L. Reitsma, B. Steele, and B. Roebuck. *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* Fiscal Year 95 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). September 1996.

Racine, C.H., M.E. Walsh, C.M. Collins, D.J. Calkins, and B.D. Roebuck. *Waterfowl Mortality in Eagle River Flats, Alaska: The Role of Munitions Compounds.* Report No. CETHA-IR-CR-91008. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). Prepared for U.S. Army Toxic and Hazardous Materials Agency. January 1991.

Roebuck, B.D. *Analysis of White Phosphorus (P_4) in Biota at Eagle River Flats, Fort Richardson, Alaska: 1995 Field Season.* Preliminary report. December 1, 1995.

Roebuck, B.D. Dartmouth Medical School. Letter to W.A. Gossweiler, U.S. Army. June 21, 1994a.

Roebuck, B.D., M.E. Walsh, C.H. Racine, L. Reitsma, B. Steele, and S-I Nam. "Predation of Ducks Poisoned by White Phosphorous: Exposure and Risk to Predators." *Environmental Toxicology and Chemistry.* Vol. 13, No. 10. 1994b. pp. 1613-1618.

Rosenberg, D.H. Alaska Department of Fish and Game. Personal communication. 1994.

Selkregg, L.L. *Environmental Atlas of the Greater Anchorage Area Borough.* University of Alaska Anchorage, Arctic Environmental Information and Data Center. 1972.

Spanggord, R.J., R. Rewick, T.-W. Chou, R. Wilson, R.T. Podoll, T. Mill, R. Parnas, R. Platz, and D. Roberts. *Environmental Fate of White Phosphorus/Felt and Red Phosphorus/Butyl Rubber Military Screening Smokes.* SRI International, Menlo Park, California. April 1985.

Sparling, D.W., R. Grove, E. Hill, M. Gustafson, and P. Klein. *Preliminary Report of Activities–1994, Eagle River Flats, Alaska. Draft Report.* National Biological Survey, Maryland. December 13, 1994.

Suter, G.W. *Ecological Risk Assessment.* Lewis Publishers, Chelsea, Michigan. 1993.

Suter, G.W., II, M.E. Will, and C. Evans. *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Terrestrial Plants.* ES/ER/TM-85. Oak Ridge National Laboratory, Environmental Sciences Division, under the direction of the Environmental Restoration Risk Assessment Council. 1993.

Tweten, R. *Eagle River Flats Waterfowl Mortality Investigation Progress Report.* U.S. Fish and Wildlife Service, Anchorage, Alaska. 1989.

U.S. Army Cold Regions Research and Engineering Laboratory (CRREL).*Rapid Uptake and Disappearance of White Phosphorus in American Kestrels.* In conjunction with Dartmouth Medical School. Undated.

U.S. Army Corps of Engineers (COE). *Geotechnical Report for Groundwater Monitoring Network, Fort Richardson, Alaska.* February 1996.

U.S. Army Corps of Engineers (COE). *Risk Assessment Handbook.* Vol. II, Environmental Evaluation. EM-200-1-6. November 1995a.

U.S. Army Environmental Hygiene Agency (USAEHA). *Draft Workplan. Eagle River Flats, Fort Richardson, Alaska, Toxicological and Ecological Evaluation.* March 1993.

U.S. Army Environmental Hygiene Agency (USAEHA). *Receiving Water Biological Study No. 32-24-H1ZV-93: Water, Sediment, Macroinvertebrate and Fish Sampling, Eagle River Flats, Fort Richardson, Alaska, 12-23 July 1993.* Final report. March 1994.

U.S. Army Environmental Hygiene Agency (USAEHA). *Receiving Water Biological Study No. 32-24-H37Y-94: Evaluation of White Phosphorus Effects on the Aquatic Ecosystem, Eagle River Flats, Fort Richardson, Alaska, 8-17 May, 22 August - 9 September 1994.* Final report. April 1995.

U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). *Comprehensive Workplan ERF 1992/1993.* Compiled by CPT Steven Bird. February 1992.

U.S. Environmental Protection Agency (USEPA). *Briefing the BTAG: Initial Description of Setting, History, and Ecology of a Site.* EPA ECO Update, Vol. 1, No. 5, Publication 9345.0-05I. August 1992d.

U.S. Environmental Protection Agency (USEPA). *CERCLA Compliance with Other Laws Manual, Part I.* 1988.

U.S. Environmental Protection Agency (USEPA). *Developing a Wo 'k Scope for Ecological Assessments.* EPA ECO Update, Vol. 1, No. 4, Publication 9345.0-0.5I. May 1992c.

U.S. Environmental Protection Agency (USEPA). *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference.* EPA 600/3-89-013. March 1989b.

U.S. Environmental Protection Agency (USEPA). *Ecological Assessment of Superfund Sites: An Overview.* EPA ECO Update, Vol. 1, No. 2, Publication 9345.0-05I. December 1991c.

U.S. Environmental Protection Agency (USEPA). *Ecological Significance and Selection of Candidate Assessment Endpoints.* EPA ECO Update, Vol. 3, No. 1, Publication 9345.0-11. January 1996a.

U.S. Environmental Protection Agency (USEPA). *Ecotox Thresholds.* EPA ECO Update, Vol. 3, No. 2, Publication 9345.0-12FSI. January 1996b.

U.S. Environmental Protection Agency (USEPA). *Field Studies for Ecological Risk Assessment.* EPA ECO Update, Vol. 2, No. 3, Publication 9345.0-05I. September 1994a.

U.S. Environmental Protection Agency (USEPA). *Framework for Ecological Risk Assessment.* EPA/630/R-92/001. February 1992a.

U.S. Environmental Protection Agency (USEPA). *Profile of Drinking Water Contaminants for Emergency Response, White Phosphorus.* June 1991a.

U.S. Environmental Protection Agency (USEPA). *Risk Assessment Guidance for Superfund.* Vol. I, Human Evaluation Manual, Part A. EPA/540/1-89/002. December 1989a.

U.S. Environmental Protection Agency (USEPA). *The Role of BTAGs in Ecological Assessment.* EPA ECO Update, Vol. 1, No 1, Publication 9345.0-05I. September 1991b.

U.S. Environmental Protection Agency (USEPA). *The Role of Natural Resource Trustees in the Superfund Process.* EPA ECO Update, Vol. 1, No. 3, Publication 9345.0-05I. March 1992b.

U.S. Environmental Protection Agency (USEPA). *Selecting and Using Reference Information in Superfund Ecological Risk Assessments.* EPA ECO Update, Vol. 2, No. 4, Publication 9345.0-05I. September 1994b.

U.S. Environmental Protection Agency (USEPA). *Test Methods for Evaluating Solid Waste.* Vol. 1B: Laboratory Manual, Physical/Chemical Methods. 3rd Ed. SW 846. November 1986.

U.S. Environmental Protection Agency (USEPA). *Wildlife Exposure Factors Handbook.* Office of Research and Development, Washington, DC. EPA/600/R-93/187a. December 1993.

U.S. Geological Survey (USGS). *Groundwater Site Inventory Database.* November 1993.

U.S. Geological Survey (USGS). Hydro Data, Vol. 2.0. USGS Daily Values/Western: Period of Record. CD ROM. U.S. West Optical Publishing Co. 1990.

Van Wazer, J.R. *Phosphorus and Its Compounds, Volume I: Chemistry.* New York: Interscience Publishers, Inc. 1958.

Vince, S. W., and A.A. Snow. "Plant Zonation in Alaskan Salt Marsh I: Distribution Abundance and Environmental Factors." *J. Ecol.* Vol. 72, pp. 651-663. 1984. (as cited in Racine et al., 1994).

Walsh, M.E., C.M. Collins, and R. Bailey. *Intrinsic Remediation of WP Particles in Intermittent Ponded Areas of ERF.* Prepared for U.S. Army Cold Regions Research and Engineering Laboratory. 1996.

Walsh, M.E., C. Racine, C. Collins, M.R. Walsh, Maj. M. Meeks, R. Bailey, J. Cummings, R. Johnson, K. Gruver, P. Pochop, J. Davis, C. Rossi, W. Eldridge, L. Reitsma, B. Steele, and S. Burston, III. *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats,* Alaska Fiscal Year 1996 Draft Report. Charles M. Collins and David W. Cate, eds. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). March 1997.

Yon, R.L., R.S. Wentsel, and J.M. Bane. *Programmatic Life Cycle Environmental Assessment for Smoke/Obscurants - Red, White, and Plasticized White Phosphorous.* Vol. 2. Prepared for Project Manager for Smoke/Obscurants. USAAMCC, Environmental Technology Division, Aberdeen Proving Ground. July 1983.

Appendix A
Ecological Risk Assessment

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Abbreviations

ADFG	Alaska Department of Fish and Game
AOPECs	area of potential ecological concern
ATSDR	Agency for Toxic Substances and Disease Registry
bw	body weight
CER	comprehensive evaluation report
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COE	U.S. Army Corps of Engineers
COPEC	chemical of potential ecological concern
CRREL	U.S. Army Cold Regions Research and Engineering Laboratory
CSM	conceptual site model
CTV	critical toxicity value
DQO	data quality objective
EcoRA	ecological risk assessment
EOD	explosive ordnance disposal
ERF	Eagle River Flats
FS	feasibility study
GIS	Geographical Information System
ha	hectare
HMX	cyclotetramethylenetetranitramine
kg	kilogram
LD_{50}	lethal dose for 50 percent mortality
LOAEL	lowest observed adverse effect level
LOEL	lowest observed effect level
m	meter
µg	microgram
µg/g	micrograms per gram
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µL	microliter
mg/kg	milligrams per kilogram
mm	millimeter
NOAEL	no observed adverse effect level
NOEC	no observed effect concentration
NOEL	no observed effect level
NWHRC	National Wildlife Health Research Center
OB/OD	Open Burning/Open Detonation
OUC	Operable Unit C
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RCRA	Resource Conservation and Recovery Act
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine

Abbreviations

RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RfD	reference dose
RI	remedial investigation
RPM	remedial project manager
SVOC	semivolatile organic compound
UCI	Upper Cook Inlet
USAEHA	U.S. Army Environmental Hygiene Agency
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
UXO	unexploded ordnance
WP	white phosphorus
WSDABS	waterfowl species distribution and behavior survey
ww	wet weight

APPENDIX A

Ecological Risk Assessment

1.0 Introduction

The goal of an ecological risk assessment (EcoRA) is to provide a scientific foundation to assist risk managers in making decisions. Specifically, an EcoRA is intended to characterize the current and potential future threats to the environment posed by a chemical release or other stressor and to establish remedial action objectives that will protect ecological receptors at risk (U.S. Army Corps of Engineers [COE] 1995a, 1995b; U.S. Environmental Protection Agency [USEPA], 1992a). The term "stressor" is defined as any physical, chemical, or biological entity that can induce an adverse ecological response. The following sections describe the process, guidance, assumptions, and information sources used to complete the EcoRA.

Specific objectives of ecological risk assessment are to:

- *Characterize current and potential future threats to the environment*
- *Establish remedial action objectives and thus protect ecological receptors*

1.1 General Overview

The EcoRA is a process evaluating the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more stressors. For ecological risk to exist, the stressor must have the inherent ability to cause adverse effects and it must co-occur with or contact an ecological receptor long enough and at sufficient intensity to elicit the identified adverse effect(s) (COE, 1995a, 1995b; USEPA, 1992a). The process can be used to identify existing risks or forecast potential risks from stressors in the environment.

In the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process, an EcoRA entails the qualitative and/or quantitative evaluation of the actual or potential impacts of hazardous chemicals on plants or animals other than human beings or domesticated species (USEPA, 1991a, 1992a). To achieve this goal, a phased approach is used. In such an approach, the objectives and scope of the EcoRA are refined as the data are collected and analyzed. This process allows the risk assessment to proceed in a cost-effective and timely manner (USEPA, 1992b).

In CERCLA, an ecological risk assessment includes the qualitative and quantitative evaluation of actual or potential impacts. A phased approach is used.

The phased approach used to characterize ecological risk is described briefly in this section and illustrated in Figure 1-1. The phased approach allows for periodic evaluation of available data. At the completion of each phase, data are evaluated to determine whether the objectives of the EcoRA have been met or to identify additional data needs. In general, the initial step involves a qualitative evaluation of available information concerning site-related chemicals and the potential exposure to receptors. Data are reviewed and summarized to

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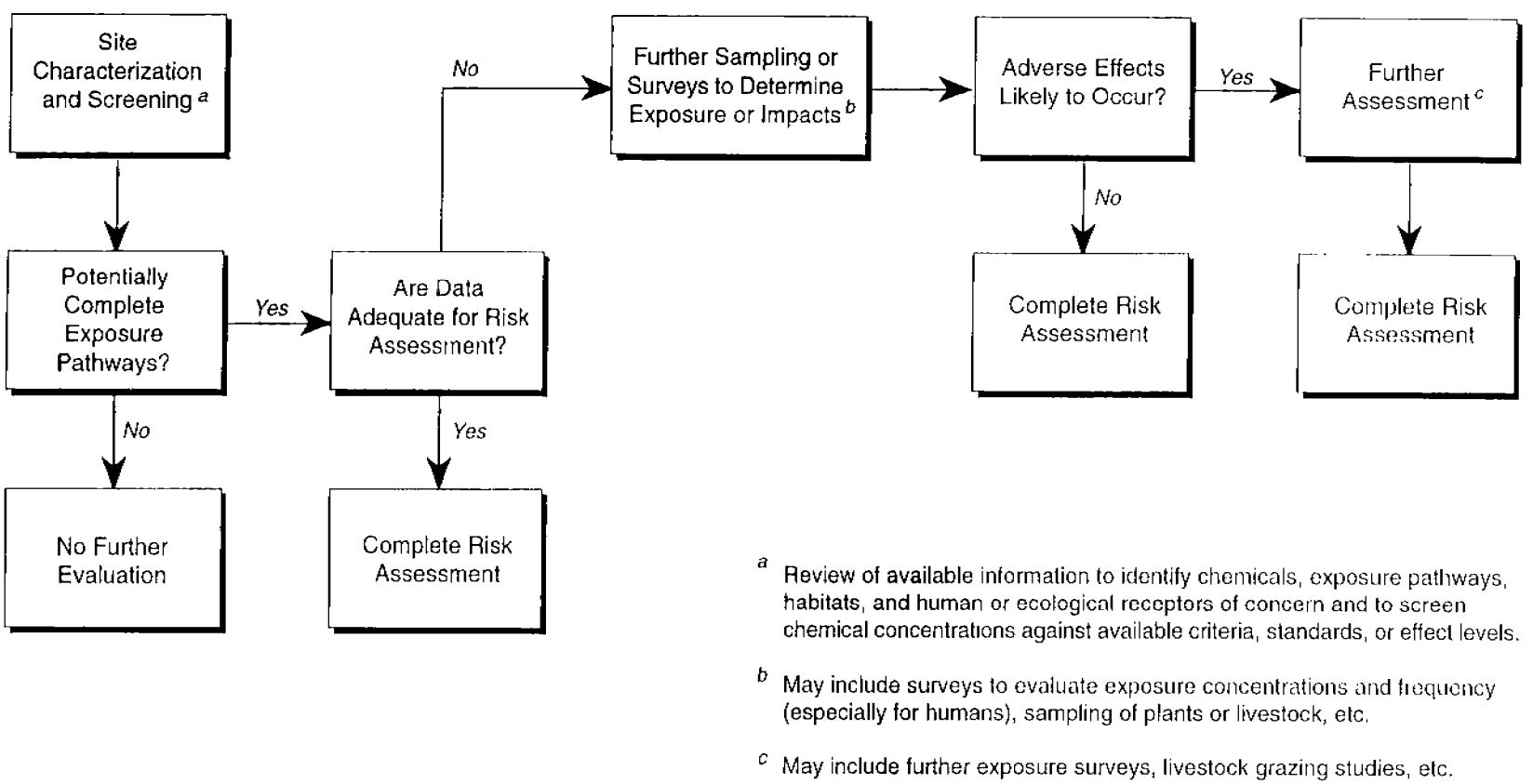


Figure 1-1

Phased Approach to Human Health and Ecological Risk Assessment

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quantify exposure and evaluate potential effects. Then exposure and risk profiles for potential effects are integrated to characterize risk associated with a particular chemical. This process begins with the use of existing data, and additional sampling is conducted to fill data gaps and refine the EcoRA in subsequent phases.

Phase I of the EcoRA provides qualitative information about the site and reviews available reports and analytical data. The *Eagle River Flats Comprehensive Evaluation Report (CER)* (CH2M HILL, 1994) provides a review of the previous site studies. Available literature and analytical data sources were reviewed to determine appropriate chemical screening and background criteria. Exposure potential, including pathways, receptors, and measurements or estimates of exposure point concentrations, were also evaluated and conceptual site models (CSMs) were developed. Phase I was completed during the development of the CERs and *Operable Unit C (OUC) Remedial Investigation (RI) and Feasibility Study (FS) Management Plan* (CH2M HILL, 1996a).

Phase II of the EcoRA provides a quantitative evaluation of exposure and potential effects at the site. Results from sampling and analysis are used to determine whether ecological impacts have occurred. Data gaps identified during the Phase I evaluations are addressed in Phase II. For example, additional data needs for Open Burning/Open Detonation (OB/OD) Pad were identified and gathered in accordance with of the *Draft Operable Unit C OB/OD Pad, Fort Richardson, Alaska, Site Investigation Work Plan* (CH2M HILL, 1996b). The EcoRA for OUC contained in this report presents the results of Phase II.

This ecological risk assessment presents the results of the Phase II assessment.

Phase III, if required, will provide additional information to complete the EcoRA. Additional data needs beyond currently available data are identified in Section 5.2, Data Gaps.

1.2 Guidance

This EcoRA has been conducted in accordance with the following guidance and advisories:

- *Risk Assessment Guidance for Superfund,* Volume II, Environmental Evaluation Manual (USEPA, 1989)
- *Ecological Assessment of Hazardous Waste Sites* (USEPA, 1991c)
- *Framework for Ecological Risk Assessment* (USEPA, 1992a)
- ECO Updates, Volume 1, Numbers 1 to 5 (USEPA, 1991a, 1991b, 1992b, 1992c, 1992d)
- ECO Updates, Volume 2, Numbers 3 and 4 (USEPA, 1994a, 1994b)
- ECO Updates, Volume 3, Numbers 1 and 2 (USEPA, 1996a, 1996b)
- *Risk Assessment Handbook,* Volume II, EM-200-1-6 (COE, 1995a)

The three major elements of an ecological risk assessment are:

- *Problem formulation, which includes a preliminary assessment of the data and a definition of the ecosystem.*
- *Analysis, which includes the exposure and ecological effects assessments.*
- *Risk characterization, which integrates the exposure and ecological effects assessments.*

The risk assessment process is based on the characterization of exposure and ecological effects. The EcoRA framework is depicted in Figure 1-2. The three major elements of the framework are problem formulation, analysis, and risk characterization (USEPA, 1992a).

Problem formulation includes a preliminary characterization of exposure and effects through an examination of existing data and data needs. In this phase, the ecosystem potentially at risk is defined and integrated with stressor characteristics and ecological effects to select assessment and measurement endpoints and to develop the CSM.

Analysis consists of two activities, the exposure assessment and the ecological effects assessment. The exposure assessment predicts or measures the spatial and temporal distributions of a stressor and its co-occurrence or contact with the ecological component of concern. The ecological effects assessment identifies and quantifies adverse effects of stressors and evaluates the cause-and-effect relationships.

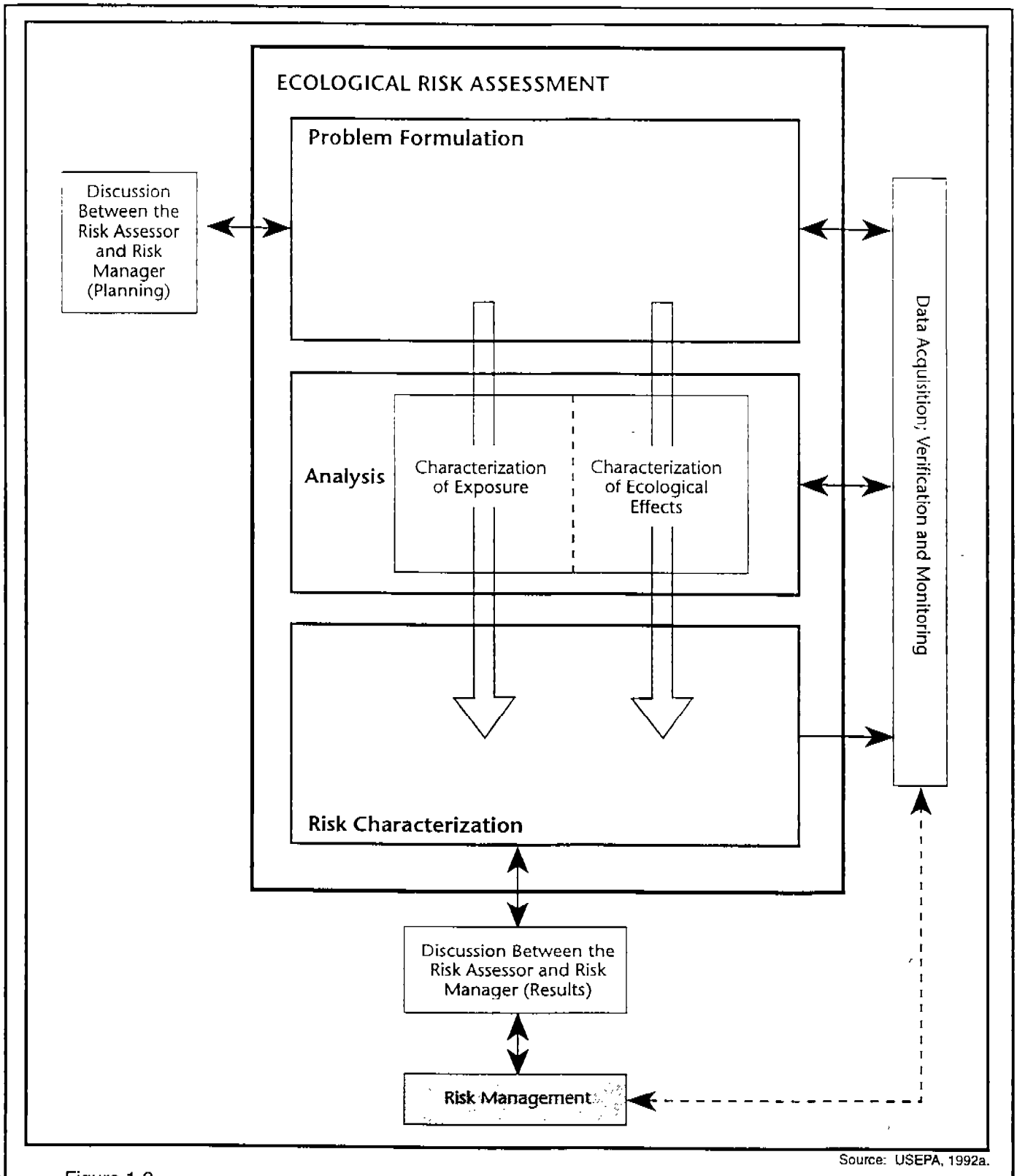
Risk characterization integrates the exposure and ecological effects assessments to evaluate the likelihood of adverse ecological effects associated with exposure to a stressor. It includes a summary of the assumptions used, the scientific uncertainties, and the strengths and weaknesses of the analyses. A discussion of the ecological significance of the risk is also presented as part of the risk characterization.

1.3 Assumptions

This ecological risk assessment is based on data from previous site investigations that were conducted by others, as summarized in the CER (CH2M HILL, 1994) and in the RI report. Under CERCLA or Resource Conservation and Recovery Act (RCRA) programs, detailed procedures to ensure the quality of the analytical data collected are usually provided in documents known as quality assurance project plans (QAPPs), but no QAPPs were available for the previous studies. Although quality data can be generated without a QAPP, the absence of documentation to demonstrate the adequacy and quality of the data can limit their usability in meeting regulatory concerns and requirements under CERCLA or RCRA programs.

The previous reports do not discuss analytical performance or validation of the available data, and the raw data were not available for review or validation. The previous reports do not interpret results from field or laboratory quality control (QC) samples that may have been analyzed. Without some data validation or data quality review, it is not possible to develop an independent assessment of the data quality or to judge the adequacy of data for meeting project objectives.

Evaluation of the Geographical Information System (GIS) and field study databases was conducted (CH2M HILL, 1996c, 1996d). These evaluations involved the use of available data to determine and document the usability of data produced in previous studies for the



Source: USEPA, 1992a.

Figure 1-2

Framework for Ecological Risk Assessment

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current investigations. Original data from the field and laboratory studies were returned to each researcher, who independently verified that the reported information was accurate. The verified data were then incorporated into Eagle River Flats (ERF) databases.

The following assumptions are made for the purpose of this EcoRA:

- In ERF, white phosphorus (WP) is the primary chemical of potential ecological concern (COPEC), and no other stressors are contributing to adverse ecological effects.
- Laboratory analytical and field data collected in previous studies are considered to be valid and usable.
- Sampling methods for WP in ERF sediments have been sufficient to obtain representative samples so that the reported WP concentrations are comparable to concentrations reported in literature.
- ERF environmental conditions have not changed significantly from those reported in earlier studies, and chemical concentrations will remain stable over time.
- Chemicals not detected or analyzed are not present.
- The observed maximum concentration is the exposure point concentration.
- The exposure point concentration is 100 percent bioavailable.
- The toxicological information used represents that which was currently available from literature and database searches.
- Baseline conditions for exposure occur when no hazing activities are taking place.

Ecological risk assessment is based on the results of a number of previous studies, principally implemented and coordinated by the U.S. Army's Cold Regions Research and Engineering Laboratory.

1.4 Information Sources

Biological and chemical investigations have been ongoing at ERF since 1980. The objective of nearly all these studies has been to determine the cause of acute mortality of waterfowl observed there. These early studies were reviewed and summarized in the CER (CH2M HILL, 1994), which provides a basis for the site and exposure characterizations discussed in this report.

The recent site investigations also were documented in reports published by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) (Racine *et al.*, 1993, 1994, 1995, 1996). This information was combined with the CER to develop the CSMs for ERF and OB/OD Pad presented in the *OUC Final RI/FS Management Plan* (CH2M HILL, 1996a). Follow-up studies, conducted on ERF during 1996, have been presented in individual reports (Eldridge, in Walsh *et*

al., 1997; Cummings *et al.*, in Walsh *et al.*, 1997; Steele *et al.*, 1997) and summarized in the current EcoRA.

2.0 Problem Formulation

2.1 Background

Problem formulation is the first phase of the ecological risk assessment.

Problem formulation is the first phase of EcoRA that establishes the goals, extent, and focus of the assessment (USEPA, 1992a). Assessment and measurement endpoints are identified on the basis of information presented in the site description (Section 2 of the RI report)—such as environmental setting, nature, and extent of WP contamination—and the CSM.

Various ecological effects may be induced by chemicals, and many methods are available for directly or indirectly measuring these effects. The methods may include field studies on bird mortality or laboratory studies such as bioassays or dosing studies. The quality and availability of these measures differ and affect the ease of obtaining data and the confidence with which we can interpret information. Although difficult to perform, field measurements directly address important ecological effects and provide clear statements about current ecological risks and performance of the remediation. Laboratory studies may be easier to perform, but they make interpretation of site remediation more difficult. Integration of field and laboratory studies facilitates interpretation of observed effects.

The objective of the problem formulation section is to provide a structure for assessing current and future impacts. The structure is constructed from the CSM (Section 5 of the RI report), through use of its characteristics and the results of previous studies to define potential assessment and measurement endpoints for ERF. This process produces a combination of biological and physical endpoints that can be used to evaluate remedial success across ERF over the long term. A series of physical measurements (pertaining to the physical endpoints) can also be used to evaluate site-specific remedial actions in the short term. Biological endpoints for the ERF have been discussed elsewhere (CH2M HILL, 1996a). From these endpoints and measurements, the data collection program for verifying that remedial objectives have been achieved can be developed to guide remedial decisionmaking.

The assessment structure has a strong basis in the studies of the past several years and is supported by the quality of collected data, the successful transfer of data to the ERF GIS, and the application of the ERF GIS to remedial action decisions contained in the structure. This assessment represents an application of the analytical structure to the available data.

The overall remediation objective is the protection of the animals, the plants, and their habitat in Eagle River Flats and nearby Knik Arm.

The overall remediation objective is the protection of the animals, the plants, and their habitat in ERF and nearby Knik Arm. Extensive investigations have been performed during the past 5 years to determine the toxic agent responsible for waterfowl mortality and its consequences at ERF. These studies were reported by CRREL (Racine *et al.*, 1993, 1994, 1995) and CH2M HILL (1994).

WP has been identified as the toxic agent, and several effects from WP exposure have been measured at ERF or in the laboratory. The variety of species and the noted impacts have been summarized in another document, from the information available at that time (CH2M HILL, 1996a). The effects that are most diagnostic for evidence of WP exposure are waterfowl mortality at ERF (as indicated by comparison to low background waterfowl mortality [Steele and Reitsma, in Racine *et al.*, 1996]), bird behavior, presence of WP in eggs or other animal tissues, and presence of Heinz bodies in blood cells. The principal biological assessment endpoint for ERF is the reduction of waterfowl mortality.

Previous studies have also identified Area C, Bread Truck, and Racine Island as the areas of highest frequency and concentrations of WP, and therefore the most likely locations where the waterfowl were becoming contaminated. Particular landcovers where the waterfowl were most often feeding included sedge marsh, permanent ponds, and intermittent ponds, particularly in the areas where WP had been found in highest quantities.

Environmental investigations at OB/OD Pad are summarized in Section 6 of the RI report. The results of analytical testing showed detectable levels of explosive residues, semivolatile organic compounds (SVOCs), and metals in surficial soil on Pad. Only metals were detected in the subsurface soil. The groundwater beneath Pad contained detectable levels of explosive residues and dissolved metals. In all cases, the detected constituents were well below the clean closure criteria established by the remedial project managers (RPMs) for OB/OD Pad.

2.2 Study Design

The following features were used to design the planning for this risk assessment. They will be revisited in the conclusions of this document to determine whether they still provide appropriate direction for the identification of problem areas for remediation, and an approach to assessing the success of remedial activities.

2.2.1 Selection of Chemicals of Potential Ecological Concern

Through previous studies, it has been determined that WP is the primary COPEC for ERF. Other chemicals were previously investigated and eliminated as potential causes of elevated waterfowl mortality at ERF (Racine *et al.*, 1993).

A number of inorganic and organic contaminants were detected in surface soils and groundwater at OB/OD Pad as summarized in Section 6 (Tables 6-4 and 6-5) of the RI report. The soil and groundwater contaminants were observed at relatively low levels in samples collected from recently installed monitoring wells on OB/OD Pad. All detected inorganic and organic contaminants were below clean closure criteria established by the RPMs. Groundwater contaminants would be diluted even further as groundwater discharged into and mixed with surface waters of ERF. Therefore, none of the detected contaminants in groundwater was retained as a COPEC for OB/OD Pad.

White phosphorus is the primary chemical of potential ecological concern for ERF.

Inorganic and organic surface soil contaminants were screened to determine whether any of these chemicals should be considered as a COPEC for OB/OD Pad. Table 2-1 shows that the maximum detected inorganic concentrations from recent soil samples were similar to or below corresponding background levels. Therefore, none of the inorganic chemicals was retained as a COPEC.

Information on critical toxicity values (CTVs) for use in screening the detected organic contaminants was limited for plants and soil invertebrates. It was possible to derive soil CTVs for small mammals by using the methods described by Opresko *et al.* (1996) and USEPA (1993). Table 2-2 shows that the maximum soil values for detected organic contaminants at OB/OD Pad were below or similar to the corresponding CTVs for the deer mouse, a representative small mammal. Therefore, none of the organic soil contaminants detected at OB/OD Pad was retained as a COPEC.

2.2.2 Selection of Areas of Potential Ecological Concern

The areas of potential ecological concern (AOPECs) have been based on physical characteristics that correspond with maximum exposure of waterfowl to WP. Therefore, the criteria used to define the AOPECs should be consistent with those characteristics that create waterfowl exposure to WP.

Ponded areas in Area C, Bread Truck, and Racine Island are the areas of potential concern.

Ponded areas were determined to be AOPECs on the basis of preference of feeding waterfowl for these areas. Earlier studies indicated that these areas of preference include sedge marsh, permanent ponds, and intermittent ponds. The geographical areas of highest potential ecological concern are Area C, Bread Truck, and Racine Island, on the basis of past studies of the frequency and concentrations of WP.

Area C/D also was considered as an AOPEC because of its proximity to Area C and Bread Truck. Although the presence of high concentrations of WP in sediments was not confirmed by the limited sampling, it was considered likely that WP could be found in some of

TABLE 2-1
Ecological Assessment of Inorganic Soil Contamination at OB/OB Pad

Inorganic	Concentration (µg/g) Maximum Detected OB/OD Pad Value	Background Range[a]	COPEC ?[b]	Basis
As	7.4	6.7 to 9.6	No	Similar to background
Ba	127	190 to 678	No	Less than background
Cr	58.4	50 to 64	No	Similar to background
Pb	10.8	12 to 15	No	Less than background
Hg	0.12U	0.097	No	Similar to background
Zn	94.3	70 to 133	No	Similar to background

[a] Background range from Table 6-4 of the RI report is range of mean values (geometric and arithmetic) for Alaska soils and superficial materials (Environmental Science and Engineering, 1990) and the Eagle River Bridge/Cottonwood Slough sediments.
[b] Chemical of Potential Ecological Concern
Note: U = Flagged by laboratory as estimated value.

TABLE 2-2
Critical Toxicity Values for Organic Soil Contamination at OB/OD Pad[a]

Organic	Maximum Reported OB/OD Pad Value (µg/g)	Deer Mouse[b] Soil CTV	COPEC[c]
2,4,6-TNT	0.36	2	No
2,4-DNT	39	10	No[e]
2,6-DNT	3.9U	199	No
2-amino-4,6-DNT	0.47	103	No
4-amino-2,6-DNT	0.45	103	No
Di-n-butylpthalate[d]	14	3,718	No
N-nitrosodiphenylamine	4.2	251	No

[a] CTV derived as described in Opresko *et al.*(1996) and *Wildlife Exposure Factors Handbook* (USEPA, 1993).
[b] Deer mouse considered to represent small mammal receptors at site.
[c] Chemical of potential ecological concern
[d] Suter *et al.*(1993) estimate a no observed effect concentration (NOEC) for plants at 200 µg/g that represents a soil CTV for plants.
[e] CTV is a conservative extrapolation that assumes plant concentration in mouse diet is equal to soil concentration. The deer mouse soil CTV is derived from data from dog toxicity studies that increases uncertainty in the value.
Note: U = Flagged by laboratory as estimated value.

the Area C/D sedge marshes, a preferred waterfowl feeding habitat. Area A also could be considered as an AOPEC because it receives the highest proportion of bird use at ERF as indicated by telemetry studies. Despite the lack of data to indicate high concentrations of WP in sediments, all three preferred feeding habitats (permanent ponds, intermittent ponds, and sedge marsh) are present in this area and waterfowl mortality has been documented.

On OB/OD Pad, inorganic surface soil contaminants were detected at levels similar to or lower than background concentrations (Table 2-1). Organic soil contaminant concentrations were below estimated CTVs for a small mammal (deer mouse). None of the detected contaminants in the OB/OD Pad surface soil and groundwater samples was retained as a COPEC. Therefore, this area is not considered to be an AOPEC.

2.2.3 Selection of Exposure Pathways, Exposure Routes, and Ecological Receptors

As discussed in the CSM for ERF (Section 5.5 of the RI report), the primary exposure pathway is by incidental ingestion of WP particles contained within pond sediments by dabbling ducks during the course of feeding in shallow ponds. In deeper ponds, swans also are exposed to WP in a similar manner. Direct ingestion of the WP particles occurs because birds regularly feed in habitats where WP is found. These birds either confuse the WP particles with their natural food items (such as invertebrate larvae or plant seeds), or accidentally ingest the particles along with pond sediments.

Dabbling ducks and swans are the principal receptors of concern, and the principal exposure route is ingestion of the particulate white phosphorus.

The ecological receptors of primary importance to this EcoRA are dabbling ducks and swans. Of all bird species observed at ERF, three species of dabbling ducks (mallards, northern pintail, and green-winged teal), have accounted for most of the bird mortality. These three duck species are considered primary ecological receptors that feed mainly in shallow ponds. Swans feed in deeper water habitats than do dabbling ducks and are also considered primary ecological receptors.

The effects on these birds can be observed through the use of the mortality transects. Radio telemetry can also be used to measure the mortality, and the land use preferences of the ducks. Aerial and ground surveys provide the population base for measuring exposure.

Minimal shorebird deaths have been discovered during the years of mortality studies in ERF. Shorebird populations include species such as greater and lesser yellowlegs, pectoral sandpipers, and dowitchers. Selective feeding behavior that limits WP uptake and the frequenting of habitat that periodically dries (allowing the WP to sublimate) likely reduces shorebird exposure. Because occasional shorebirds are found dead in ERF, this receptor has been ranked as having a moderate hazard probability. Shorebirds were not assigned a high hazard

probability because none of the observed mortality has been attributed to WP exposure (Racine *et al.*, 1993, 1994). WP was not observed in any shorebird carcasses during 1994 studies. Further research was not performed to evaluate the cause of shorebird deaths once WP was eliminated (Sparling et al., 1994).

The discussions of the CSM for OB/OD Pad (Section 6.6 of the RI report) indicate that the detected contaminants do not occur at levels that would constitute significant contaminant sources. In fact, all detected contaminants were found at levels well below the clean closure criteria established by the RPMs for OB/OD Pad.

Risk to ecological receptors at OB/OD Pad was assessed by comparing maximum concentrations of detected chemicals to available data or derived CTVs. Inorganic chemicals in surface soils at OB/OD Pad were detected at levels similar to or less than background concentrations (Table 2-1). Organic chemicals were compared to soil CTVs derived for a small mammal, the deer mouse, considered to be representative of small rodents at OB/OD Pad (Table 2-2). Larger mammals were not expected to derive a significant proportion of their diet on the limited pad area (about 4 ha).

Uncertainties could affect the decisions in the study design:

- *Particulate nature of white phosphorus increases potential error in identifying areas of potential concern.*
- *Because of sampling limitations resulting from the potential for UXO on OB/OD Pad, the low detected contaminant concentrations may not adequately represent conditions at the site.*

Risk to plants at OB/OD Pad was estimated for a single soil CTV for the organic compound, di-n-butylphthalate, detected at 14 µg/g. A no observed effect concentration (NOEC) for plants was estimated at 200 µg/g by Suter *et al.* (1993). Soil CTVs for plants for any of the other detected organic compounds were not found. Significant uptake and bioaccumulation of the detected explosive residues or semivolatile organic compounds is not expected.

No available soil CTVs for terrestrial invertebrates were found for any of the organic compounds detected at OB/OD Pad.

Overall use of OB/OD Pad by ducks, as indicated by telemetry, was very low (about 1 percent of all observations). Waterfowl were not considered as significant ecological receptors because their preferred feeding habitat, ponds and marshes, were not present at OB/OD Pad.

2.3 Uncertainties

Sampling of ERF ponds and mud flats for WP has been limited by the potential hazards from unexploded ordnance (UXO). For this reason, sampling has not been conducted in a systematic way. It is possible that areas with high levels of WP that have not been identified by the sampling and analysis program may exist. Limitations of the sampling and analysis program will affect the accuracy of delineating areas of potential concern. The choice of areas of concern has been based on the data in the current ERF GIS.

The WP in sediments was determined to occur as discrete particles distributed close to where WP munitions were detonated. This fact

increases the difficulty in sampling to quantify sediment WP concentrations. Therefore, existing measurements of the physical characteristics of WP in sediments may not be an accurate indicator of the potential hazard to waterfowl.

Although no chemicals other than WP have been associated with the elevated waterfowl mortality in ERF, it is possible that even low levels of chemicals may affect bird mortality through interaction with other stressors in the environment. In earlier studies, levels of chemicals in the environment were evaluated on the basis of expected ecological responses for individual chemicals at concentrations indicated by sampling and analysis. The potential for interaction and synergistic response among stressors was not evaluated and could affect waterfowl mortality measurements even if WP remediation activities are successful. Bird mortality is the only measurement endpoint because laboratory studies were unable to establish chronic-effect dose levels for WP.

In addition to waterfowl mortality that has been attributed to WP poisoning in ERF, there are indications that bald eagles, shorebirds, and fish-eating birds may also be affected by WP poisoning. Circumstantial evidence indicates that bald eagles may die as a result of eating poisoned ducks. The exposure routes for shorebirds and fish-eating birds are not completely understood. On the basis of the mass of WP found in the gizzard contents of some shorebirds, direct ingestion of WP particles from the sediment is one exposure route. However, it is unclear whether these birds are being exposed secondarily or whether they ingest WP particles directly. These issues will be examined in the remainder of this section.

The analysis phase includes the exposure assessment, the ecological effects assessment, and an analysis of uncertainties.

Sampling of OB/OD Pad was also limited by the potential hazards from UXO. Distribution of contaminants on Pad would also be irregular because it would be affected by where the destruction took place on Pad and whether the contaminants were spread by detonation at the surface or from within burning pits. Lack of historical details on the operations of OB/OD Pad (such as pad construction, disposed material, or disposal locations) causes uncertainty about whether the selection of sampling locations for the recent subsurface investigations (boreholes) was likely to have detected the most contaminated areas. The low concentrations of contaminants detected at the seven sample locations do not ensure that other portions of OB/OD Pad are not more highly contaminated.

No biological samples (such as plants, terrestrial invertebrates, or small mammals) were collected from OB/OD Pad for chemical analysis. Without this information, a direct assessment of these contaminant pathways could not be made. The soil CTVs for the deer mouse were derived from various toxicity studies conducted on dogs, rats, and mice. The various study results were normalized to a no observed adverse effect level (NOAEL) to estimate soil concentration.

The model assumes that plant concentrations, which comprise 84 percent of the deer mouse diet, are equal to the NOAEL soil concentration. In fact, because plant concentrations are likely to be much lower than the concentration in soil, this method tends to overestimate the soil CTV.

Exposure assessment estimates the nature, extent, and magnitude of potential exposures.

3.0 Analysis

The analysis phase of the OUC EcoRA includes the exposure assessment, the ecological effects assessment, and an analysis of uncertainties. The exposure and ecological effects assessments are used to estimate the potential ecological risks associated with exposure to COPECs at ERF. The uncertainties analysis provides a summary of the uncertainties and limitations of the information used in the exposure and ecological effects assessments.

3.1 Exposure Assessment

The exposure assessment uses site-specific information to estimate the nature, extent, and magnitude of potential exposure to ecological receptors. Methods used to evaluate potential ecological exposures at ERF and OB/OD Pad include characterization of the ecosystem, evaluation of tissue concentrations of WP in biota collected at ERF, and analysis of potential exposure to WP in environmental media collected from the different areas at ERF. Most of the research on ecosystem characterization has been focused on ERF rather than OB/OD Pad. Where appropriate, this information will be used for OB/OD Pad characterization. Site-specific data on OB/OD Pad will be included when they are available and relevant.

3.1.1 Ecosystem Characterization

ERF. Detailed descriptions of various components of ERF's ecosystem have been provided by Racine *et al.* (1993, 1994, 1995, 1996) and in reports by others (Gossweiler, 1984; CH2M HILL, 1994, 1996a). This information was summarized in Section 2 of the RI report.

The ecosystem consists of physical and biological components significant to the current assessment. Physical ecosystem components include climate, geology, soils, topography, and hydrology. These components are important because they affect WP fate and transport mechanisms and exposure routes for biota.

Biological ecosystem components are significant to the EcoRA because they represent the organisms that may be directly affected by exposure to WP in the environment (primary receptors). Biological organisms that have bioaccumulated WP may also constitute an exposure pathway for predators or scavengers that feed upon them (secondary receptors such as bald eagles, other raptors, ravens, or carnivorous mammals).

Low levels of white phosphorus in plants present low risk to grazing animals.

The potential receptors that were considered for ERF included aquatic vegetation, aquatic invertebrates, fish, and birds, as well as their consumers. Walsh (in Racine *et al.*, 1994) determined that aquatic plants growing within contaminated sediments contained low levels of WP. Walsh concluded, however, that the risk to grazing animals from plant consumption was very low when compared to incidental ingestion of the sediment containing WP particles. Low mortality of waterfowl that feed mainly on vegetation (such as geese and wigeons) supports this conclusion.

WP impacts on aquatic invertebrates and fish were investigated in separate studies by Bouwkamp (in Racine *et al.*, 1994, 1995) and Sparling (in Racine *et al.*, 1994). In general, the population diversity of benthic macroinvertebrates was not significantly different between areas with and without WP contamination (Bouwkamp, in Racine *et al.*, 1994). Sediment toxicity tests involving aquatic amphipods and midge larvae indicated that these organisms were sensitive to WP. Sampling and analysis of ERF macroinvertebrates and fish did not reveal significant accumulations of WP (Sparling, in Racine *et al.*, 1994; Bouwkamp, in Racine *et al.*, 1995). It was concluded that WP in fish and aquatic invertebrates would not constitute a significant risk for birds or mammals who eat them, and that WP was not affecting invertebrates under field conditions.

The above studies of various ERF biological components have shown that the most significant WP impacts are occurring in bird populations. Bird populations in ERF have been studied by aerial census and ground observation. Aerial census data have been collected from fixed-wing aircraft from April to October of 1988 through 1995 (Eldridge, 1990, 1991, 1992; in Racine *et al.*, 1994, 1995; in Walsh *et al.*, 1997; and Eldridge and Robertson, in Racine *et al.*, 1996). These aerial surveys represent the most complete bird population data for ERF. In addition, a similar population survey was performed during the 1995 field season for other marshes around the UCI (Eldridge, in Walsh *et al.*, 1997). This survey was intended to allow comparison of bird use between ERF and other marshes in the area.

Aquatic invertebrates are not affected by the white phosphorus at the ERF.

Ground observation duck counts made during the spring and fall of 1994 and 1995 (included in the ERF GIS) were compared to aerial survey estimates on those days when both surveys were conducted. Ground observation duck counts were also made during the 1996 field season, but the data were not available for comparison to the 1996 aerial census in time for this report.

Secondary receptors include predators and scavengers such as the bald eagle, herring gull, raven, wolf, coyote, and fox. Studies of activities and potential risks related to scavengers and predators have been reported by Reitsma and Steele and Cummings *et al.* (in Racine *et al.*, 1995) and by Roebuck (1995).

OB/OD Pad. Ecosystem characteristics associated with the upland areas surrounding ERF have been described by Bennett (1982) and Gossweiler (1984). These reports describe the general ecological setting, as well as the predominant vegetation and animal communities found at Fort Richardson. They also provide the basis for a description of the biological components associated with OB/OD Pad.

More detailed information on historical use and potential contamination of OB/OD Pad was provided in the CER and *Site Investigation Work Plan* (CH2M HILL, 1994, 1996b). Previously existing information was combined with the results from subsurface investigations and analytical testing of soils and groundwater at OB/OD Pad to develop the discussions of the conceptual model presented in Section 6.6 of the RI of this report.

In general, OB/OD Pad is a graded area, approximately 4 ha in size, adjacent to ERF. OB/OD Pad consists of coarse materials (sandy gravels and gravelly sands) derived from glacial till. Groundwater is approximately 6 to 9 m below the ground surface at OB/OD Pad and has a very shallow gradient. Expected groundwater flow is to the southeast toward Eagle River, which flows within 30 m of the southern corner of OB/OD Pad.

Analytical testing of groundwater samples collected during the recent field activities indicated detectable levels of explosive residues (hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX] and cyclotetramethylenetetranitramine [HMX]) and metals (arsenic, barium, chromium. lead, and zinc). Concentrations of contaminants in groundwater samples collected from beneath OB/OD Pad were generally very low and well below the clean closure criteria established by the RPMs. The groundwater samples were unfiltered (analyzed for total constituent concentrations), so the dissolved, mobile concentrations in groundwater would be expected to be considerably lower. In addition, considerable dilution of contaminants would be expected to occur as groundwater was discharged from beneath Pad into ERF. For these reasons, it is not anticipated that groundwater transport would provide a significant exposure pathway for aquatic organisms in ERF adjacent to OB/OD Pad or for terrestrial organisms on OB/OD Pad.

It is not anticipated that groundwater transport would provide a significant exposure pathway for aquatic organisms in ERF adjacent to OB/OD Pad or for terrestrial organisms on OB/OD Pad.

Analytical testing of surficial soils indicated detectable levels of explosive residues (2,4,6-TNT; 2,4-DNT; 2,6-DNT; 2-amino-4,6-DNT; and 4-amino-2,6-DNT) at two of the seven investigated locations (MW-2 and MW-3). SVOCs included di-n-butylphthalate and n-nitrosodiphenylamine, which were detected in surficial soil at Well MW-2. Explosive residues and other organic contaminants were not detected in deeper soil samples. Metals were detected at all seven sampling locations and included arsenic, barium, chromium. lead, mercury, and zinc. All detected inorganic concentrations were similar

to the corresponding background levels presented in Table 6-4 of the RI report.

At OB/OD Pad, the preferred feeding habitat of waterfowl, ponds and marshes, is not present. Telemetry has shown that overall duck use of OB/OD Pad is low.

The potential ecological receptors on OB/OD Pad include plants, terrestrial invertebrates, birds, and mammals. The risk to ecological receptors at OB/OD Pad was assessed by comparing maximum concentrations of detected chemicals to available data or derived CTVs. Inorganic chemicals in surface soils at OB/OD Pad were detected at levels similar to or less than background concentrations (Table 2-1). Organic chemicals were compared to soil CTVs derived for a small mammal, the deer mouse, considered to be representative of small rodents at OB/OD Pad (Table 2-2). On the basis of available information, the risk to small mammals is considered to be low; therefore, none of the detected inorganic or organic chemicals was considered as a COPEC. Because larger mammals were not expected to derive a significant proportion of their diet on the limited pad habitat (about 4 ha), the expected risk to larger mammals also is considered to be low.

Risk to plants at OB/OD Pad was estimated for a single soil CTV for the organic compound, di-n-butylphthalate, detected at 14 µg/g. A NOEC for plants was estimated at 200 µg/g by Suter *et al.* (1993). Soil CTVs for plants were not found for any of the other detected organic compounds. Significant uptake and bioaccumulation of the detected explosive residues or SVOCs is not expected. On the basis of the available information, the risk to terrestrial plants is considered to be low.

No available soil CTVs for terrestrial invertebrates were found for any organic compounds detected at OB/OD Pad; therefore, these compounds could not be evaluated quantitatively for the risk they represent to terrestrial invertebrates. Because the inorganics and all organics occurred only at low levels, however, they were similar or lower than corresponding background levels. It is not expected that the inorganic chemical levels detected on OB/OD Pad would constitute a risk for terrestrial invertebrates.

Overall use of OB/OD Pad by ducks, as indicated by telemetry, was very low (about 1 percent of all observations). Waterfowl were not anticipated to be significant ecological receptors because their preferred feeding habitat, ponds and marshes, were not present at OB/OD Pad.

Impacts to aquatic organisms in the ERF areas adjacent to OB/OD Pad are not anticipated. The low inorganic and organic concentrations detected in groundwater beneath OB/OD Pad would be expected to be substantially diluted as groundwater discharged to the surface waters of ERF.

Aerial surveys have measured the bird populations in Eagle River Flats and other marshes in UCI.

3.1.2 Water Bird Population Surveys

Aerial Census. This discussion is based on data provided in reports (Eldridge, 1990, 1991, 1992; in Racine *et al.*, 1994, 1995; in Walsh *et al.*, 1997; and Eldridge and Robertson, in Racine *et al.*, 1996). Bird counts from ERF aerial population surveys were summarized by the following bird groups: swans, geese, ducks, shorebirds, gulls and terns, and loons and grebes. In addition, individual bird counts were also summarized for mallards, northern pintails, green-winged teals, bald eagles, sandhill cranes, and common ravens. The mallards, northern pintails, and green-winged teals were summarized individually because they accounted for nearly 97 percent of the observed mortality at ERF (CH2M HILL, 1994).

Waterfowl are present principally during two seasons, during spring and fall migrations, at the Eagle River Flats.

Overall counts of bird groups were plotted against the survey date to estimate the relative distributions of birds throughout the field season. The waterfowl bird group included swans, geese, and ducks. Waterfowl numbers from 1989 to 1995 were highly variable but, in general, were highest during late April to early May and late August to October. The changing numbers of birds in ERF throughout the year is due to migration patterns of the birds. In general, elevated waterfowl counts were observed in spring just after ice thawed and again in the fall before winter migration (Eldridge, 1990, 1991, 1992; in Racine *et al.*, 1994, 1995; in Walsh *et al.*, 1997; and Eldridge and Robertson, in Racine *et al.*, 1996). The increases in waterfowl numbers during these times were more obvious for the geese and ducks than for the swans. Waterfowl numbers were lower during summer periods.

Numbers of shorebirds, gulls, and terns were also highly variable throughout the year. The distributions of these birds, however, did not show elevated numbers in spring and fall. Populations of these birds in ERF were generally highest through the summer months and declined in late August to early September.

Greater numbers of bald eagles also are observed in the spring and fall.

Bald eagle numbers were generally similar to waterfowl numbers, with elevations in the spring and fall. Elevated numbers of bald eagles in the spring were correlated with fish (eulachon and salmon) migrations to Upper Cook Inlet (UCI) streams (Rosenberg, 1994). Racine *et al.* (1993) indicate that unusually high bald eagle numbers were observed during the 1991 and 1992 field seasons; this phenomenon was probably associated with the large number of duck carcasses from high waterfowl mortality. Distributions of raptors, ravens, sandhill cranes, and grebes were highly variable.

Bird use (bird-days) at ERF for a given year was estimated by use of the bird counts from the aerial census. Within each month, the sum of the bird counts for a particular species group or individual species was divided by the number of aerial surveys to obtain an average number of birds per survey. This value was multiplied by the number

of days in the month to estimate bird-day use for the month. This index of bird use was intended to normalize bird counts relative to monthly surveys (number of survey flights).

Total annual bird use in ERF was estimated for the various bird groups and individual species from 1989 to 1996 (Table 3-1). The bird groups, in order of decreasing average annual bird use, are as follows: ducks, geese, shorebirds, swans, gulls and terns, raptors (bald eagles, peregrine falcons, northern harriers, and osprey), and loons and grebes. Individual species, in order of decreasing average annual bird use, are as follows: mallards, northern pintails, green-winged teals, sandhill cranes, bald eagles, and ravens.

Ducks are the most prevalent bird at the Eagle River Flats. The number of duck use days (ducks present times number of days) ranged from 73,000 to 130,000 from 1989 to 1996.

Average estimated annual bird use of waterfowl ranged from about 100,000 bird-days for ducks to 9,400 bird-days for swans (Table 3-1). Use of ERF by ducks and geese between 1989 and 1996 has been variable. An increase in use by these bird groups since 1993 could imply that the birds are becoming habituated to hazing at ERF. Swan use has not varied dramatically between 1989 and 1996 (Figure 3-1) but has shown a slowly decreasing trend since 1990.

Use of ERF by shorebirds has been variable between 1989 and 1996, with the lowest use records in 1996. Use of ERF by gulls and terns has been relatively constant during this period (Figure 3-1 and Table 3-1). Bald eagle use of ERF was highest in 1991 but steadily decreased through 1995. A slight increase was observed during the 1996 field season compared to the 1995 field season. (Figure 3-1 and Table 3-1).

Use of ERF by swans indicates that, although elevated numbers are observed in the spring, more swans use ERF in the fall (Figure 3-2). Swan use in the fall was highest in 1990 and has been variable, but lower, since that time. Use of ERF by geese is higher during periods in the spring and fall (Figure 3-2). Use of ERF by geese in the spring is generally higher than swan use. The highest number of spring geese was observed in the 1995 field season. Use of ERF by geese in the fall appears to have been highest in 1989 and has generally decreased since that time. Duck use of ERF also shows elevated bird numbers during spring and fall (Figure 3-2). Overall, more ducks than either swans or geese are using ERF. Duck numbers during the fall months were highest in the 1990 field season.

Dabbling ducks represent about 29 percent of the birds at Eagle River Flats, and 97 percent of the mortality.

Three duck species, mallard, northern pintail, and green-winged teal, account for approximately 65 percent of duck use and 37 percent of total waterfowl use of ERF. These three dabbling duck species have a disproportionately high mortality in ERF; they account for nearly 97 percent of bird deaths, although they represent less than 22 percent of all birds using ERF (Table 3-1).

Average annual uses by mallard and northern pintail were similar (approximately 28,000 and 21,000 bird-days, respectively); green-winged teal use was lower (approximately 15,000 bird-days)

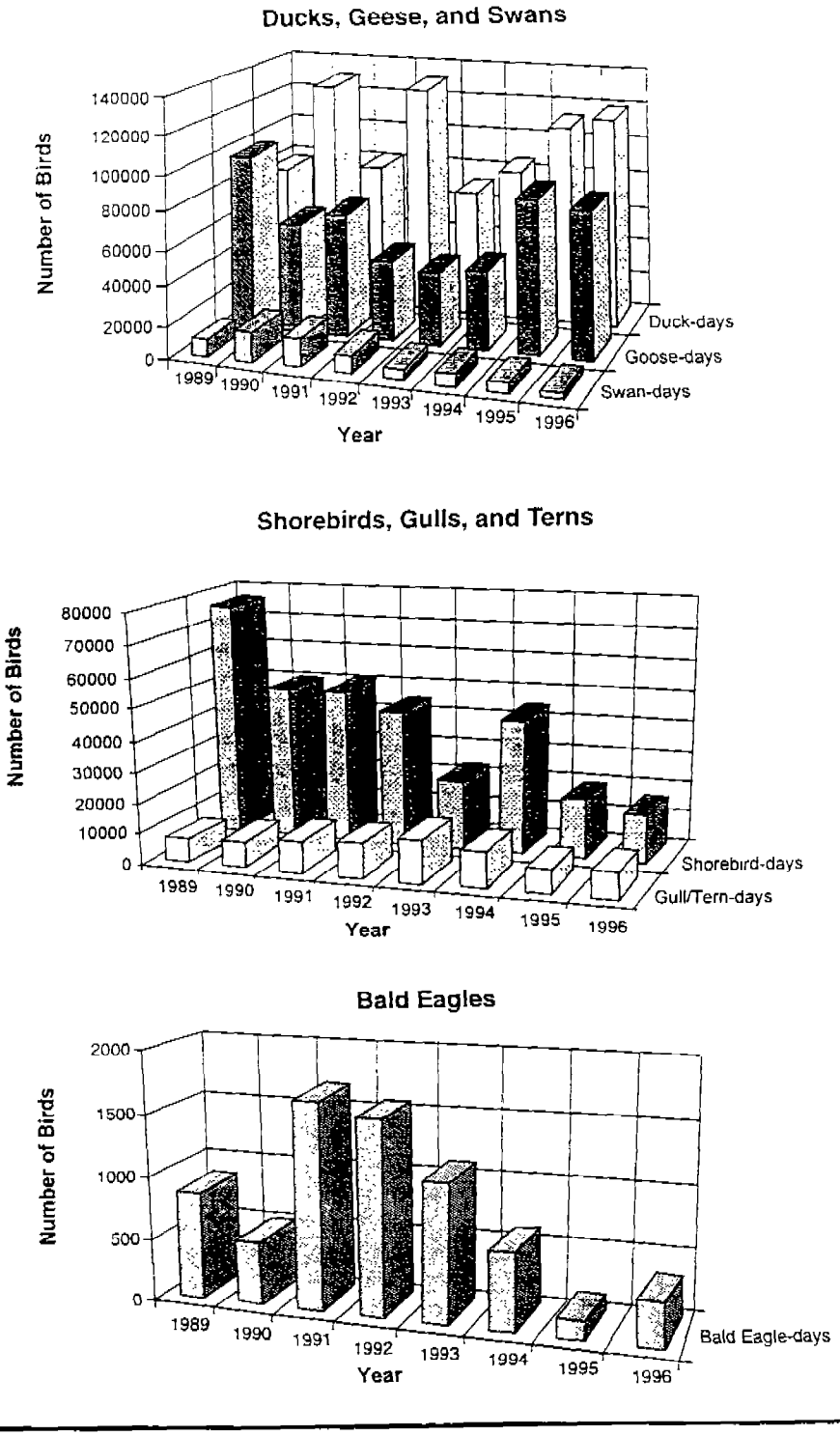


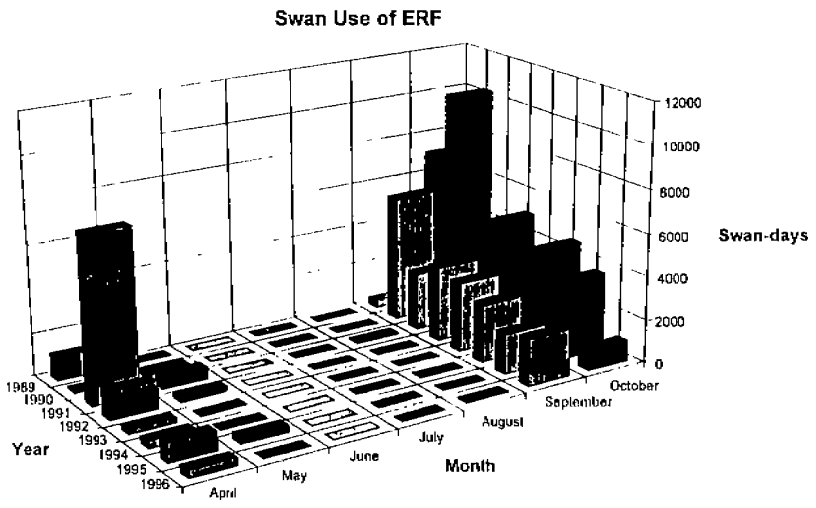
Figure 3-1

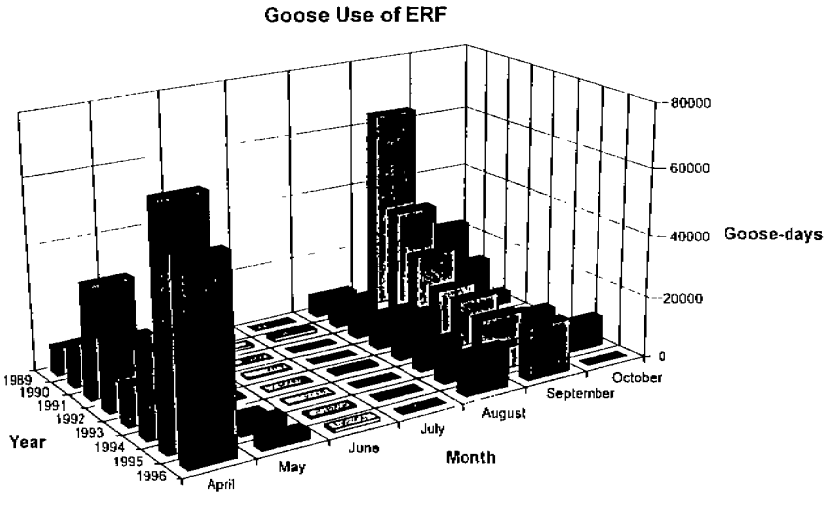
Waterfowl Use of ERF by Year

Operable Unit C
Environmental Risk Assessment
Fort Richardson, Alaska

CH2MHILL

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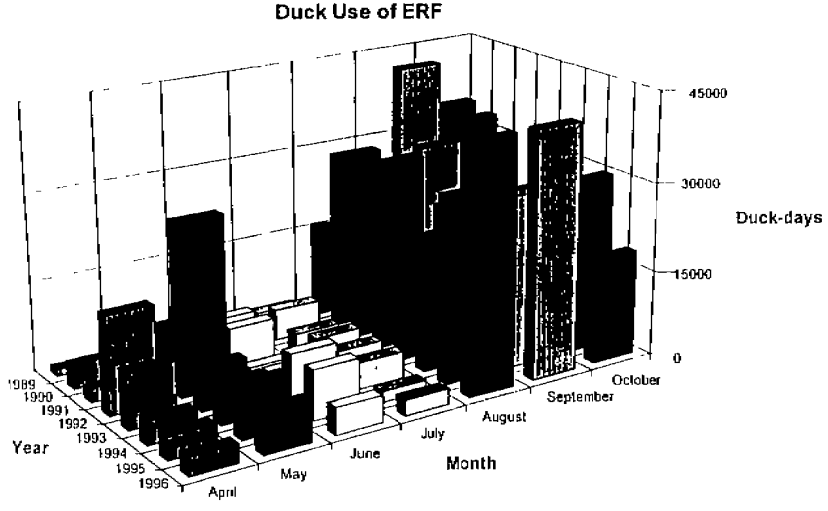


Figure 3-2

Waterfowl Use of ERF by Month

Operable Unit C
Ecological Risk Assessment
Fort Richardson, Alaska

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TABLE 3-1
Use of ERF by Different Bird Groups and Species from 1989 to 1996

Bird	Use by Year (bird-days)								
	1989	1990	1991	1992	1993	1994	1995	1996	Average
Swan	8,600	16,000	15,000	10,000	7000	7,700	6,700	3,700	9,400
Goose	96,000	61,000	68,000	45,000	41,000	44,000	85,000	82,000	65,000
Duck	75,000	130,000	80,000	130,000	73,000	84,000	110,000	120,000	100,000
Mallard	37,000	33,000	33,000	36,000	12,000	20,000	22,000	28,000	28,000
Pintail	17,000	38,000	13,000	41,000	17,000	12,000	16,000	14,000	21,000
Green-winged teal	7,900	10,000	9,000	24,000	15,000	13,000	29,000	15,000	15,000
Gull/tern	7,200	8,400	10,000	11,000	14,000	12,000	7,500	8,600	9,800
Shorebird	76,000	50,000	50,000	44,000	22,000	43,000	19,000	16,000	40,000
Bald eagle	850	510	1,700	1,600	1,000	610	140	250	830
Sandhill crane	1,700	530	990	940	1,600	2,200	1,800	1,300	1,400
Raven	10	82	320	970	1,300	64	21	--	390
Other raptor	56	--	24	4	0.0	15	--	--	20
Loon/grebe	20	--	--	38	190	120	8	250	110

Notes:
Bird-days are normalized according to the number of surveys in each month.
-- = These bird groups were not surveyed in the corresponding year.

Swan use of Eagle River Flats is highest in the fall, although swans are also found in the spring.

(Table 3-1). From 1989 to 1996, mallard use of ERF was highest in late summer to early fall (Figure 3-3). Northern pintail use during this period was more variable, with the highest recorded springtime use in 1992 and 1993 and the highest fall use in 1990 (Figure 3-3). Green-winged teal use was also higher in the fall than spring; however, elevated numbers were observed during the month of May in all years except 1989, and particularly high springtime use was recorded in 1992 (Figure 3-3).

During the 1995 field season aerial surveys were also conducted at the following UCI marshes: Susitna Flats, Palmer Hay Flats, Goose Bay, Trading Bay, Redoubt Bay, and Chickaloon Flats (Eldridge and Robertson, in Racine *et al.*, 1996.) Bird use of these marshes was also estimated to allow comparison to the 1995 ERF bird use estimates. Bird use for the following bird groups was summarized: swans, geese, ducks, bald eagles, and ravens. The results indicate that waterfowl use of ERF was relatively low when compared to the total bird use of the surveyed UCI marshes (3 percent for swans and ducks and 4 percent for geese). Use of ERF by bald eagles represented approximately 9 percent of eagle use of the surveyed UCI marshes. Use of ERF by ravens represented approximately 5 percent of raven use of the surveyed UCI marshes. The results of the comparisons indicate that the numbers of birds using ERF are a relatively small proportion of the total numbers of birds using other marshes in the region.

In 1995, ducks and swans from Eagle River Flats each represented 3 percent of the total bird use of UCI.

During the fall months (August, September, and October) of the 1996 field season, aerial surveys were conducted on several of the same UCI marshes, except Redoubt Bay and Trading Bay (Eldridge, in Walsh *et al.*, 1997). The 1995 fall bird census was compared to the 1996 fall census, as shown in Table 3-2. In general, the table shows that the 1996 fall season had lower swan use at all the surveyed marshes except Chickaloon Flats. Goose utilization in the fall was higher in 1996 than in 1995 for all the surveys of UCI marshes. Duck use showed a similar higher trend, except at Palmer Hay Flats and Goose Bay. Fall use by nonwaterfowl species was variable between 1995 and 1996. The table does indicate potentially higher fall use of Susitna Flats by gulls and terns, shorebirds, and cranes, as would be expected by the larger size of this marsh. For its size, ERF showed a relatively large population of shorebirds and cranes in both 1995 and 1996. The loon/grebe and raven surveys were not compared because these bird groups were not surveyed uniformly between the 2 years.

Ground Survey. Ground surveys of ERF bird numbers were conducted during the 1994 and 1995 field seasons by Reitsma and Steele (in Racine *et al.*, 1994, 1995). These surveys were conducted by observations from Cole Point for limited periods during the spring and fall, when bird numbers in ERF were elevated. Because the ground surveys were completed during limited time intervals in spring and fall and included only two field seasons, the data were not used to develop estimates of annual bird use at ERF. However, the data were compared with data collected from aerial surveys on the same dates in both 1994 and 1995.

Population estimates from Cole Point were similar to those from the aerial surveys during the spring, but were substantially lower in the fall. They also did not show the day-to-day variability of the aerial surveys.

Estimates of total duck numbers for ERF for both the ground survey and aerial survey on matching survey dates in 1994 and 1995 are depicted in Figure 3-4. In general, the comparison shows that the ground survey and aerial survey estimates track more closely in the spring than in the fall. The ground survey estimates were slightly higher than the aerial survey estimates in the spring, when duck numbers were slightly lower and vegetative cover was less. Ground survey estimates for the fall period were consistently lower than the aerial survey estimates and do not show the wide fluctuations in the population that was seen in the aerial surveys.

When 1994 and 1995 duck counts by ground and aerial surveys were assessed by individual areas, the following differences were observed. In the spring, ground survey duck counts were roughly equal to or greater than aerial survey counts. In the fall, aerial duck counts were generally higher than ground survey counts, especially in areas more distant from Cole Point (such as Areas C, C/D, and D and Bread Truck). Ground survey counts were consistently higher than aerial survey counts for Racine Island and consistently lower for Area B.

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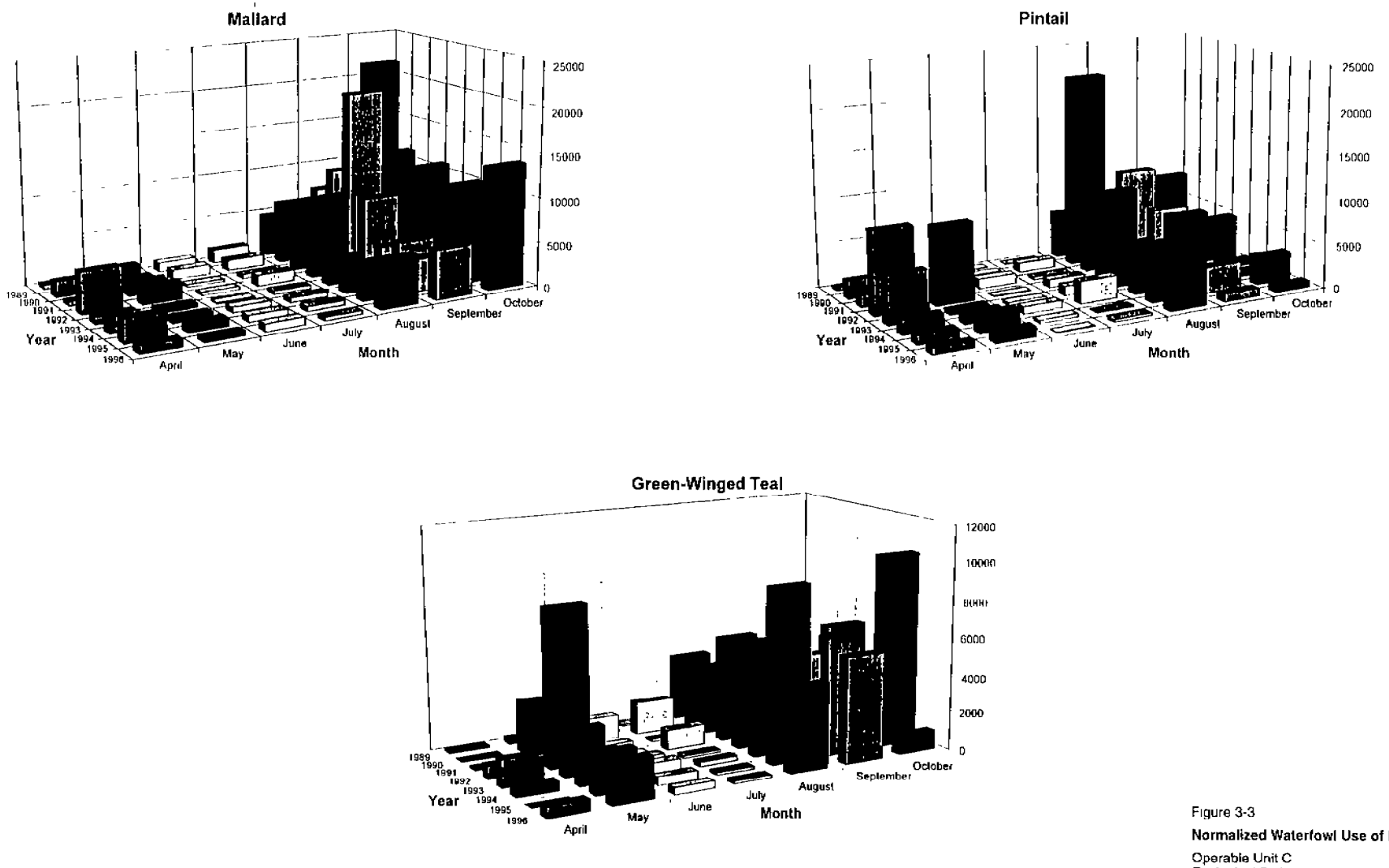


Figure 3-3

Normalized Waterfowl Use of ERF

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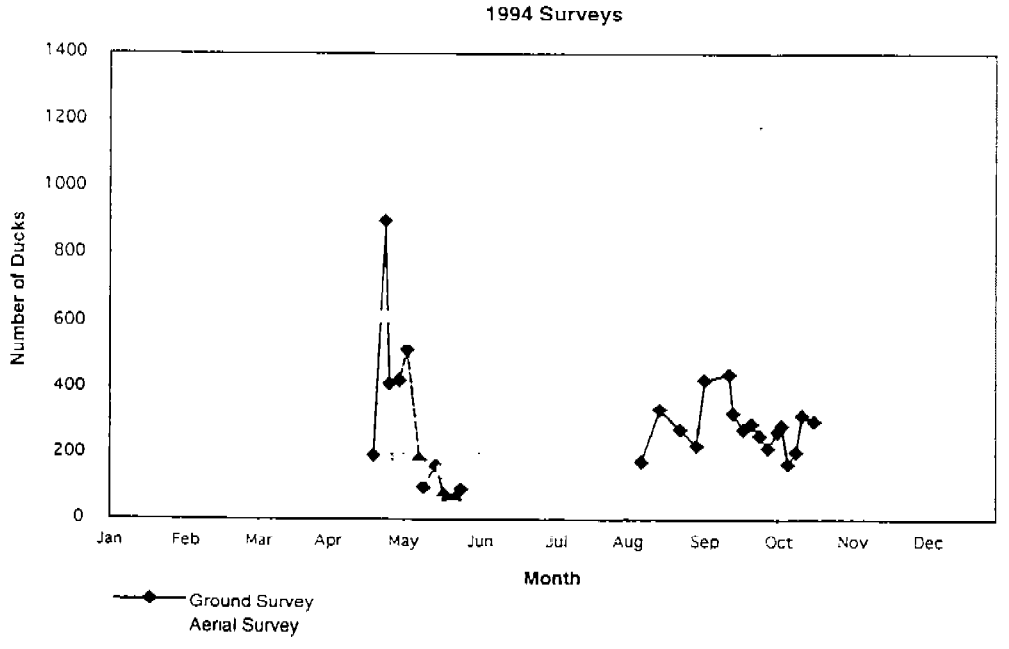
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TABLE 3-2
Fall Bird Use of Upper Cook Inlet Marshes: 1995 and 1996[a]

Normalized	Palmer Hay Flats		Goose Bay		Susitna Flats		Eagle River Flats		Chickaloon Flats	
Bird-days[b]	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996
Swan-days	7,340	1,230	186	101	30,700	24,900	5,510	3,270	72.3	280
Goose-days	9,420	19,700	997	1,750	30,800	91,700	18,200	26,100	71,300	118,000
Duck-days	139,000	93,500	44,300	15,700	987,000	1,070,000	89,200	101,000	199,000	428,000
Eagle-days	39.8	15.5	22.5	155	38.1	37.5	73	109	100	82.0
Gull/tern-days	1,230	209	192	0	3,150	8,160	153	177	72.3	160
Shorebird-days	517	504	713	171	4,100	5,930	2,510	3,120	517	300
Crane-days	31.0	15.5	18.6	38.8	432	171	649	753	0	250
Loon/grebe-days	304	316	0	0	160	240	0	0	0	0
Raven-days	0	--	0	--	10	--	16.7	--	0	--

[a] Fall months include August, September, and October surveys.
[b] Bird counts normalized by dividing by the number of aerial surveys in the month.

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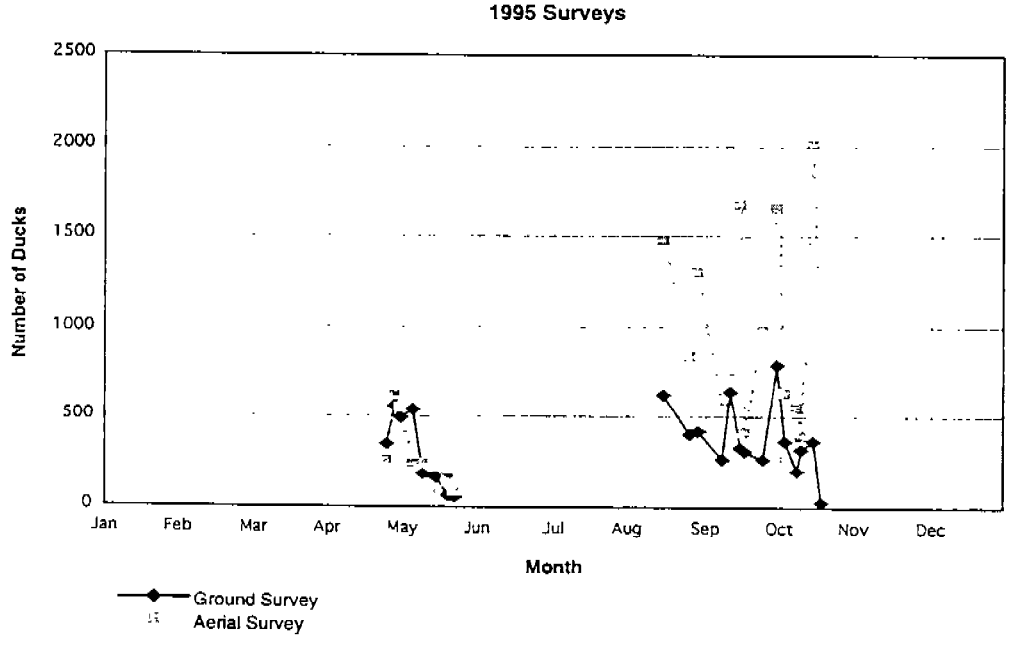


Figure 3-4

Comparison of ERF Duck Counts by Different Survey Methods

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Although these areas are relatively close to the Cole Point observation station, habitat (mud flats and ponds) and conditions on Racine Island allow relatively unobstructed views. However, views of Area B may be obstructed because of different habitat conditions, as well as possible impairment by trees on Cole Point. This information indicates that obstruction of the surveyor's vision by vegetation (especially in the fall) and other factors, including weather, bird behavior, and hazing, have affected the ground and aerial survey counts.

Susitna Flats is an important spring staging area for swans, geese, and ducks.

Regression analysis was conducted for the estimated total ERF duck numbers for each method and for all matching survey dates. The correlation coefficients for 1994 and 1995 were 0.31 and 0.52, respectively. Analysis of the 1996 aerial and ground survey data was not completed because the ground survey counts were not available at the time of this report. The ground survey data do support the aerial survey data by indicating an increase in duck numbers in spring and fall.

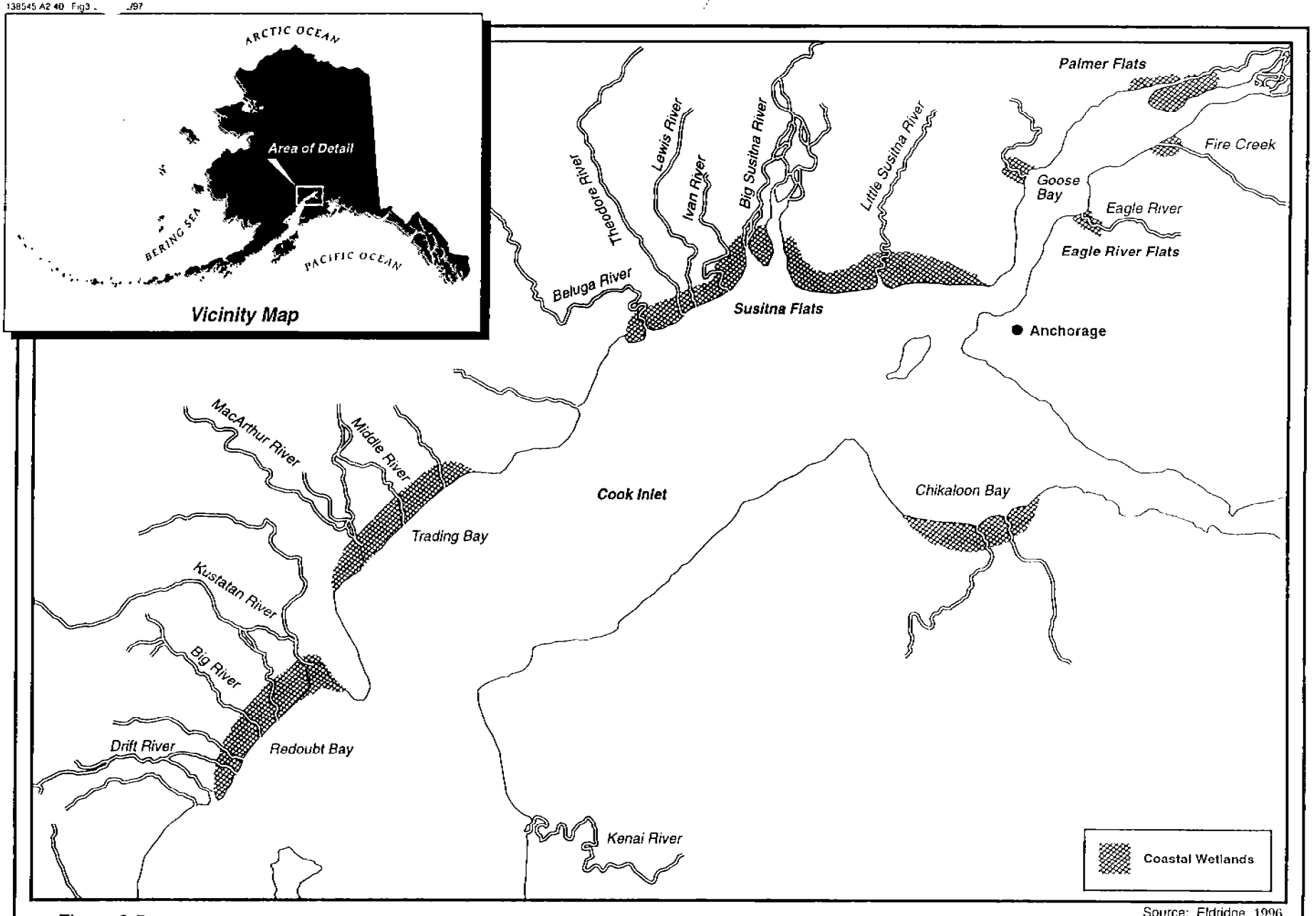
Additional Aerial Surveys. In addition to the aerial surveys of ERF, the U.S. Fish and Wildlife Service (USFWS) also surveyed several UCI marshes in 1995. These offsite aerial surveys included Palmer Hay Flats, Goose Bay, Susitna Flats, Trading Bay, Redoubt Bay, and Chickaloon Flats (Figure 3-5). A total of 25 offsite aerial surveys were conducted in 1995. Numbers of swans, geese, ducks, and other birds observed during the surveys were recorded (Eldridge and Robertson, in Racine *et al.*, 1996).

Use of UCI marshes by swans was most concentrated in spring 1995, when peak numbers reached 8,000 birds in late April (compared with about 60 observed in ERF at the same time). Highest mean numbers occurred in Susitna Flats and Palmer Hay Flats during spring and fall, possibly because of wetter habitat in those marshes. The largest concentration of swans recorded in 1995 occurred at Swan Lake, near the mouth of the Big Susitna River, where 1,600 swans were observed on September 26 (compared with 268 observed in ERF the same day).

Goose numbers followed a trend similar to the trend for swans, with peak numbers above 55,000 occurring in late April. In spring, mean numbers of geese were highest in Susitna Flats, followed by Trading Bay. Numbers of breeding geese are generally low, but they are also difficult to observe until they form molt and brood flocks (Eldridge and Robertson, in Racine *et al.*, 1996). Mean fall geese numbers were highest in Chickaloon Flats, followed by Trading Bay.

Similar species of ducks found in ERF also use other UCI marshes.

The species composition of ducks using UCI marshes in 1995 was similar to that for ERF (Eldridge and Robertson, in Racine *et al.*, 1996). Dabbling ducks constituted 97 percent of observations. Duck numbers peaked in late April in UCI—approaching 20,000—then declined rapidly. Mean numbers of ducks in spring were highest in Susitna Flats, followed by Trading Bay. A small peak in late June reflected



Source: Eldridge, 1996.

Figure 3-5

Location of Coastal Wetlands, Including ERF, in Upper Cook Inlet Surveyed in 1995

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premolting flocks of male American wigeon, similar to that observed in ERF. Numbers increased rapidly in mid-August, peaked in late August at more than 45,000 birds, and then declined gradually. Mean numbers of ducks in the fall were highest in Susitna Flats.

Figure 3-6 shows a comparison of total numbers, presented as percentages, of ducks and swans observed in UCI marshes and in ERF. A straight comparison of the waterbird numbers in UCI marshes and ERF cannot be made without a discussion of major habitat differences between these areas.

Shoreline topography affects habitat use by waterfowl.

Intertidal mud flats provide extensive feeding habitat for ducks and shorebirds and loafing habitat for geese throughout UCI. Intertidal mud flats extend up to 3.2 kilometers (km) in width at low tide off Susitna Flats, Trading Bay, Redoubt Bay, and Chickaloon Flats. Productive intertidal mud flats are minimally available in Knik Arm, including ERF, Goose Bay, and Palmer Hay Flats, where the shoreline is much more abrupt and the effect of fresh water is much greater (Eldridge and Robertson, in Racine *et al.*, 1996). During fall, these mud flats appear to be preferred by ducks for feeding, as shown in Figure 3-7.

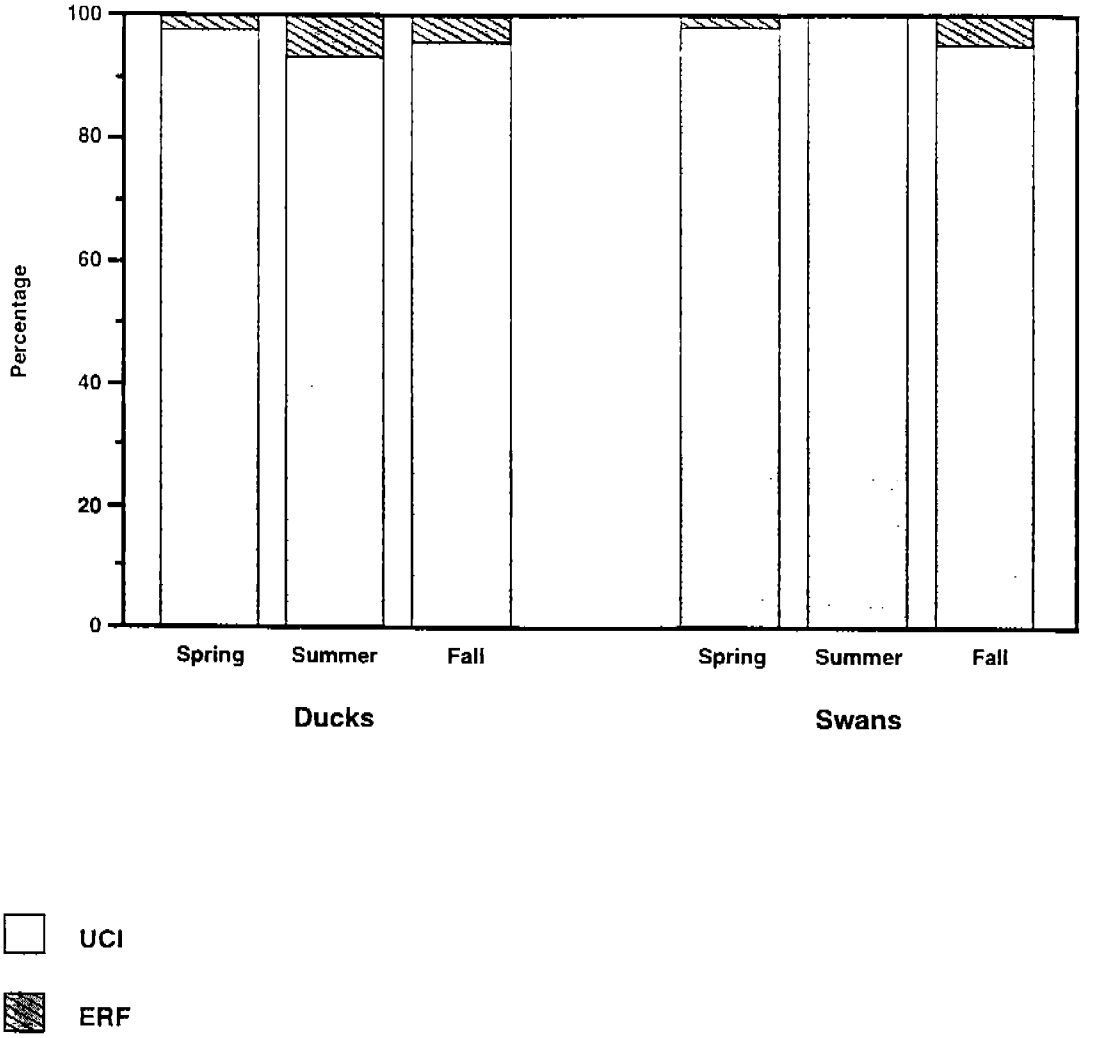
Ducks also may be more visible on mud flats versus vegetated marshes.

The difference in numbers of ducks on mud flats versus vegetated marshes may also be a result of better visibility on mud flats. A comparison of duck densities at inland habitats reveals that considerably higher fall densities were recorded on inland marshes of ERF than on inland marshes of UCI. This difference may be partially attributed to better coverage of ERF than UCI during aerial surveys, to hunting on other UCI marshes (compared with the sanctuary of ERF), or to greater productivity of ERF marshes (Eldridge and Robertson, in Racine *et al.*, 1996).

3.1.3 White Phosphorus Tissue Analysis

Various species of plants and animals were collected from ERF for analysis of tissue concentrations of WP. In addition, laboratory bioaccumulation studies were conducted on prey and predator species representative of those found at ERF. Biota collected from different areas at ERF included waterfowl (pintail, green-winged teal, mallard, and tundra swan), other bird species (Northern phalarope, lesser yellowlegs, greater yellowlegs, arctic tern, mew gull, dowitcher, sandhill crane, and eagle), mammals (coyote), plants (sedge, bulrush, and arrowgrass), fish (stickleback and mixed species), and invertebrates (chironomid, damselfly, dragonfly, and mixed invertebrate species). Species used in laboratory bioaccumulation studies included mallards, chickens, and kestrels.

This section provides a summary of tissue concentrations of WP found in biota, both field-collected and from laboratory tests. Summary results of the different tissue analyses are presented in Table 3-3 (birds



Source: Eldridge, 1996.

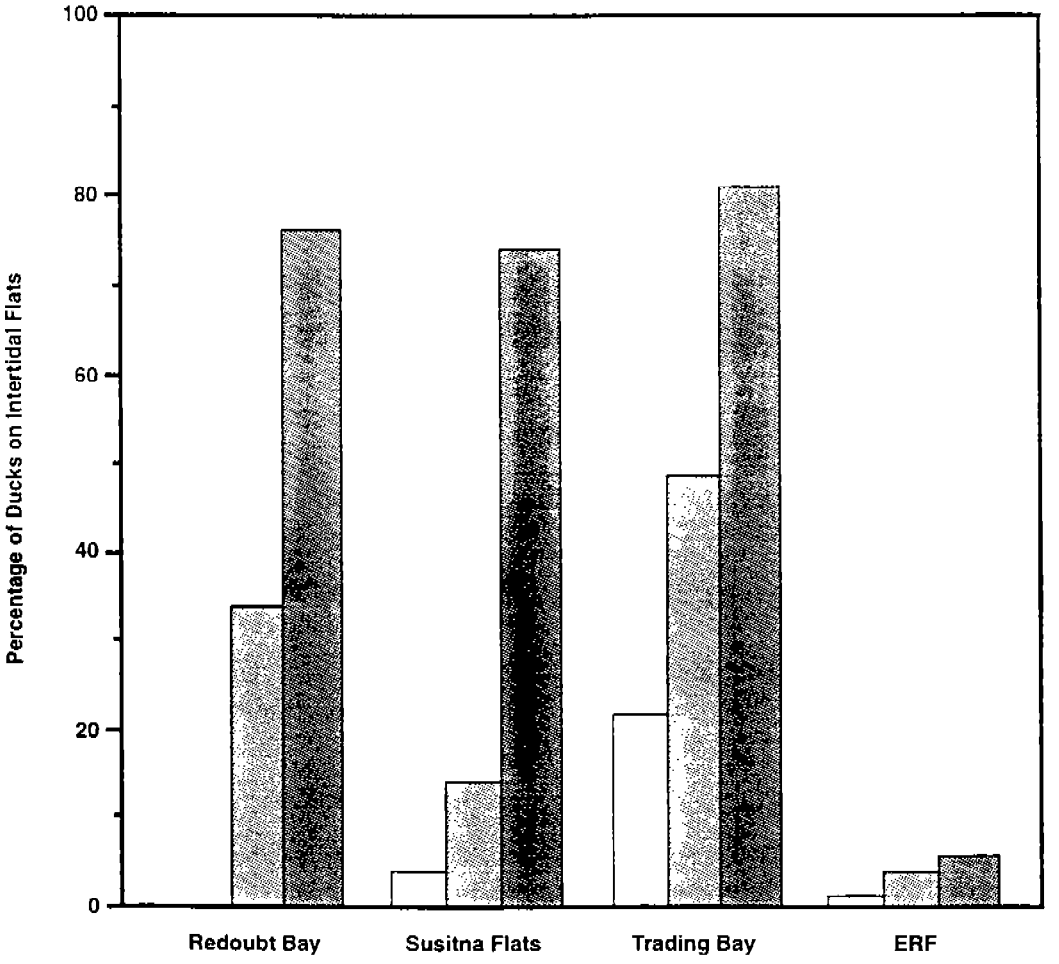
Figure 3-6

Percentage of Ducks and Swans Observed in UCI Coastal Wetlands and ERF

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Source: Eldridge, 1996.

Figure 3-7

Percentage of Ducks Observed on Intertidal Flats of Redoubt Bay, Susitna Flats, Trading Bay, and ERF in Spring, Summer, and Fall 1995

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Table 3-3
Summary Table of White Phosphorus Tissue Concentrations in Birds and Mammals—Field Studies

Species	Tissue	Parameter	Range	Unit	Study
Waterfowl					
Blue-winged teal	Skin	concentration	Det.	µg/g ww	Sparling et al., in Racine et al.1994
Duck	Fat	concentration	ND-2.846	µg/g	Roebuck and Nam in Racine et al., 1995
	In digestive tract	WP mass	0.032-0.169	µg	Roebuck and Nam in Racine et al., 1995
Native ducks (green-winged teal and pintail)	Skin/fat	concentration	0.018-1.57	µg/g ww	Roebuck et al., 1994
	Brain	concentration	0.010-0.060	µg/g ww	Roebuck et al., 1994
	Breast muscle	concentration	<0.5	µg/g ww	Roebuck et al.,1994
	Thigh muscle	concentration	<0.5	µg/g ww	Roebuck et al.,1994
	Heart	concentration	<0.5	µg/g ww	Roebuck et al.,1994
	Kidney	concentration	<0.5	µg/g ww	Roebuck et al.,1994
	Liver	concentration	<0.5	µg/g ww	Roebuck et al.,1994
	Spleen	concentration	<0.5	µg/g ww	Roebuck et al.,1994
Green-winged teal	Blood	concentration	0	µg/g	Racine et al., 1991
	Brain	concentration	0	µg/g	Racine et al., 1991
	Digestive Tract	WP mass	ND-3	µg	Roebuck and Nam in Racine et al., 1995
	Fat	concentration	0.045	µg/g	Racine et al., 1991
	Fat	concentration	0.96-19.06	µg/g ww	Sparling et al., in Racine et al.1994
	Gizzard contents	concentration	0.08-0.56	µg/g	Racine et al., 1991
	Gizzard contents	concentration	0-3150	µg/g ww	Sparling et al., in Racine et al.1994
	Gizzard contents	WP mass	ND-11.4	µg	Roebuck, 1995
	Gut	concentration	0	µg/g ww	Sparling et al., in Racine et al.1994
	Heart	concentration	0-0.19	µg/g	Racine et al., 1991
	Intestinal contents	WP mass	0.081	µg	Racine et al., 1991
	Intestines	concentration	0.005-0.94	µg/g	Racine et al., 1991
	Kidney	concentration	0-0.019	µg/g	Racine et al., 1991
	Liver	concentration	0-0.144	µg/g	Racine et al., 1991
	Liver	concentration	0-2.70	µg/g ww	Sparling et al., in Racine et al.1994
	Pectoral muscle	concentration	0.0016	µg/g	Racine et al., 1991
	Gizzard muscle	concentration	trace	µg/g	Racine et al., 1991
	Skin	concentration	0.012-6.34	µg/g ww	Roebuck et al., 1994
Teal	Abdominal Fat	concentration	0.521	µg/g ww	Roebuck et al., 1994
	Gizzard contents	WP mass	0.021-8,820	µg	Roebuck et al., 1994
	Breast muscle	concentration	0.052-5.92	µg/g ww	Roebuck et al., 1994
	Skin	concentration	0.30-5.71	µg/g ww	Sparling et al., in Racine et al.1994
	Unknown tissue	concentration	0.001-0.560	µg/g ww	Roebuck et al., 1994

Table 3-3
Summary Table of White Phosphorus Tissue Concentrations in Birds and Mammals—Field Studies

Species	Tissue	Parameter	Range	Unit	Study
Mallard (some birds introduced to ERF)	Brain	concentration	<0.5	µg/g ww	Roebuck et al.,1994
	Fat	concentration	0	µg/g	Racine et al., 1991
	Fat	concentration	0.23-1.05	µg/g ww	Sparling et al., in Racine et al.1994
	Abdominal fat	concentration	0.42	µg/g ww	Roebuck et al., 1994
	Gizzard contents	concentration	0.21-628	µg/g ww	Sparling et al., in Racine et al.1994
	Gizzard contents	concentration	0.28-19.5	µg/g	Racine et al., 1991
	Gizzard contents	WP mass	ND-21,400	µg	Roebuck, 1995
	Gizzard contents	WP mass	1.32	µg	Roebuck et al., 1994
	Heart	concentration	<0.5	µg/g ww	Roebuck et al.,1994
	Kidney	concentration	<0.5	µg/g ww	Roebuck et al.,1994
	Liver	concentration	0-21.4	µg/g ww	Sparling et al., in Racine et al.1994
	Liver	concentration	<0.5	µg/g ww	Roebuck et al.,1994
	Breast muscle	concentration	<0.5 - 0.004	µg/g ww	Roebuck et al., 1994
	Thigh muscle	concentration	<0.5	µg/g ww	Roebuck et al.,1994
	Skin/fat	concentration	0.406-2.35	µg/g ww	Roebuck et al., 1994
	Skin	concentration	0.06	µg/g ww	Roebuck et al., 1994
	Skin	concentration	0-20.5	µg/g ww	Sparling et al., in Racine et al.1994
	Spleen	concentration	<0.5	µg/g ww	Roebuck et al.,1994
Pintail	Gizzard contents	concentration	74	µg/g	Racine et al., 1991
	Gizzard contents	concentration	0.24-96.9	µg/g ww	Sparling et al., in Racine et al.1994
	Gizzard contents	WP mass	ND-80.9	µg	Roebuck 1995
	Heart	concentration	0	µg/g	Racine et al., 1991
	Intestinal contents	concentration	0.82	µg/g	Racine et al., 1991
	Liver	concentration	0.049	µg/g	Racine et al., 1991
	Liver	concentration	0-0.17	µg/g ww	Sparling et al., in Racine et al.1994
	Wing muscle	concentration	0.017	µg/g ww	Roebuck et al.,1994
	Skin	concentration	Det-2.64	µg/g ww	Sparling et al., in Racine et al.1994
Shoveler	Gizzard contents	WP mass	0.751	µg	Roebuck et al.,1994
	Abdominal Fat	concentration	0.047	µg/g ww	Roebuck et al.,1994
	Breast muscle	concentration	ND	µg/g ww	Roebuck et al.,1994
	Muscle	concentration	0.06	µg/g ww	Roebuck et al.,1994
	Skin	concentration	0.067	µg/g ww	Roebuck et al.,1994
Tundra swan	Blood whole	concentration	0	µg/g	Racine et al., 1992b
	Blood serum	concentration	0	µg/g	Racine et al., 1991
	Fat	concentration	0-2.9	µg/g	Racine et al., 1991, and,1992b
	Gizzard contents	WP mass	0.0238	µg	Roebuck, 1995
	Gizzard contents	concentration	0.022-206	µg/g	Racine et al., 1991
Swan	Skin	concentration	0.01-0.14	µg/g	Racine et al., 1992c
Non-waterfowl					
Golden eagle	Fat	concentration	0.02	µg/g ww	Sparling et al., in Racine et al.1995

Table 3-3
Summary Table of White Phosphorus Tissue Concentrations in Birds and Mammals—Field Studies

Species	Tissue	Parameter	Range	Unit	Study
Bald eagle	Fat	concentration	0.060	µg/g ww	Roebuck et al.,1994
	Skin	concentration	0.010	µg/g ww	Roebuck et al.,1994
Greater yellowlegs	Skin	concentration	ND-0.40	µg/g ww	Sparling et al., in Racine et al.1994
Pectoral sandpiper	Gizzard	concentration	12.35	µg/g ww	Roebuck et al.,1994
	Fat	concentration	0.555	µg/g ww	Roebuck et al.,1994
	Skin	concentration	0.33	µg/g ww	Roebuck et al.,1994
Red-necked phalarope	Gizzard contents	concentration	0.051-15,500	µg/g ww	Roebuck et al.,1994
	Skin	concentration	0.451-3.190	µg/g ww	Roebuck et al.,1994
	Intestine remains	concentration	4.565	µg/g ww	Roebuck et al.,1994
	Yolk in yolk sacs	concentration	0.031-0.106	µg/g ww	Roebuck et al.,1994
Eggs					
Herring gull egg	Entire egg contents	concentration	0.003	µg/g ww	Roebuck et al.,1994
Controls collected from Susitna Flats					
Green-winged teal	Fat	concentration	0	µg/g	Racine et al., 1991
	Gizzard contents	concentration	0	µg/g	Racine et al., 1991
Pen enclosures at ERF					
Mallard	In entire digestive tract	WP mass	2-2,000	µg	Roebuck and Nam in Racine et al., 1995. Sparling et al., in Racine et al., 1994
	Fat	concentration	ND-1.504	µg/g	Roebuck and Nam in Racine et al., 1995. Sparling et al., in Racine et al., 1994
Mammals					
Coyote	Leg muscle	WP mass	ND		Roebuck, 1995

O = WP was either not detected or was below detection limits.
ND = Not detected.
Det. = Detected, but not reported.

Notes:

This table summarizes data reported in Appendix A.
The data presented may be average values.
The following nonwaterfowl samples were nondetect:
- Northern phalarope: Skin, crop and gizzard, crop contents.
- Lesser yellowlegs: Skin, crop contents, liver.
- Greater yellowlegs: Crop contents.
- Arctic tern: Skin, crop contents.
- Mew gull: Skin, crop contents.
- Dowitcher: Skin, crop contents.
- Sandhill crane: Gizzard contents.

Sparling et al., in Racine et al., 1994; Roebuck, 1995.

and mammals), Table 3-4 (fish and invertebrates), and Table 3-5 (plants). A full report on the tissue concentrations in birds is included in Attachment 1.

Birds. Concentrations of WP reported from tissue analysis of birds are summarized in Table 3-3. The data are summarized according to bird species and tissue. Median values, other than those reported in Roebuck *et al.* (1994), were calculated from specific wet weight (ww) values pertaining to a specified tissue. Values that were given as detected but at unspecified levels (presence, absence analyses) or as below detection levels (therefore, WP concentration unknown), or in ranges with median values, were not used.

Ducks exposed to white phosphorus by ingestion had measurable white phosphorus in their gizzards, fat, skin, and liver.

For field-collected mallards that had been exposed to in situ WP, gizzard content WP concentrations ranged from 0.21 microgram per gram (µg/g) ww to 628 µg/g-ww (Sparling *et al.*, in Racine *et al.*, 1994). The median value for WP concentrations in the gizzard (only including those reported as wet weight values) was 74.5 µg/g-ww. The mass of WP in the gizzard content ranged from nondetectable levels to 21,400 micrograms (µg) (Roebuck, 1995). Liver WP concentrations ranged from nondetectable levels to 21.4 µg/g-ww (Sparling *et al.*, in Racine *et al.*, 1994), with a median for all values reported in wet weight of 0.27 µg/g. Skin WP concentrations ranged from below detection levels to 20.5 µg/g-ww (Sparling *et al.*, in Racine *et al.*, 1994). The median value pertaining only to WP concentrations reported as wet weight values was 1.33 µg/g.

Mallards that had been kept in pen enclosures in ERF showed a mass of WP in the entire digestive tract that ranged from 2 µg to 2,000 µg (Roebuck and Nam, in Racine *et al.*, 1995). The median for reported WP mass values was 109 µg. The fat WP concentration for the mallards from pen enclosures ranged from nondetectable levels to 1.504 µg/g (Roebuck and Nam, in Racine *et al.*, 1995).

The WP concentration in the tissue of mallards in toxicological studies varied according to the dose and form of WP administered; ranges are summarized according to these two variables. Some studies administered WP dissolved in oil. Mallards receiving a WP dose of less than 6.1 milligrams per kilogram (mg/kg) of body weight (bw) dissolved in oil showed WP concentrations in the liver below detection levels. A WP dose of 6.1 mg/kg-bw gave mean WP concentrations in the liver that ranged from below detection levels in surviving birds to 0.014 µg/g-ww in dead birds. At a WP dose of 7.1 mg/kg-bw, mean WP concentrations in the liver ranged from below detection limits in survivors to 0.006 µg/g-ww in dead birds. At a WP dose of 8.0 mg/kg-bw (dissolved in oil), nondetectable levels were found in the liver of mallards that survived; the mean liver WP concentration for the dead birds was 0.001 µg/g-ww. At a WP dose of 9.1 mg/kg-bw, below-detection levels were found in survivors, and

Table 3-4

Summary of White Phosphorus Tissue Concentrations in Fish and Invertebrates

Specimen	Sample Size	Sample No./Site	Concentration of White Phosphporus in Tissue (mg/kg)	Source	Type Study	Form of WP
Fish						
Fish		A1	<10 ww	USAEHA 1994	In field	In situ
Fish		A2	<10 ww	USAEHA 1994	In field	In situ
Fish		CD1	<10 ww	USAEHA 1994	In field	In situ
Fish		CD2	<10 ww	USAEHA 1994	In field	In situ
Fish		BTP5	<14 ww	USAEHA 1995	In field	In situ
Fish		BT1	<10 ww	USAEHA 1994	In field	In situ
Fish		BT2	<10 ww	USAEHA 1994	In field	In situ
Fish		BT3	<10 ww	USAEHA 1994	In field	In situ
Fish		C1	<10 ww	USAEHA 1994	In field	In situ
Fish		C2	<10 ww	USAEHA 1994	In field	In situ
Fish		C3	<10 ww	USAEHA 1994	In field	In situ
Fish		DUP1	<10 ww	USAEHA 1994	In field	In situ
Fish		RI1	<10 ww	USAEHA 1994	In field	In situ
Fish		RI2	<10 ww	USAEHA 1994	In field	In situ
Fish		GB1	<10 ww	USAEHA 1994	In field	In situ
Fish		GB2	<10 ww	USAEHA 1994	In field	In situ
Fish	16	Bread truck pond	ND	Sparling, in Racine et al., 1994	In field	In situ
Fish	35	BTP, Area C near OB/OD Pad, Area B, and Area D	ND	Sparling, in Racine et al., 1994	In field	In situ
Stickleback	2	C3	<25 ww	USAEHA 1995	In field	In situ
Stickleback	2	DUP1	<25 ww	USAEHA 1995	In field	In situ
Stickleback	several	CD1	<15 ww	USAEHA 1995	In field	In situ
Stickleback	several	CD2	<17 ww	USAEHA 1995	In field	In situ
Stickleback	3	BP1	<90 ww	USAEHA 1995	In field	In situ
Stickleback	9	BP3	<25 ww	USAEHA 1995	In field	In situ
Stickleback	42	BP4	<14 ww	USAEHA 1995	In field	In situ
Stickleback	3	DP1	<21 ww	USAEHA 1995	In field	In situ
Stickleback	3	DP2	<31 ww	USAEHA 1995	In field	In situ
Stickleback	1	DP3	<90 ww	USAEHA 1995	In field	In situ
Stickleback		A1	<3.7ww	USAEHA 1995	In field	In situ
Stickleback		A2	<3.7ww	USAEHA 1995	In field	In situ
Stickleback		A3	<3.7ww	USAEHA 1995	In field	In situ
Stickleback		A4	67.8 ww	USAEHA 1995	In field	In situ
Stickleback		A5	<18 ww	USAEHA 1995	In field	In situ
Stickleback		B1	<18 ww	USAEHA 1995	In field	In situ
Stickleback		B2	<3.7 ww	USAEHA 1995	In field	In situ
Stickleback		B3	<18 ww	USAEHA 1995	In field	In situ
Stickleback		BT1	<18 ww	USAEHA 1995	In field	In situ
Stickleback		BT2	<18 ww	USAEHA 1995	In field	In situ
Stickleback		C2	<18 ww	USAEHA 1995	In field	In situ
Stickleback		DUP2	<18 ww	USAEHA 1995	In field	In situ
Stickleback		C3	<18 ww	USAEHA 1995	In field	In situ
Stickleback		DUP1	<18 ww	USAEHA 1995	In field	In situ

Table 3-4

Summary of White Phosphorus Tissue Concentrations in Fish and Invertebrates

Specimen	Sample Size	Sample No./Site	Concentration of White Phosphporus in Tissue (mg/kg)	Source	Type Study	Form of WP
Stickleback		C5	<18 ww	USAEHA 1995	In field	In situ
Stickleback		CD1	<18 ww	USAEHA 1995	In field	In situ
Stickleback		CD2	<18 ww	USAEHA 1995	In field	In situ
Stickleback		D1	<18 ww	USAEHA 1995	In field	In situ
Stickleback		D2	<18 ww	USAEHA 1995	In field	In situ
Stickleback		D3	<18 ww	USAEHA 1995	In field	In situ
Stickleback		GB2	<18 ww	USAEHA 1995	In field	In situ
Stickleback		GB3	<18 ww	USAEHA 1995	In field	In situ
Stickleback		GB4	<18 ww	USAEHA 1995	In field	In situ
Stickleback		RI1	24.1 ww	USAEHA 1995	In field	In situ
Stickleback		RI2	82.3 ww	USAEHA 1995	In field	In situ
Stickleback		DT1	<18 ww	USAEHA 1995	In field	In situ
Invertebrates						
Chironomus		A1	<37 ww	USAEHA 1995	In field	In situ
Chironomus		A2	<16 ww	USAEHA 1995	In field	In situ
Chironomus		BT1	<18 ww	USAEHA 1995	In field	In situ
Chironomus		BT2	<15 ww	USAEHA 1995	In field	In situ
Chironomus		BT3	<13 ww	USAEHA 1995	In field	In situ
Chironomus		C1	<14 ww	USAEHA 1995	In field	In situ
Chironomus		C2	<18 ww	USAEHA 1995	In field	In situ
Chironomus		DUP2	<17 ww	USAEHA 1995	In field	In situ
Chironomus		GB1	<21 ww	USAEHA 1995	In field	In situ
Chironomus		GB2	<14 ww	USAEHA 1995	In field	In situ
Chironomus		BP1	<40 ww	USAEHA 1995	In field	In situ
Damselflies	20	FC1	<11 ww	USAEHA 1995	In field	In situ
Dragonflies/Damselflies	20/100	C3	<23 ww	USAEHA 1995	In field	In situ
Dragonflies/Damselflies	30/36	DUP1	<12 ww	USAEHA 1995	In field	In situ
Dragonflies/Damselflies	20/30	CD1	<12 ww	USAEHA 1995	In field	In situ
Dragonflies/Damselflies	20/30	CD2	<15 ww	USAEHA 1995	In field	In situ
Dragonflies/Damselflies	10/30	RI1	<13 ww	USAEHA 1995	In field	In situ
Dragonflies/Damselflies	10/40	RI2	<20 ww	USAEHA 1995	In field	In situ
Dragonflies/Damselflies	30/10	BP2	<12 ww	USAEHA 1995	In field	In situ
Dragonflies/Damselflies	8/9	BP3	<21 ww	USAEHA 1995	In field	In situ
Dragonflies/Damselflies	30/30	BP4	<13 ww	USAEHA 1995	In field	In situ
Dragonflies/Damselflies		C3	<3.7 ww	USAEHA 1995	In field	In situ
Dragonflies/Damselflies		DUP1	<3.7 ww	USAEHA 1995	In field	In situ
Dragonflies/Damselflies		C5	<5.4 ww	USAEHA 1995	In field	In situ
Dragonflies/Damselflies		CD2	<3.7 ww	USAEHA 1995	In field	In situ
Dragonflies/Damselflies		RI1	<11 ww	USAEHA 1995	In field	In situ

Table 3-4

Summary of White Phosphorus Tissue Concentrations in Fish and Invertebrates

Specimen	Sample Size	Sample No./Site	Concentration of White Phosphporus in Tissue (mg/kg)	Source	Type Study	Form of WP
Dragonflies/Damselflies		RI2	67.6 ww	USAEHA 1995	In field	In situ
Invertebrates		BTP3	<31 ww	USAEHA 1995	In field	In situ
Invertebrates		BTP5	<180 ww	USAEHA 1995	In field	In situ
Invertebrates		BTP8	<12 ww	USAEHA 1995	In field	In situ
Invertebrates		BTP9	<14 ww	USAEHA 1995	In field	In situ
Invertebrates	14	Bread Truck pond	ND	Sparling, in Racine et al., 1994	In field	In situ
Invertebrates	25	BTP, Area C near OB/OD Pad, Area B and Area D	ND	Sparling, in Racine et al., 1994	In field	In situ
Mixed Invertebrates		CP1	<27 ww	USAEHA 1995	In field	In situ
Mixed Invertebrates		CP2	<31 ww	USAEHA 1995	In field	In situ
Mixed Invertebrates		CP3	<12 ww	USAEHA 1995	In field	In situ
Mixed Invertebrates		DP1	<23 ww	USAEHA 1995	In field	In situ
Mixed Invertebrates		DP3	<12 ww	USAEHA 1995	In field	In situ
Mousies*	2	DP2	<220 ww	USAEHA 1995	In field	In situ

Notes:

ND = Nondetect

*Mousies = Order: Diptera; Family: Syrphidae (aquatic larvae)

Table 3-5
Summary of White Phosphorus Tissue Concentrations in Plants

Specimen	Sample Size	Sample No./ Site	Type of tissue	Concentration of White Phosphorus in Tissue (µg/kg)	Source	Type Study	Form of WP
Plants							
Zannichellia palustris		Site 52 (222) Area C near Canoe Point		ND	Walsh, in Racine et al., 1994	In field	In situ
Zannichellia palustris		Miller's hole Area C		160 ww	Walsh, in Racine et al., 1994	In field	In situ
Zannichellia palustris		Site 280 50 m NE of C tower		ND	Walsh, in Racine et al., 1994	In field	In situ
Sedge (*Carex lyngbyei*)		Site 110 Area C in Sedge Marsh (Smoke Hole)	roots	2270 ww	Walsh, in Racine et al., 1994	In field	In situ
Sedge (*Carex lyngbyei*)		Site 110 Area C in Sedge Marsh	shoots, leaves	ND	Walsh, in Racine et al., 1994	In field	In situ
Sedge (*Carex lyngbyei*)		Site 110 Area C in Sedge Marsh (Smoke Hole)	seeds	ND	Walsh, in Racine et al., 1994	In field	In situ
Bulrush (*Scirpus paludosus*)		Site 615 Area C Bulrush Area	root bulb	ND	Walsh, in Racine et al., 1994	In field	In situ
Bulrush (*Scirpus paludosus*)		Site 615 Area C Bulrush Area	roots	ND	Walsh, in Racine et al., 1994	In field	In situ
Bulrush (*Scirpus paludosus*)		Site 615 Area C Bulrush Area	rhizome	110 ww	Walsh, in Racine et al., 1994	In field	In situ
Bulrush (*Scirpus paludosus*)	2	Site 615 Area C Bulrush Area	whole plant	ND	Walsh, in Racine et al., 1994	In field	In situ
Bulrush (*Scirpus paludosus*)	2	Site 280 50 m NE of C tower	roots	ND	Walsh, in Racine et al., 1994	In field	In situ
Bulrush (*Scirpus paludosus*)		Site 280 50 m NE of C tower	peeled rhizome	ND	Walsh, in Racine et al., 1994	In field	In situ
Bulrush (*Scirpus paludosus*)		Site 285 175 m NE of C tower	seeds, seedlings	ND	Walsh, in Racine et al., 1994	In field	In situ
Hippuris tetraphylla		Site 615 Area C Bulrush Area	whole plant	ND	Walsh, in Racine et al., 1994	In field	In situ
Hippuris tetraphylla		Site 615 Area C Bulrush Area	rhizome	ND	Walsh, in Racine et al., 1994	In field	In situ
Hippuris tetraphylla		Site 615 Area C Bulrush Area	roots	ND	Walsh, in Racine et al., 1994	In field	In situ
Hippuris tetraphylla		Site 615 Area C Bulrush Area	leaves, shoots	ND	Walsh, in Racine et al., 1994	In field	In situ
Potamogeton pectinatus	4	Site 615 Area C Bulrush Area		ND	Walsh, in Racine et al., 1994	In field	In situ
Arrowgrass (*Triglochin maritima*)		Site 883 Area C west side of pond	base	ND	Walsh, in Racine et al., 1994	In field	In situ
Arrowgrass (*Triglochin maritima*)		Site 883 Area C west side of pond	leaves	ND	Walsh, in Racine et al., 1994	In field	In situ

Notes:
ND = Nondetect

dead birds had a mean liver WP concentration of 0.002 µg/g-ww (Sparling *et al.*, in Racine *et al.*, 1994).

Tissue analysis was performed after dosing mallards with white phosphorus in a pelletized form and dissolved in oil.

A study by Racine *et al.* (1991, 1992b) showed that six mallards exposed to WP dissolved in oil at a dose of 12 mg/kg-bw accumulated between 0.39 and 3.52 µg/g of WP in the fat.

Mallards also were dosed with WP in a pelletized form (Table 3-3). Birds dosed with 2.4 mg of pelletized WP/kilogram (kg), showed a mean liver WP concentration ranging from 0.003 µg/g-ww in survivors to 0.005 µg/g-ww in dead birds. At a dose of 3.4 mg of pelletized WP/kg, mean liver WP concentrations ranged from 0.003 µg/g-ww in survivors to 0.940 µg/g-ww in dead birds. When a 6.5-mg dose of pelletized WP/kg was administered, below-detection levels of WP were found in the liver of survivors, and a mean concentration of 0.001 µg/g-ww was found in dead birds (Sparling *et al.*, in Racine *et al.*, 1995). Birds administered a single pelletized WP dose of 4 mg/kg-bw, suspended in distilled water, showed a mean WP concentration in the liver of 0.001 µg/g-ww. After a single pelletized WP dose of 1 mg/kg-bw suspended in distilled water, mean liver WP concentrations ranged from nondetectable values recorded 240, 96, 24, and 6 hours after dosing to 0.003 µg/g-ww recorded 3 hours after dosing. A single pelletized WP dose of 2 mg/kg-bw suspended in distilled water left nondetectable levels of WP in the liver after 24 and 96 hours, with the highest concentration of 0.010 µg/g-ww 3 hours after dosing (Sparling *et al.*, in Racine *et al.*, 1995).

Skin concentrations of WP were found in mallards exposed to WP dissolved in oil (Table 3-3). Mallards that survived after exposure to a WP dose of less than 6.1 mg/kg-bw showed a below-detection skin WP concentration; one bird died having a skin WP concentration of 0.132 µg/g-ww. After a WP exposure of 6.1 mg/kg-bw, the surviving mallards showed below-detection skin concentrations; the mean WP concentration for the dead birds was 0.408 µg/g-ww. A WP dose of 7.1 mg/kg-bw gave a mean WP concentration of 0.004 µg/g-ww in the skin of surviving birds and 0.458 µg/g-ww in dead birds. After a WP dose of 8.0 mg/kg-bw, one bird survived with a WP skin concentration level below detection levels; the dead birds had a mean skin WP concentration of 0.463 µg/g-ww. A WP dose of 9.1 mg/kg-bw left the surviving birds with WP skin concentrations below the detection limits; the dead birds had a mean WP skin concentration of 0.199 µg/g-ww (Sparling *et al.*, in Racine *et al.*, 1994). Sparling *et al.* (in Racine *et al.*, 1994) stated that the highest concentrations in the skin of mallards dosed with WP dissolved in oil ranged between 0.6 and 0.7 µg/g-ww. Racine *et al.* (1992b) showed that five mallards exposed to a WP-in-oil dose of 12 mg/kg-bw accumulated between 0.59 µg/g and 2.23 µg/g of WP in the skin.

Fat concentrations of WP were recorded in mallards after various doses of WP in different forms (Table 3-6). Sparling *et al.* (in Racine *et al.*, 1994) dosed mallards with WP in oil At a WP dose of less than 6.1 mg/kg-bw, mean WP concentrations in fat ranged from 0.001 µg/g-ww in survivors to 0.275 µg/g-ww in one dead bird. At a WP dose of 6.1 mg/kg-bw, the WP fat concentrations were below detection levels in survivors; the mean concentration in dead birds was 0.562 µg/g-ww. A WP dose of 7.1 mg/kg-bw led to WP in fat at a mean of 0.022 µg/g-ww in survivors and 1.054 µg/g-ww in dead birds. Sparling *et al.* (in Racine *et al.*, 1994) stated that for a WP dose of 7.1 mg/kg-bw, the highest WP level measured in fat was 1.78 µg/g-ww. After a WP dose of 8.0 mg/kg-bw, one bird survived with WP concentrations in fat of 0.004 µg/g-ww, and dead birds had a mean WP concentration of 0.632 µg/g-ww. A WP dose of 9.1 mg/kg-bw gave survivors a mean WP concentration in fat of 0.007 µg/g-ww and dead birds a WP concentration of 0.442 µg/g-ww.

Tissue analysis included studies of fat concentrations of white phosphorus.

Racine *et al.* (1991, 1992b) showed that six mallards exposed to WP dissolved in oil at a dose of 12 mg/kg-bw accumulated between 0.39 and 3.52 µg/g WP in the fat.

Mallards also were dosed with the pelletized WP. After a pelletized WP dose of 2.4 mg/kg, a range of below-detection WP levels for surviving birds and a mean WP level of 0.657 µg/g-ww for dead birds were found in fat. After a dose of pelletized WP of 3.4 mg/kg, mean values of 0.039 µg/g-ww for survivors and 0.187 µg/g-ww for dead birds were found. A pelletized WP dose of 6.5 mg/kg gave mean values of 0.312 µg/g-ww for dead birds and 0.313 µg/g-ww for survivors (Sparling *et al.*, in Racine *et al.*, 1995). Mallards exposed to a single pelletized WP dose of 4 mg/kg suspended in distilled water showed a mean WP fat concentration of 0.178 µg/g-ww. Those with a pelletized WP dose of 1 mg/kg suspended in distilled water had a range between a mean of 0.001 µg/g-ww, 96 and 240 hours after the dose, and 0.074 µg/g-ww, 6 hours after dose. Mallards given a pelletized WP dose of 2 mg/kg suspended in distilled water showed mean WP fat concentrations of 0.113 µg/g-ww 12 hours after the dose and 0.001 µg/g-ww 96 hours after the dose (Sparling *et al.*, in Racine *et al.*, 1995).

The concentration of WP in pintail gizzard contents ranged from a minimum of 0.24 µg/g-ww to a maximum of 96.9 µg/g-ww (Sparling *et al.*, in Racine *et al.*, 1994). The median WP concentration in pintail gizzard contents, with only the inclusion of concentrations reported in wet weights, was 24.4 µg/g-ww. The mass of WP in the gizzard contents, when stated, ranged from nondetectable levels to 111 µg (Roebuck, 1995; Racine *et al.*, 1991). In the liver of pintails, the concentration of WP ranged from below detection limits to 0.17 µg/g-ww (Sparling *et al.*, in Racine *et al.*, 1994). The maximum specified WP concentration in the skin of pintails was 2.64 µg/g-ww

TABLE 3-6
Summary of White Phosphorus Tissue Concentrations in Birds—Laboratory Studies[a, b]

		White Phosphorus								
		Dissolved in Oil			Particulate Form			Unspecified/Other		
Species	Tissue	Dose (mg/kg - bw)	Concentration Range (µg/g)	Mass of WP (µg)	Dose (mg/kg)	Concentration Range (µg/g)	Mass of WP (µg)	Dose (mg/kg - bw)	Concentration Range (µ/g)	Mass of WP (µg)
Mallard[c, d, e]	Liver	<6.1	0 - 0 ww		2.4	0.003 - 0.005 ww				
		6.1	0 - 0.014 ww		3.4	0.003 - 0.940 ww				
		7.1	0 - 0.006 ww		6.5	0 - 0.001 ww				
		8.0	0 - 0.001 ww		4	0.001 ww				
		9.1	0 - 0.002 ww		1	0.0 - 0.003 ww				
		12	0.01 - 0.68		2	0.0 - 0.010 ww				
Mallard[c, d, e]	Fat	7.1	0.90 - 1.78 ww		2.4	0 - 0.657 ww				
		<6.1	0.001 - 0.275 ww		3.4	0.039 - 0.187 ww				
		6.1	0 - 0.562 ww		6.5	0.312 - 0.313 ww				
		7.1	0.022 - 1.054 ww		4	0.178 ww				
		8.0	0.004 - 0.632 ww		1	0.001 - 0.074 ww				
		9.1	0.007 - 0.442 ww		2	0.001 - 0.113 ww				
		12	0.39 - 3.52							
Mallard [c, d]	Skin	<6.1	0 - 0.132 ww							
		6.1	0 - 0.408 ww							
		7.1	0.004 - 0.458 ww							
		8.0	0 - 0.463 ww							
		9.1	0 - 0.199 ww							
			0.6 - 0.7 ww							
		12	0.59 - 2.23							
Mallard[f]	Breast muscle							12	0.013 - 0.052	
Mallard[f]	Brain							12	0.000 - 0.007	
Mallard[g]	Kidney				4	0.007 ww				
					1	0.0 - 0.001 ww				
					2	0.0 - 0.011 ww				

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TABLE 3-6
Summary of White Phosphorus Tissue Concentrations in Birds—Laboratory Studies[a, b]

		White Phosphorus								
		Dissolved in Oil			Particulate Form			Unspecified/Other		
Species	Tissue	Dose (mg/kg - bw)	Concentration Range (µg/g)	Mass of WP (µg)	Dose (mg/kg)	Concentration Range (µg/g)	Mass of WP (µg)	Dose (mg/kg - bw)	Concentration Range (µ/g)	Mass of WP (µg)
Mallard[g]	Unabsorbed WP in digestive tract				12 mg WP/kg - bw		<3,500			
Mallard[g]	Residual WP in digestive tract	12		544	12		1,887			
					12		962			
Mallard[g]	Bile of gall bladder							12	ND - 0.242	
Kestrel[g]	Fat							Fed WP contaminated poultry with upper digestive system removed, avg. WP residue in chicks, 0.134 mg/g tissue ww	0.009 ww	
								Fed intact WP contaminated poultry chicks with 1.1 µg WP pellet implanted in crop	0 079 ww	
Kestrel[h]	Whole gizzard							7 - day avg. exposure - 70 µg	0.08	
Kestrel[h]	Thigh muscle							7 - day avg. daily exposure - 70 µg	0.03	
Chicken[g]	Eggs	Gavaged with 1 mg WP/k·	0.025 - 0.04 µg/ egg							

[a]This table summarizes data presented in Attachment 1.
[b]Not including controls.
[c]Sparling et al., In Racine et al., 1994.
[d]Racine et al., 1992b.
[e]Sparling et al., In Racine et al., 1995.
[f]Racine et al., 1991 and 1992a.
[g]Roebuck and Nam, in Racine et al., 1995.
[h]Nam et al., 1994.
Notes:
0 = WP was either not detected or was below detection limits.
Reported concentrations of WP in tissue may be average values.

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(Sparling *et al.*, in Racine *et al.*, 1994). These values came from field-collected birds that had been exposed to in situ WP.

The concentration of WP in gizzard contents of green-winged teal ranged from levels below the detection limits to 3,150 µg/g-ww (Sparling *et al.*, in Racine *et al.*, 1994). The median for the WP concentration in the gizzard contents, including only values reported as wet weights, was 2.15 µg/g-ww. The mass of WP in the gizzard contents, when stated, ranged from nondetectable levels to 8.820 µg (Roebuck *et al.*, 1994; Roebuck, 1995). This range may include teal other than the green-winged teal. In the liver, concentrations ranged from below detection limits to 2.70 µg/g-ww (Sparling *et al.*, in Racine *et al.*, 1994). The median for WP concentrations in the livers of green-winged teals, including only values reported in wet weights, was 0.17 µg/g-ww. Kidney tissue gave a WP range from below detection levels to 0.019 µg/g (Racine *et al.*, 1991). Skin tissue had a WP concentration ranging from 0.012 to 6.34 µg/g-ww (Roebuck *et al.*, 1994). This range may include teal other than the green-winged teal. For skin tissue, the median WP concentration with respect to only values reported as wet weight was 1.25 µg/g-ww. The fat tissue of green-winged teals had a WP concentration ranging from 0.045 µg/g (Racine *et al.*, 1991) to 19.06 µg/g-ww (Sparling *et al.*, in Racine *et al.*, 1994). The median value for fat WP concentrations, taken only from values reported as wet weights, was 1.51 µg/g-ww. Analyzed breast muscle of teals had WP concentrations ranging from 0.001 to 0.560 µg/g-ww (Roebuck *et al.*, 1994). The green-winged teals analyzed were collected from the field, where they had been exposed to in situ WP.

Tundra swans exposed to white phosphorus in Eagle River Flats had measurable concentrations in their gizzard and fat.

A northern shoveler from ERF was found to have 0.751 µg of WP in its gizzard contents, an abdominal fat WP concentration of 0.047 µg/g-ww, and a skin WP concentration of 0.067 µg/g-ww (Roebuck *et al.*, 1994). Another shoveler was found with a muscle WP concentration of 0.06 µg/g-ww.

Tundra swans were collected from ERF, where they had been exposed to in situ WP. Racine *et al.* (1991) reported WP concentrations in gizzard contents of swans that ranged from 0.022 µg/g to 206 µg/g. The mean WP concentration in the gizzard contents was 0.058 µg/g. WP concentrations in fat were shown to range from below detection levels (Racine *et al.*, 1992a) to 2.9 µg/g (Racine *et al.*, 1991). A wild swan exposed to in situ WP was found to have skin concentrations ranging from 0.01 to 0.14 µg/g (Racine *et al.*, 1992b).

Red-necked phalaropes collected from ERF, where they had been exposed to in situ WP, were found to have WP masses in the gizzard contents ranging from 0.51 µg/g-ww to 15,500 µg-ww, with a reported median value of 1.17 µg-ww (Roebuck *et al.*, 1994). Skin concentrations were found to range between 0.451 µg/g-ww and 3.190 µg/g-ww, with a reported median value of 0.593 µg/g-ww. The yolk sacs in

Kestrels fed white-phosphorus-contaminated poultry chicks had detectable white phosphorus in their fat.

three red-necked phalaropes contained a WP concentration ranging from 0.031 µg/g-ww to 0.106 µg/g-ww, with a reported median value of 0.080 µg/g-ww.

A pectoral sandpiper found dead in ERF was shown to have a WP concentration of 12.35 µg/g-ww in its gizzard (Roebuck *et al.*, 1994). This same sandpiper had a skin WP concentration of 0.330 µg/g-ww and a fat WP concentration of 0.555 µg/g-ww.

Kestrels were examined during a toxicological study in which they were fed WP-contaminated poultry chicks. The WP concentrations found in the kestrel fat ranged from 0.009 µg/g-ww for those fed poultry chicks with the upper digestive system removed, to 0.079 µg/g-ww for kestrels fed intact contaminated poultry chicks with a 1.1 mg WP pellet implanted in the crop (Sparling *et al.*, in Racine *et al.*, 1995). The whole gizzard of a kestrel exposed to WP-containing food for 7 days was analyzed and shown to have a WP concentration of 0.08 µg/g (Nam *et al.*, 1994).

A dead eagle found in Eagle River Flats had detectable white phosphorus in its fat.

A golden eagle found dead in ERF had fat containing WP concentrations of 0.02 µg/g (Sparling *et al.*, 1994). A bald eagle collected from ERF had fat containing WP concentrations of 0.060 µg/g-ww and skin concentrations of 0.010 µg/g-ww (Roebuck *et al.*, 1994).

A WP concentration in a herring gull egg was 0.003 µg/g-ww (Roebuck *et al.*, 1994).

Virtually all fish samples taken from Eagle River Flats were nondetectable for white phosphorus.

Mammals. The results for the WP analyses of mammalian tissues are shown in Table 3-3. In only one study were nondetectable levels of WP observed; these were found in the leg muscle of a coyote collected from behind Canoe Point tower in the woods close to ERF (Roebuck, 1995).

Fish. A summary of the WP tissue concentrations in fish collected in ERF is presented in Table 3-4. The fish samples were collected as part of three studies (U.S. Army Environmental Hygiene Agency [USAEHA], 1994, 1995; Sparling, in Racine *et al.*, 1994). WP was detected in 3 of 54 samples of stickleback (*Apeltes quadracus*) as follows (USAEHA, 1995): 67.8 µg/kg ww in one sample collected from Site A4; and 24.1 and 82.3 µg/kg ww in samples collected from Racine Island.

Virtually all samples of aquatic invertebrates from Eagle River Flats had nondetectable white phosphorus.

Invertebrates. A summary of the WP tissue concentrations in aquatic invertebrates collected in ERF is presented in Table 3-4. The invertebrate samples were collected as part of two studies (USAEHA, 1995; Sparling, in Racine *et al.*, 1994). Of 39 samples submitted for WP analysis, only a single composite sample of dragonflies and damselflies collected from Racine Island tested positive for WP. The samples had a WP concentration of 67.6 µg/kg ww.

Plants grown in areas of high white phosphorus concentration had detectable white phosphorus in their tissues.

Plants. The summary of WP tissue concentrations in plants is presented in Table 3-5. WP was detected in three of the samples analyzed. A sample of *Zannichellia palustris* taken from Miller's Hole in Area C showed a WP tissue concentration of 160 µg/kg ww. The roots of a sedge (*Carex lyngbyei*) sample, taken from Site 110, Area C, had a WP concentration of 2,270 µg/kg ww. A bulrush (*Scirpus paludosus*) rhizome collected from Site 615, Area C, had a WP concentration of 110 µg/kg ww.

Other plant samples analyzed at ERF showed nondetectable levels. These included *Zannichellia palustris* samples collected from Site 52 (222), Area C, and Site 280, 50 meters (m) northeast of C tower, and samples of the shoots and leaves and seeds taken from the sedge (*C. lyngbyei*) collected at Site 110, Area C. The root bulb, root and whole plant of bulrush (*S. paludosus*) collected at Site 615, Area C, showed nondetectable levels, as did the roots and peeled rhizome of bulrush (*S. paludosus*) collected at Site 280, 50 m northeast of C tower, and the seed and seedlings of bulrush (*S. paludosus*) collected at Site 285, 175 m northeast of C tower. Samples of the whole plant, rhizome, roots, and leaves and shoots of *Hippuris tetraphylla* collected from Site 615, Area C, all showed nondetectable values, as did samples of *Potamogeton pectinatus* from Site 615, Area C. Samples of the base and leaves of Arrowgrass (*Triglochin maritima*) from Site 883, Area C, also had nondetectable levels (Walsh, in Racine *et al.*, 1994).

3.2 Ecological Effects Assessment

The ecological effects assessment evaluates cause and effect relationships between COPECs and ecological receptors. A relationship between cause and effect is established through evaluation of field studies, laboratory studies, and toxicity tests conducted at OUC, as well as evaluation of literature on the ecological effects of COPECs.

3.2.1 Field Studies

The following discussion addresses results of field studies conducted at ERF by various researchers.

Waterfowl Mortality. The high mortality of waterfowl in ERF was first recognized in 1980, and investigations of the problem began in 1982. Tweten (1989) summarized the early studies conducted by the Alaska Department of Fish and Game (ADFG), USFWS, and USAEHA, and other agencies through that time. Dabbling ducks (such as northern pintails, mallards, and green-winged teals) and swans (trumpeter and tundra) are the most affected species. Mortality of dabbling ducks has been concentrated in four areas of ERF (Area A, C, Racine Island, and Bread Truck), where suitable pond habitat is located (Figure 3-8) (Racine *et al.*, 1992a).

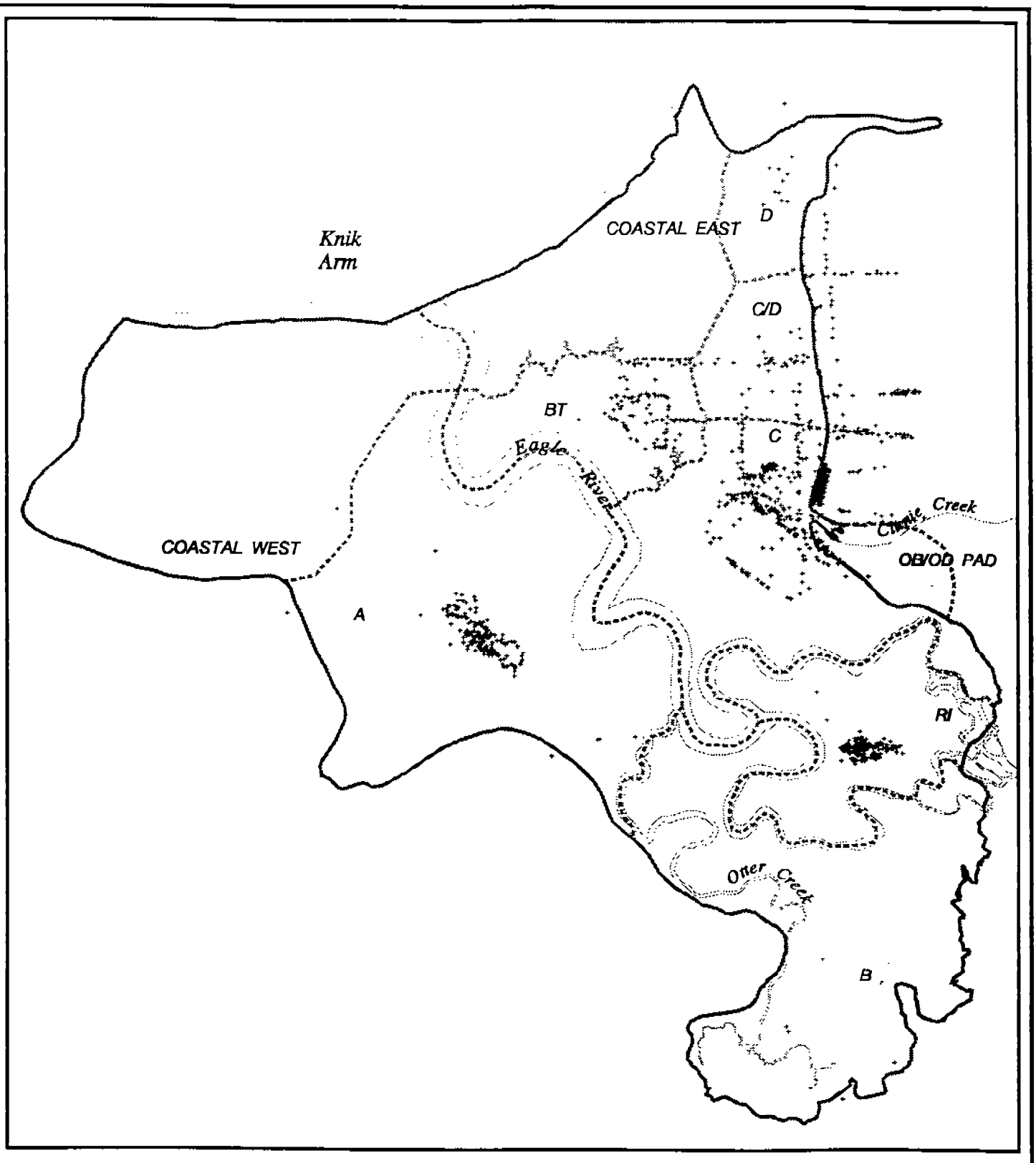


Figure 3-8

Carcasses

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february 13, 1997 AML: /proj2/arcfit/fig.aml PLOT FILE: /proj2/arcfit/fig3-81.eps

Waterfowl mortality has been concentrated in Area A, Area C, Bread Truck, and Racine Island.

Attempts to count and tabulate the species of bird carcasses in various parts of ERF were made between 1983 and 1995 (Reitsma and Steele, in Racine *et al.*, 1995). Many of the early mortality counts were made in conjunction with the collection of carcasses by USFWS for necropsy by the National Wildlife Health Research Center (NWHRC). Reitsma and Steele (in Racine *et al.*, 1993) included feather piles and carcasses as indicators of mortality. Table 3-7 summarizes the observations in 1988.

TABLE 3-7
Numbers of Carcasses and Feather Piles Either Observed or Collected Between April 20 and October 7, 1988

Species	Fresh Carcasses	Feather Piles
Northern pintail	117	118
Mallard	113	46
Green-winged teal	97	62
Northern shoveler	13	28
American wigeon	1	5
Gadwall	1	0
Least sandpiper	1	0
Semipalmated sandpiper	1	0
Dowitcher sp.	1	0
Yellowlegs	1	0
Swans	10	2
Bald eagle	1	0
Mew gull	1	0
Raven	0	1
Canada goose	0	2
Unknown ducks	0	254
Unknown shorebird	0	14
Unknown gull	0	1
TOTAL	**358**	**573**

Source: Tweten, 1989.

These studies assessed the rate of waterfowl mortality to detect year-to-year changes as WP exposure decreased because of remediation efforts. Feather piles and carcasses were counted on sample areas of ERF and in the surrounding woods to more accurately estimate total mortality and detect potential new areas of high mortality. Note that birds were being hazed during these periods, to reduce their presence in contaminated areas and their mortality, but this action affected the results. Observation of waterfowl and remains of dead waterfowl from 1991 to 1993 indicated that spring staging differs from autumn staging (Reitsma and Steele, in Racine *et al.*, 1993); eagle predation and scavenging of carcasses are much more prevalent in spring than in fall. The evidence of dead waterfowl is almost entirely in the form of feather piles in spring and carcasses in fall. Consequently, different measures have been developed for quantifying mortality in spring and fall. To enhance these measures, mortality was monitored over the

entire spring and fall staging periods and many more transects were established to include more area in ERF and the surrounding woods.

Permanent transects for counting bird carcasses and feather piles were established in 1992 to provide a consistent basis for detecting changes in mortality over time.

To detect changes in mortality between years, duck carcasses were counted along permanent transects that were established in 1992 (Figure 3-9). These transects were not designed to measure the total number of ducks dying, but to obtain a large enough sample of carcasses to compare mortality between years. Three types of transects were used: (1) 10-m-wide swaths adjacent to areas of known high waterfowl use, (2) areas where waterfowl use was not known (not conducted in 1992) and (3) edges of ponds heavily used by waterfowl (Reitsma and Steele, in Racine *et al.*, 1993). Transects were monitored from April to May and from mid-August to late October. In spring, transect counts of carcasses were supplemented with counts of feather piles on a transect within ERF, in a 1-hectare (ha) quadrant in the forest immediately adjacent to Area C, and along transects extending into the forest from the edge of ERF (Figure 3-10, with woodland transects). During spring migration, almost all dead or near-dead ducks are eaten by predators or scavengers, primarily bald eagles. Some are consumed where they are captured, and some are carried to other locations (Reitsma and Steele, in Racine *et al.*, 1993).

Reitsma and Steele (in Racine *et al.*, 1993) also used the predation rate as an index to mortality. During observation periods, all activity of predators within a specified area was observed. An average rate of predation was then calculated and compared to the predation rate in the study year.

Total mortality in spring was calculated from the number of feather piles on woodland transects and the proportion of carcasses that were fully or partially removed from ERF during predation observations (Table 3-8). There was an estimated bird loss of 386 (with a 95 percent confidence interval of 161 to 611) in the spring of 1993. When the calculated number of carcasses left in ERF was included, the total estimate of mortality was 570 (with a 95 percent confidence interval of 238 to 611).

The level of duck use in contaminated areas was much lower in 1995 than in previous years. Very few carcasses or feather piles were found in spring 1995. As in 1994, the rate of predation on sick or dying ducks was much lower than in 1992 or 1993 (Reitsma and Steele, in Racine *et al.*, 1995) (Table 3-9). The mortality ratio for the 1996 field season was not determined because increased health and safety requirements by the Army precluded observations along permanent mortality transects within ERF (Steele *et al.*, 1997).

For 1993, total spring bird mortality was estimated at 386, with a 95 percent confidence interval of 161 to 611. Fall mortality was estimated at 144 birds.

The estimate of fall mortality for the fall migration period was based on sample transects extrapolated to the entire area (Table 3-10). In 1993, fall mortality did not account for the high concentration of carcasses found in small ponds on Racine Island, an area surrounded

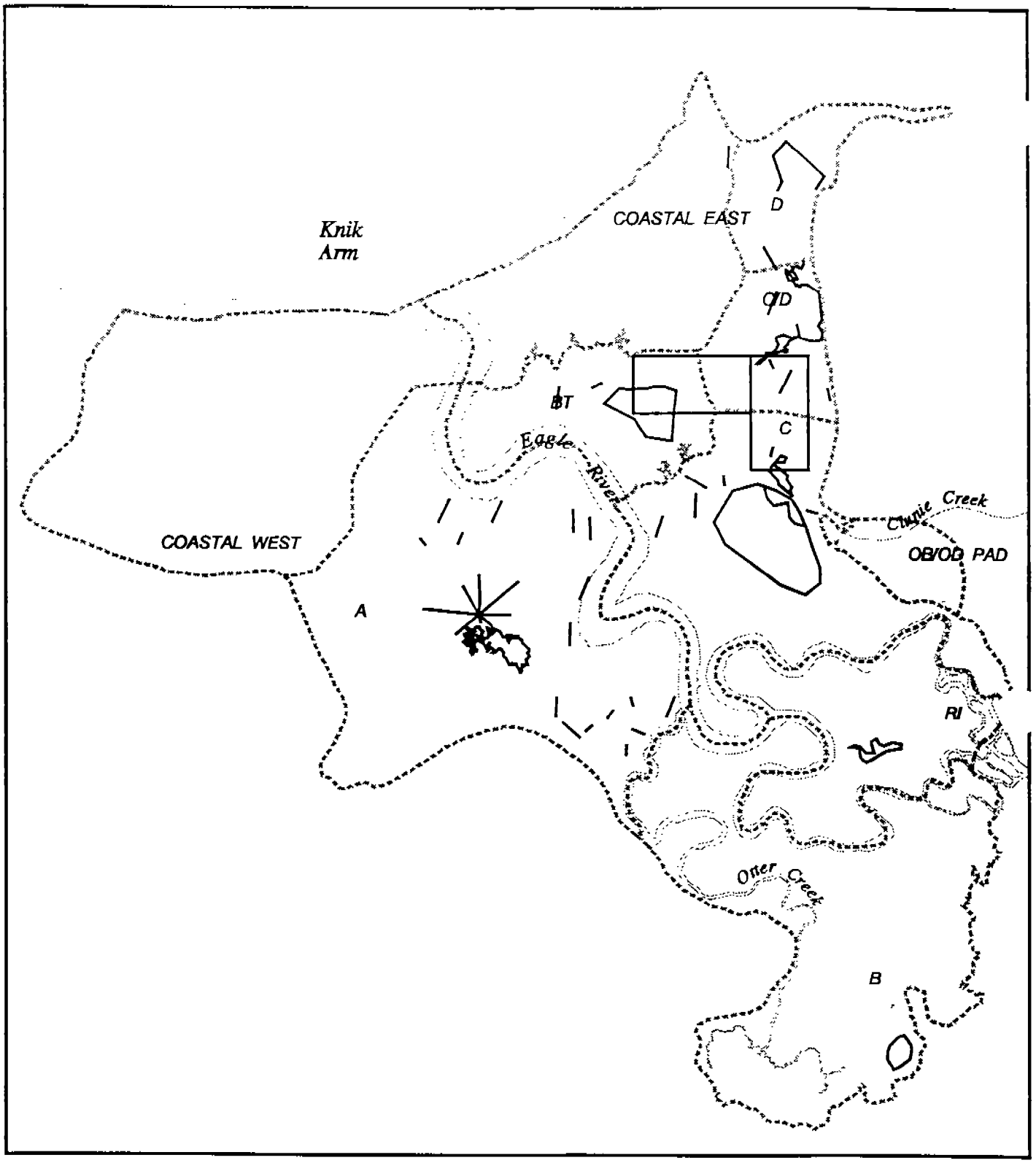


Figure 3-9

Mortality Transects in Eagle River Flats

N

Mortality Transect

Scale 1:24000
1 cm = 240 m

0 meters 720

Mapping and database source: Racine et al, 1996.

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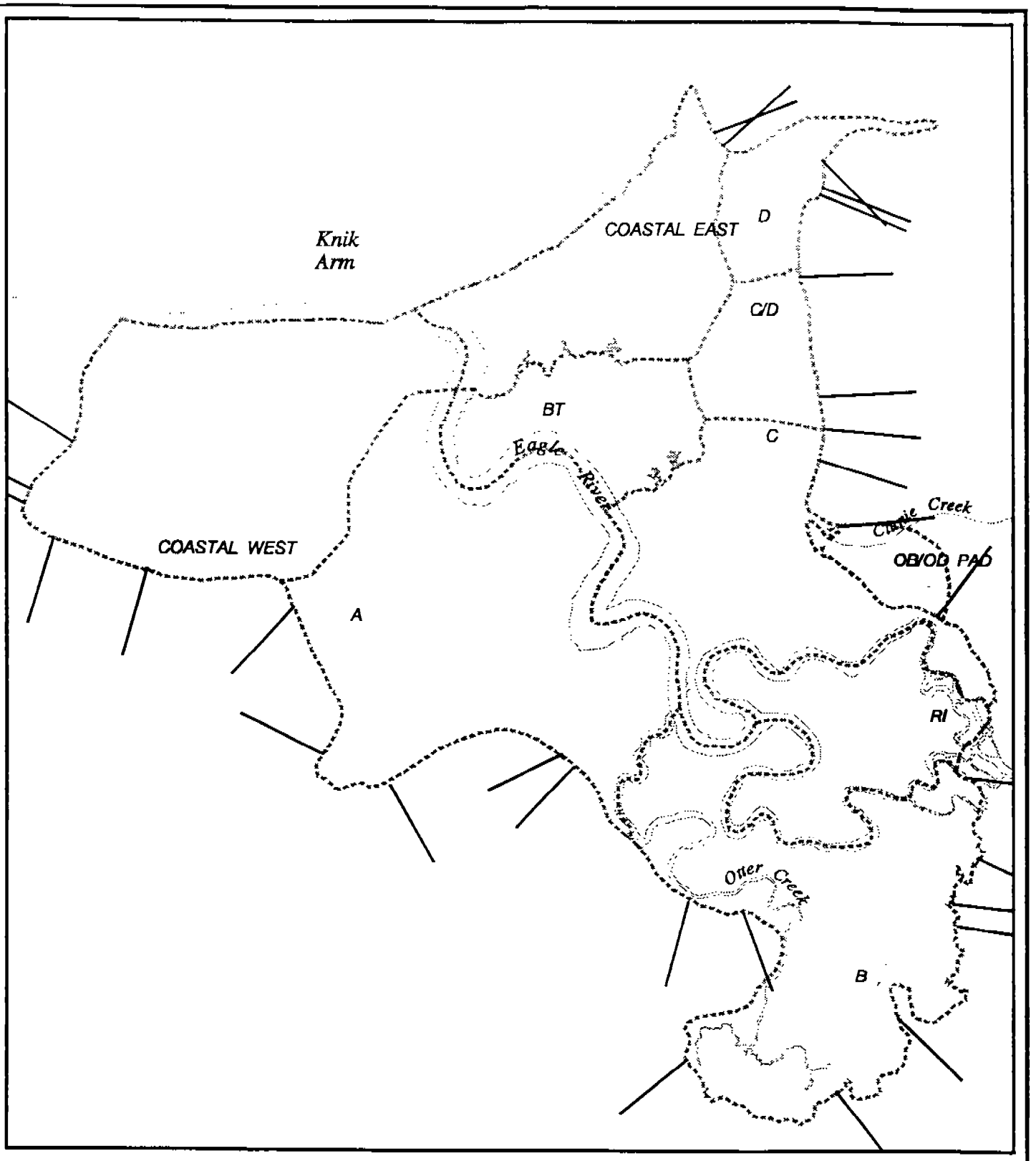


Figure 3-10

Mortality Transects in Woodlands

N

Mortality Transect

Scale 1:24000
1 cm = 240 m

0 meters 720

Mapping and database source: Racine et al, 1996.

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TABLE 3-8
Calculation of Total Mortality in ERF in Spring 1993

Region (Area)	Carcasses per 15 m of shoreline	Length of shoreline (m)	Carcass estimate	95% CI[a]
I (D)	0.2	661	9	
II (C)	3.8 (1.11 - 6.49)	1254	318	(93 - 543)
III (Eagle River)	0.2	1387	18	
IV (Cole Point)	0	1634	0	
V (A)	0.2	1569	21	
VI (N.W.)	0.2	1535	20	
TOTAL			**386**	**(161 - 611)**

[a]The 95 percent confidence intervals (CIs) are based on the only region with more than one carcass.

Note:
There were five 15-m-wide transects extending 400 m into the woodland from ERF in each region.

Source: Reitsma and Steele, in Racine *et al.*, 1994.

by channels of the Eagle River. In 1995, more carcasses were found at ERF in fall than have been found since 1992, a year of very high mortality (Reitsma and Steele, in Racine *et al.*, 1995).

Mortality generally decreased from 1992 through 1995.

Spring mortality was similar in 1992 and 1993, but dropped significantly in 1994 and appeared to remain low in 1995, although the low exposure rate precludes strong conclusions about the mortality in 1995. In fall of 1993, mortality dropped. It remained low in 1994 and dropped slightly in 1995, despite higher duck use of ERF (Reitsma and Steele, in Racine *et al.*, 1995). Three possible reasons for the lower mortality in fall are (1) implementation of hazing in the most contaminated areas; (2) lack of suitable foraging habitat; and (3) reduction of available WP.

Mortality also was studied in 1993, 1994, 1995, and 1996 by Cummings *et al.* (Cummings *et al.*, in Racine *et al.*, 1993, 1994, 1995, 1996; in Walsh *et al.* 1997) with radio telemetry. As part of their study of waterfowl distribution and movement in ERF, they recorded the mortality of transmitter-equipped ducks using ERF from August 8 to October 24, 1993; April 30 to May 21, 1994; August 8 to September 30 1994; August 1 to October 17, 1995; and August 3 to October 15, 1996. Hazing was occurring during much of these periods, except during the 1996 field season. Ducks that could not be detected as moving or that did not move more than 10 degrees in 2 or 3 days were visually located to determine their status. Dead ducks or their remains were recovered and saved for WP analysis. Mortality results for the 1993

TABLE 3-9
Ratios of Carcasses Counted on Transects to the Exposure Rate in the Corresponding Area

	Mortality Ratio			
Year	1992	1993	1994	1995
Fall				
Area C Transects	0.0312	0.0031	0.0047	0.0033
Area A Transects	0.0544	0.0044	0.0061	0.0052
Area BT Transects	0.0246	0.0059	0.0065	0.0016
Total Transects	**0.0443**	**0.0039**	**0.0058**	**0.0031**
Spring[a]				
Area C Transects	0.0159	0.0050	0.0002	0
Area A Transects	0.0117	0.0039	0	0
Area BT Transects	0.0205	0.0070	0	0
Total Transects	**0.0146**	**0.0045**	**0**	**0**
Woodland Quadrant	0.0173	0.0152	0.0048	0
Woodland Transects	0.0118	0.0074	0.0017	0

[a] Exposure rate refers to the number of ducks estimated from ground surveys.
[b] Spring counts of carcasses include feather piles as well as carcasses.
Source: Steele and Reitsma, in Racine *et al.*, 1996.

TABLE 3-10
Calculation of the Estimate of Total Mortality During the Fall Migration, 1993

Area	Area of site sampled (ha)	Carcasses found	Total area (ha)	Estimated carcasses
C/D pond border	0.25	4	4.6	74
BT pond border	0.30	1	4.8	16
C ponds border	0.75	1	11.29	15
A ponds border	0.50	0	6.03	0
Otter Creek pond border	0.25	1	2.63	11
East sedge/mud flat	0.70	0	60.35	0
East bulrush	1.00	2	14.24	28
West sedge/mud flat	1.00	0	48.13	0
West bulrush	0.80	0	15.77	0
Total	5.55	9	103.94	144

Source: Reitsma and Steele, in Racine *et al.*, 1994.

to 1995 studies are summarized in Tables 3-11, 3-12, and 3-13. The average mortality of the dabbling ducks across these three studies was 16 percent (19 of 120 birds were tracked and died in ERF).

TABLE 3-11
Duck Mortality in ERF from August 8 to October 24, 1993

	Mallard (N=12)	Northern pintail (N=11)	Green-winged teal (N=11)	American wigeon (N=2)	Northern shoveler (N=3)	Total (N=39)
Mortality (No.)	2	2	3	1	0	8
Average days (No.)	28	20	21	3	0	20.3
Range (No. days)	13 - 43	7 - 33	11 - 37	3	0	7 - 43

N = Number of birds equipped with transmitters.
Source: Cummings *et al.* in Racine *et al.*, 1994.

TABLE 3-12
Duck Mortality in ERF in Spring and Fall of 1994

	Mallard (N=27)	Northern pintail (N=1)	Green-winged teal (N=4)	American wigeon (N=1)	Northern shoveler (N=1)	Goldeneye (N=1)	Total (N=35)
Spring - April 30 to May 21, 1994							
Mortality (No.)	3	0	1	--	0	0	4
Average days (No.)	13.7 - 47.7	0	10	--	0	0	13
Range (No. days)	12 - 51	0	10	--	0	0	10 - 51
Fall - August 8 to September 30, 1994							
Mortality (No.)	2	2	3	1	0	--	8
Average days (No.)	28	20	21	3	0	--	20.3
Range (No. days)	13 - 43	7 - 33	11 - 37	3	0	--	3 - 43

Notes: N = Number of birds equipped with transmitters.
-- = No data available.
Source: Cummings *et al.*, in Racine *et al.*, 1996.

TABLE 3-13
Duck Mortality in ERF from August 1 to October 17, 1995

	Mallard (N=17)	Northern pintail (N=16)	Green-winged teal (N=21)
Mortality (No.)	4	0	1
Average days (No.)	40	46	27
Range (No. days)	1 - 78	6 - 72	1 - 51

Note: N = Number of birds equipped with transmitters.
Source: Cummings *et al.*, in Racine *et al.*, 1996.

During the 1996 fall field season, mallards were selected as the indicator species to monitor WP effects on waterfowl (Cummings *et al.*, in Walsh *et al.*, 1997). Starting on August 3, 107 mallards were captured and equipped with either standard transmitters (53 ducks) or simple mortality transmitters (54 ducks) and were monitored until October 15. The mortality results of this study are summarized in Table 3-14, which indicates that 37 birds (35 percent) died of WP poisoning. The increase in the telemetered bird mortality was attributed to the lack of hazing during the 1996 field season that resulted in higher use of WP-contaminated ERF areas.

Radio telemetry studies in 1993 through 1995 suggest a duck mortality of about 16 percent. The duck mortality was 35 percent in the 1996 telemetry study.

Bird Use. Ducks were captured and monitored in ERF to determine daily movements, turnover rates, and site-specific exposure during 1993, 1994, 1995, and 1996 (Cummings *et al.*, in Racine *et al.*, 1993, 1994, 1995, 1996; in Walsh *et al.*, 1997). Captured ducks were banded, and their weights, sexes, and ages were recorded before release. In addition, mallards, northern pintails, and green-winged teals were fitted with radio transmitters. These birds were then tracked from stations or by helicopter to determine location and movement. Summaries of the results of the study are provided in Tables 3-15 through 3-18.

USFWS conducted aerial bird population surveys of ERF during spring, summer, and fall (April through October) from 1989 through 1996 as part of ongoing water bird studies. The objective of these surveys was to monitor bird abundance and distribution in ERF during spring, summer, and, fall (Eldridge, 1990, 1991, 1992; Eldridge, in Racine *et al.*, 1994, 1995; Eldridge and Robertson, in Racine *et al.*, 1996). Waterfowl were counted or estimated and recorded by species or species group. Results of these 8 years of study are presented in Section 3.1.1.

As part of the waterfowl and mortality study conducted by Reitsma and Steele (in Racine *et al.*, 1993), surveys were conducted in two haze-free periods during the study year, in spring and fall. The waterfowl species distribution and behavior surveys (WSDABSs) measured waterfowl use of specific ERF areas when their choice of habitat was not affected by human activity. WSDABS included target waterfowl species such as mallard, northern pintail, and green-winged teal. For each species, the observation location was mapped and activities (feeding, loafing, preening, or swimming) were noted. Activities of other waterfowl (wigeons and shovelers) in the area also were recorded, but their locations were not mapped (Reitsma and Steele, in Racine, *et al.*, 1993).

As part of their telemetry study of eagles and waterfowl, Cummings *et al.* (in Racine *et al.*, 1994, 1995, 1996; in Walsh *et al.*, 1997) calculated the daily turnover rate of birds fitted with transmitters in ERF by dividing the number of radio-equipped ducks that departed from ERF each day

TABLE 3-14
Mallard Mortality in ERF from August 3 to October 15, 1996

Transmitter Type	ERF Area									
	A	B	C	D	BT	C/D	RI	CE/CW	Total	Percent
Standard (n = 53)	3	2	3	0	1	2	4	0	15	28
Mortality (N =54)	5	0	10	0	1	4	2	0	22	41
Total (N = 107)	8	2	13	0	2	6	6	0	37	35

Source: Cummings *et al.*, in Walsh *et al.*, 1997.

TABLE 3-15
Status of Ducks in ERF from August 8 to October 24, 1993

Species	Number of Ducks							
	Radioed	Only tagged	Mortality		Remaining in ERF through 30 September	No contact		Observed off ERF
			In ERF	Off ERF		In ERF 24 October	before 30 September	
Mallard	12		2	1	9	2	1	3
Northern pintail	11		2	1	3	0[a]	7	2
Green-winged teal	11		3	0	1	0	4	1
American wigeon	2	18	1	0	0	0	1	1
Northern shoveler	3	5	0	1	1	0	2	1
Total	**39**	**23**	**8**	**3**	**14**	**2**	**15**	**8**

[a] One northern pintail found dead.
Source: Cummings *et al.*, in Racine *et al.*, 1994.

TABLE 3-16
Status of Waterfowl and Eagles in ERF from May 4 to May 21, 1994

Species	Number of birds						
	Radioed	Mortality		Remaining in ERF through May 21	No Contact before May 21	In ERF October 13	Observed off ERF
		In ERF	Off ERF				
Mallard	27	5	2	14	0	2	23
Green-winged teal	4	1	0	1	0	0	3
Shoveler	1	0	1	1	0	0	1
Pintail	1	0	0	0	0	0	1
Goldeneye	1	0	0	1	0	0	1
Eagle	10	0	0	2	1	0	9
Total	**44**	**6**	**3**	**19**	**1**	**2**	**38**

Source: Cummings *et al.*, in Racine *et al.*, 1995.

TABLE 3-17
Status of Waterfowl and Eagles in ERF from August 1 to October 17, 1995

	Number of Ducks					
	Mortality			Remaining on ERF	Remaining on ERF	
Species	Radioed	In ERF	Off ERF	through September 5	through October 17	Observed off ERF
Mallard	17	4	0	9	7	11
Pintail	16	0	1	10	6	11
Green-winged teal	21	1	1	12	0	14
Eagles	21	0	0	--	9	12
Total	75	5	2	31	22	48

Source: Cummings *et al.*, in Racine *et al.*, 1996.

TABLE 3-18
Ducks Leaving ERF from August 8 to September 30, 1993

	Mallard	Northern pintail	Green-winged teal	American wigeon	Northern shoveler	Total
Ducks (No.)	1	7	4	1	2	15
Average days in ERF (No.)	15	12.3	16.5	1	9.5	12.5
Range (No. days)	15	1 -32	1 - 32	1	1 - 18	1 - 32

Source: Cummings *et al.*, in Racine *et al.*, 1994.

Bird telemetry studies during nonhazing periods showed that ducks preferred sedge marshes (29 percent of the observations), permanent ponds (11 percent), and Ramenski's sedge meadow (10 percent).

by the total (by species) with radios. The daily turnover rate was used to determine the relative WP risk to birds using ERF.

Turnover rates for waterfowl were lower in 1995 and 1996 than in 1993 or 1994 (Cummings *et al.*, in Racine *et al.*, 1996; in Walsh *et al.*, 1997).

Bird telemetry studies conducted from 1993 to 1996 were used to describe duck habitat preference. The ERF GIS was used to overlay the observation locations with the ERF landcover to determine which habitat was being used at the time of each observation. Only observations made during nonhazing periods were used to simulate normal bird habitat use patterns. The studies indicated that sedge marshes (28.7 percent) and permanent ponds (11.4 percent) were the two most commonly used habitats by ERF ducks. Various meadow types (Ramenski's sedge [10.0 percent], halophytic herb [7.5 percent], and interior sedge [9.0 percent]) had lower duck use percentages. Intermittent ponds were used by ERF ducks in approximately 7.4 percent of observations. Approximately 7.8 percent of ERF duck observations were not classified according to habitat type.

During the 1996 aerial surveys, Eldridge and Robertson (in Racine *et al.*, 1996) also estimated duck preference for different areas of ERF. The aerial survey divided ERF duck use by four different landform types: ponds, Knik Arm shoreline, Eagle River, and tideguts. Duck use percentage for each landform type was estimated by dividing the number of ducks observed on the landforms by the total number of ducks counted in ERF for the time period. The fall duck counts represented 86 percent of the ducks counted in ERF during the 1996 field season (19,561 out of 22,708 total ducks). For the fall period only, the pond use was estimated at 72 percent by the aerial survey. This estimated percentage for duck use was much higher than the corresponding fall 1996 estimate of duck use of ponds by telemetry, which was 16 percent (total for intermittent and permanent ponds) (Cummings *et al.*, in Walsh *et al.*, 1997). The difference in the habitat (landform) duck use is likely attributable to different limitations of the two survey methods (such as time of survey, relative accuracy of instruments or observers, or influence of survey method on bird behavior).

Telemetry studies also were used to study population dynamics of dowitchers and bald eagles. Dowitchers and bald eagles were studied during the 1994 field season to assess the average length of time spent in ERF, distribution, daily turnover rates, and mortality (Cummings *et al.*, in Racine *et al.*, 1995). Bald eagle studies were continued into the 1995 field season and were expanded to include a comparison of the reproductive success of ERF eagle nests with that of eagle nests in other UCI marshes (Cummings *et al.*, in Racine *et al.*, 1996).

Dowitchers were chosen as the species to represent shorebirds in ERF. In August 1994, 20 birds were captured and equipped with radios. Telemetry monitoring of these birds indicated that they spent an average of 6.8 days (range of up to 17 days) in ERF. During this time, dowitcher distribution was roughly evenly divided among Areas A, C, C/D, and D and Bread Truck. The instrumented birds were not observed in Area B or on Racine Island. The daily turnover rate of dowitchers was estimated to be 5 percent, with more than 55 percent of birds leaving within an 8-day period. The greatest turnover occurred between August 22 and August 25, when seven birds left ERF; this number represented an approximately 12 percent daily turnover rate. No mortality of instrumented dowitchers was observed during the 1994 field season (Cummings *et al.*, in Racine *et al.*, 1995).

Bald eagles were considered the representative species for predatory and scavenging birds.

Bald eagles were considered the representative species for predatory and scavenging birds. Between April 30 and May 19, 1994, 10 bald eagles were captured and fitted with radio transmitters. Of these 10 birds, 3 were fitted with satellite transmitters so that the birds could be tracked at greater distances from ERF. The telemetry studies indicated that eagles spent an average of 3 days (range of 1 to 9 days) in ERF. Most of the time was spent in the wooded areas surrounding

ERF, except for limited time spent in Areas A and B, and on Racine Island. At the end of the spring migration period (May 21), only 2 of the 10 eagles remained in ERF. By September, only 3 of 10 eagles could be found within a 90-km search radius of ERF. As of December 7, 1994, the eagles had dispersed to locations on Kodiak Island and near Cordova, Alaska (Cummings *et al.*, in Racine *et al.*, 1995).

Between April 24 and 31, 1995, 14 additional bald eagles were captured in ERF and fitted with radio transmitters. Of these 14 eagles, 8 received satellite transmitters. Two of these eight birds were breeding adults from two nest sites surrounding ERF. Telemetry and observational data on eagles in 1995 indicated that the length of stay in ERF averaged 1.2 days (range of 1 to 25 days) during the spring and 0.2 day (range of up to 50 days) during the fall. Again, eagles spent most of their time in the wooded areas surrounding ERF. Eagle observations in ERF were limited to Areas A, C, and C/D in the spring and Areas A and C/D in the fall (Cummings *et al.*, in Racine *et al.*, 1996).

Studies of the nesting success of eagles in ERF did not indicate a significant difference from birds nesting in Susitna and Chickaloon Flats. Eagle nests in ERF (three nests) produced an average of 1.3 eggs and fledged an average of 0.33 eaglet. Eagles in Susitna Flats (10 nests) produced an average of 1.6 eggs per nest and fledged an average of 0.6 eaglet. Eagles in Chickaloon Flats (seven nests) produced an average of 1.0 eggs and fledged an average of 0.28 eaglet. Telemetry studies indicated that no eagle mortality occurred during the 1994, 1995, or 1996 field seasons while eagles used ERF or the 268-km radio contact area (Cummings *et al.*, in Walsh *et al.*, 1997).

The lethal dose for 50 percent mortality for adult and juvenile male mallards was 6.4 mg/kg-bw.

3.2.2 Laboratory and Field Toxicity Tests

Laboratory and field toxicity tests were conducted on media collected from ERF, as well as on biota representative of those species using ERF. The results of these studies are summarized in the following subsections.

Birds. Laboratory and field toxicity tests have been conducted on birds (primarily mallards) to determine acute and chronic toxicities, as well as potential effects on secondary receptors. The results of these studies are presented below.

Acute Toxicity Tests. Various types of toxicity tests were conducted by Sparling *et al.* (in Racine *et al.*, 1994, 1995) and by Roebuck and Nam (in Racine *et al.*, 1995). These tests included the following:

- Acute WP toxicity in juvenile and adult male and female mallards
- Acute toxicity of WP dissolved in oil
- Acute toxicity of WP in a pelletized form

- Acute toxicity of different sizes of particulate WP as opposed to dissolved WP
- Identification of acute biomarkers of WP exposure
- Comparison of organ damage observed in laboratory toxicity tests versus under field conditions

The results of these studies are discussed below.

In 1993, acute toxicity tests on male and female mallards were conducted with WP dissolved in oil (Sparling *et al.*, in Racine *et al.*, 1994) and in 1994 (Sparling *et al.*, in Racine *et al.*, 1995). In the 1993 studies, adult male and female birds were treated with a single dose of WP dissolved in oil. Mortality in adult male birds was dose-dependent. The lowest dose resulting in mortality was 5.2 mg/kg-bw, and the lethal dose for 50 percent mortality (LD_{50}) was 6.4 mg/kg-bw. This value was confirmed for juvenile male mallards. The lowest dose resulting in death of female birds was 4.0 mg/kg-bw, but mortality at doses greater than 4.0 mg/kg-bw was inconsistent. Therefore, an LD_{50} for female mallards could not be determined. Observations made during the acute toxicity tests indicated three distinct phases of WP toxicity:

1. Signs included lethargy, mild loss of appetite, general malaise, and slight trembling in the legs. This phase could last from a few hours to a few days, at which time birds would either recover or advance to more intense signs of toxicity.
2. Signs included severe tremors in the legs or back and head bobbing in which the neck was ventrally flexed and then moved rhythmically across the breast. This phase generally lasted only for a few minutes.
3. Signs included severe and intense convulsions, dyspnea (shortness of breath), ataxia (clumsiness or inability to walk), secretion of a yellow fluid from the nares, watery excretion from the cloaca, and finally death. This phase typically lasted less than 30 minutes, but could last up to an hour.

Several histopathological changes were noted from exposure to white phosphorus.

In addition, the time from onset of signs to death tended to be dose-dependent (Sparling *et al.*, in Racine *et al.*, 1994). Birds treated with less than 6.0 mg/kg-bw exhibited a median time of 7 hours for onset of signs, 4.5 hours from beginning of signs to death, and 11 hours from dosing to death. Birds treated with higher doses had shorter times for each category.

Histopathological changes also were observed for each dose group (Sparling *et al.*, in Racine *et al.*, 1994). In general, damage was observed in the liver, spleen, heart, and duodenum in birds treated with WP at

5.2 mg/kg-bw or greater. Histopathologic effects included the following:

- Petechiae in the pancreas and coronary fat bands—first observed in birds dosed with WP at 6.1 mg/kg-bw. Coronary petechiae were found more frequently in birds that had died within 24 hours of dosing than in those that survived.
- Liver foci (small spots or blemishes on the surface of the liver)—first observed in birds dosed with WP at 5.2 mg/kg-bw.
- Liver ecchymoses (necrotic areas)—first observed in birds dosed with WP at 5.2 mg/kg-bw.
- Congested duodena (swollen red areas)—first observed in birds dosed with WP at 6.1 mg/kg-bw.

The lethal dose for 50 percent mortality in female mallards was 6.81 mg/kg body weight. Females were more sensitive than males at lower doses, and less sensitive at higher doses.

These acute toxicity tests were repeated for female mallards in the 1994 studies (Sparling *et al.*, in Racine *et al.*, 1995) because an LD_{50} for female mallards could not be determined from the results of the 1993 studies. Results indicate that adult female mallards treated with WP dissolved in oil exhibited an LD_{50} of 6.81 mg/kg-bw. Although males and females had similar LD_{50} values (from the two studies), females were more sensitive to lower doses and less sensitive to higher doses than males. The estimated LD_{20} and LD_{70} levels for females were >3 mg/kg-bw and >9 mg/kg-bw, respectively, whereas the LD_{20} and LD_{70} levels for males were 5.5 mg/kg-bw and 7.5 mg/kg-bw, respectively.

Similar acute toxicity tests with pelletized WP were also conducted (Sparling *et al.*, in Racine *et al.*, 1995) because waterfowl at ERF were more likely exposed to pelletized WP. Adult male mallards were dosed with 6.5 mg/kg-bw, and 12 of the 14 test birds died within 24 hours (86 percent). This number was greater than expected, and indicated that pelletized WP was more toxic than WP dissolved in oil. An LD_{50} for pelletized WP was not obtained from this study, but was estimated at 3 to 4 mg/kg-bw for male mallards.

The form of white phosphorus (dissolved or in pellets) had no significant effect on the toxicity in mallards. Studies generally indicated that the size of the dose was the primary determining factor in toxicity.

Tests with dissolved and particulate WP were conducted to determine whether the toxicity and fate of ingested WP were a function of particle size and available surface area (Roebuck and Nam, in Racine *et al.*, 1995). Farm-raised mallards ranging from 2 to 5 months old were dosed with approximately 12 mg/kg-bw of WP (ranging from 12.34 to 12.84 mg/kg-bw) in one of the following forms: dissolved in oil, small particles (0.5 to 1.2 millimeters [mm] in diameter), or large particles (1.0 to 2.4 mm in diameter). The ranges of WP particles tested were similar to those typically found in sediments at ERF. Those ducks dosed with small particles received approximately 10 times the number of particles as those dosed with the large particles, but at half the diameter. Therefore, ducks dosed with the small particles received two to four times the surface area as those dosed with the large

particles at the same total dose (12 mg/kg-bw). Results of the study were as follows for the different treatment groups:

- Time from dosing to onset of convulsions was 2 to 6 hours for all groups.
- Times from dosing to death (no statistical differences) were as follows: dissolved (250 minutes), small particles (300 minutes), and large particles (230 minutes).
- Residual amounts of unabsorbed WP in the digestive tract were as follows: dissolved WP (4 percent of dose), small particles (19 percent of dose), and large particles (8 percent of dose).
- Amounts of WP in gizzard (percent of residual amount in digestive tract) were as follows: dissolved (trace), small particles (78 percent), and large particles (64 percent).
- Distributions of WP in digestive tracts, including the gizzard, in the dissolved-dose group differed significantly from those in either particle-dose group.
- Distributions of WP particles in digestive tracts were similar for experimental mallards used in this study and for ducks found dead at ERF.

There was no indication that the form of WP (either dissolved or particulate) significantly affected toxicity in mallards, and the acute LD_{50} estimates made from other studies that used WP either dissolved in oil or in pelletized form would be equally predictive of toxicity for ducks in the field (Roebuck and Nam, in Racine *et al.*, 1995). The amount of time before obvious signs of toxicity (convulsions) or until death varied widely within each treatment group and therefore did not result in any significant differences between the treatment groups. This variability could have been due to differences in absorption rates or factors specific to individual ducks. This variability could not be accounted for, but overall, the study indicated that the amount of WP ingested was the primary determining factor of toxicity.

Blood chemistry changes were detected, but they were not solely indicative of white phosphorus exposure.

Studies also were conducted to determine bioindicators of WP exposure (Sparling *et al.*, in Racine *et al.*, 1995). Mallards were dosed with 5.3 mg/kg-bw/day of WP in corn oil for 3 or 6 days and then evaluated for blood chemistry and WP tissue residues (discussed in Section 3.1.3).

Blood chemistry results indicated both toxicity and a dose-response relationship. Blood chemical parameters significantly different from controls after 3 days of treatment included the following:

- Blood urea nitrogen
- Blood urea nitrogen/creatinine ratio
- Potassium

- Lactate dehydrogenase
- Aspartate aminotransferase/alanine aminotransferase ratio
- Glucose

In addition to those measured after 3 days, blood chemical parameters significantly different from controls after 6 days of treatment included the following:

- Hematocrit
- Hemoglobin
- Chloride
- Sodium
- Phosphorus

These parameters indicated changes in liver or kidney function or in general blood characteristics, and were not solely indicative of WP exposure (Sparling *et al.*, in Racine *et al.*, 1995). However, the combination of changes in some indicators (such as reduced hematocrit and hemoglobin) could be used as an indicator of WP exposure. In addition, although there were slight differences in some parameters between males and females, the blood chemical parameters measured were equally diagnostic for both males and females.

Toxicological effects in birds tested under laboratory conditions were also compared to those observed in the field (Sparling *et al.*, in Racine *et al.*, 1994). Ten farm-raised mallards with no previous exposure to WP were placed in pens in C pond for 6 hours, then collected and evaluated for histopathologic effects. Thirty percent of exposed birds died within 24 hours of exposure and many others had signs of sublethal exposure, including congested duodena, coronary petechiae, liver foci, friable livers, and pancreatic petechiae. These signs were similar to those observed in laboratory tests.

A lowest observed effect (LOEL) was estimated to be about 4 mg/kg of body weight per day for white phosphorus dissolved in oil. The LOEL based on sublethal effects would be less than 2 mg/kg of body weight per day.

Chronic Toxicity Tests. Subchronic and chronic toxicity tests were conducted by Sparling *et al.* (in Racine *et al.*, 1994, 1995). These tests included subchronic toxicity tests, chronic toxicity tests, and preliminary mallard reproductive studies. The results of these studies are presented in the paragraphs that follow.

Subchronic toxicity tests were conducted to develop a lowest observed effect level (LOEL) and to determine effects of subchronic exposure (Sparling *et al.*, in Racine *et al.*, 1994). Tests to develop a LOEL were conducted on birds that had been treated with WP at 2.6 and 3.7 mg/kg-bw/day. Results indicated that there was no significant damage to liver, kidneys, or heart tissue at any of the tested concentrations, but one bird treated at 2.6 mg/kg-bw/day and two birds treated at 3.7 mg/kg-bw/day showed liver foci. There were no deaths among birds treated at 2.6 or 3.7 mg/kg-bw/day. An acute LOEL based on mortality was estimated for WP dissolved in oil:

approximately 4 mg/kg-bw/day; a LOEL based on sublethal effects would be less than 2 mg/kg-bw/day.

Chronic LOEL based on mortality as the endpoint was between 1.5 and 2 mg/kg of body weight per day.

The effects of repeated subchronic exposures were tested in adult male and female mallards treated with WP doses of 3.7, 4.8, 5.3, and 5.7 mg/kg-bw/day for 4 days (Sparling *et al.*, in Racine *et al.*, 1994). Results of these tests indicated that mortality and histopathologic effects (liver and kidney damage) were consistent with acute exposures. The repeated subchronic exposure did not alter mortality, and there was no evidence that repeated exposures resulted in either increased or decreased mortality or histopathological changes compared to single doses at similar concentrations.

Chronic toxicity tests were conducted with pelletized WP given at doses of 2.4 and 3.4 mg/kg-bw/day for 10 days to adult male mallards (Sparling *et al.*, in Racine *et al.*, 1995). Birds treated with 2.4 mg/kg-bw/day exhibited liver and kidney damage. Liver damage included fatty degeneration, liver foci, hepatic cell necrosis, and haemosporidian deposits in the Kupffer cells. Kidney damage included hyaline droplet nephrosis and multifocal vacuolation of the distal convoluted tubules. In addition, three of the test birds died after the eighth treatment; one of these birds had a smoking gizzard. Birds treated with 3.4 mg/kg-bw/day also exhibited liver and kidney damage. Six of these test birds died; others treated at this level showed significant weight loss (19 percent) and decreased hematocrit levels. From this study, a LOEL could not be identified because death occurred at the lowest dose tested. However, it was estimated that a LOEL based on an endpoint of mortality would range between 1.5 and 2.0 mg/kg-bw/day. LOELs based on other effects, such as reproduction, probably would be much lower.

Hens exposed to sublethal levels of white phosphorus had reduced reproductive output and deformed embryos.

Preliminary reproductive studies were conducted with mallard hens dosed with 2.6 mg/kg-bw/day or 1.3 mg/kg-bw/day of pelletized WP in water for 5 days (Sparling *et al.*, in Racine *et al.*, 1995). Birds treated with the higher dose either died or ceased laying eggs after the second dose. Surviving ducks laid between zero and 3 eggs, as opposed to 5 to 13 in controls. Of the eggs laid, only four hatched, and most of these were the earliest eggs laid. Birds treated at the lower dose also had fewer eggs than controls. In this group, only nine eggs had developing embryos and only one hatched. The study indicated that hens exposed to sublethal levels of WP had reduced reproductive output and deformed embryos. The embryos that failed to hatch from both treatment groups had teratogenic deformities, including scoliosis, lordosis, submandibular edema, microphthalmia, and spina bifida.

Toxicity to Secondary Receptors. WP toxicity in secondary receptors (birds that prey on dead or dying ducks) was studied by Sparling *et al.* (in Racine *et al.*, 1995), Nam *et al.* (1994), and Roebuck *et al.* (1994). The first two studies were conducted on American kestrels as a surrogate species for bald eagles, herring gulls, and common ravens, which have

Kestrels can receive a lethal dose of white phosphorus when fed contaminated chicks, at a dose of between 6.8 and 10.8 mg/kg of body weight per day.

been observed feeding on dead or dying ducks at ERF. The final study modeled the potential risks to bald eagles feeding on WP-contaminated ducks on the basis of WP concentrations in ducks from WP-contaminated areas of ERF. The results of these studies are presented below.

In studies conducted by Sparling *et al.* (in Racine *et al.*, 1995), male domestic poultry chicks were dosed with WP and fed to male and female kestrels so that the dose to each kestrel was between 6.8 and 10.8 mg/kg-bw/day. Dosing was continued until 50 percent of the kestrels died. Signs of toxicity to kestrels included rigid body posture and extreme lethargy. In addition, hematocrit, hemoglobin, final body weight, and liver-body weight ratio were significantly different from controls. Results of this study indicated that the greatest risk to secondary receptors was through ingestion of portions of the digestive tract that contained pelletized WP, although ingestion of tissues containing WP residues also resulted in toxicity and some mortality. The persistence of WP in tissues of living and dead prey may also affect potential exposure by secondary receptors.

Nam *et al.* (1994) exposed American kestrels to WP in the diet at two concentrations: 6.4 µg/g of food, which was similar to maximum concentrations of WP in tissues of ducks found dead at ERF, and 0.7 µg/g of food, which represented a lower exposure. All birds were dosed with the higher concentration for 2 days and then split into two groups. The first group (accumulation group) was fed the higher concentration for an additional 5 days. The second group (cyclic group) was fed the lower concentration for 3 days and then the higher concentration for 2 days. Tissues from the kestrels were analyzed for WP content, with the following results:

- **Accumulation group.** Tissue concentrations in fat were not statistically different from control concentrations, but concentrations in skin were. The tissue concentrations increased over time, an indication that exposure to a higher dose would probably have resulted in significant accumulation in fat as well.
- **Cyclic group.** Tissue concentrations in fat declined when the dose was reduced, an indication that although uptake of WP in the tissues is rapid, loss is also rapid.

The study indicated that although the uptake of WP by predators was rapid, the potential for bioaccumulation in the food chain might be limited because of the rapid loss upon reduction of dose. Bioaccumulation and toxicity could be significant if the ingested dose exceeded the degradation rate of the receptor. In addition, ingestion of a WP-contaminated duck's gizzard could result in a dose to the predator more than 100 times the dose received from ingestion of tissues alone.

Field studies were conducted to address the potential for WP uptake and bioaccumulation at ERF. Analytical testing of field-collected animals included aquatic organisms and secondary predators (eagles and a single coyote). Detectable levels of WP were found in some tissues of these animals, but not at levels that would indicate significant bioaccumulation.

In studies conducted by Roebuck *et al.* (1994), WP concentrations were analyzed in tissues from ducks collected in a WP-affected area of ERF in which predation by eagles, herring gulls, and ravens had been observed (Area C). Ducks collected from this area included the following:

Uptake of white phosphorus was rapid in predators, but the loss was also rapid when the dose was reduced. This finding suggested a limited potential for bioaccumulation in the food chain.

- Group A—15 ducks collected from the same area as predation
- Group B—3 ducks that exhibited obvious signs of WP toxicity and subsequently died
- Group C—5 ducks that had been partially eaten
- Group D—4 mallards that were transported to ERF and maintained in pens in Area C

Tissues analyzed for WP included fat, skin, breast muscle, wing tissue, and gizzard contents. The ranges of tissue concentrations for ducks in each group are summarized in Table 3-19.

The potential risk of WP ingestion by an eagle was then estimated by use of the maximum tissue concentrations from the ducks collected. For ingestion of gizzard contents, the corresponding daily dose to an eagle would be 1.76 mg/kg-bw. For ingestion of tissues, including fat, skin, and muscle, the corresponding daily dose to an eagle would be 0.09 mg/kg-bw. A single daily dose of gizzard and tissues could provide a predator with almost half of the estimated LD_{50} (1 to 2 mg/kg-bw). This finding indicates that predators may be exposed to harmful doses of WP. In addition, exposure to lower levels could result in sublethal effects such as decreased reproductivity or survival. However, field studies of eagles (considered secondary receptors at ERF) have included WP tissue analysis and nesting success monitored by telemetry and have not confirmed that sublethal effects are occurring.

Macroinvertebrates. Laboratory toxicity tests and field studies of aquatic biota were conducted to determine the LC_{50}, no observed effect level (NOEL), and LOEL of WP present in sediment, as well as impacts on benthic macroinvertebrate community structure. The results of these studies are presented below.

Laboratory Tests. Initial 30-day sediment toxicity studies were conducted in 1993 (Bouwkamp, in Racine *et al.*, 1994). The toxicity test used sediment collected from Location RI2 on Racine Island. The

TABLE 3-19
Ranges of Tissue Concentrations for Ducks in Fat, Skin. Breast Muscle, Wing Tissue, and Gizzard

Group	Range of WP Tissue Concentrations (µg/g-ww)				Mass of WP in Gizzard Contents (µg)
	Fat	Skin	Breast Muscle	Wing Tissue	
A	0.047 - 5.92	0.012 - 6.34	ND - 0.56	--	0.021 - 8,820
B	0.018 - 1.57	0.018 - 1.57	<0.5	--	--
C	0.235	0.142	0.006 - 0.06	0.017 - 0.022	1,084
D	0.406 - 2.35	0.406 - 2.35	<0.5	--	--

Notes:
-- = not analyzed.
ND = not detected.
Single values represent analyses of only one sample for the given group and tissue.

Chronic 30-day toxicity tests were conducted on sediment containing two species of macroinvertebrates from Racine Island.

sediment concentration of WP was 1,740 mg/kg ww. Toxicity studies were conducted on serial dilutions of 0, 20, 40, 60, 80, and 100 percent ERF sediment diluted with reference sediment collected from Goose Bay. Toxicity was tested in the amphipod, *Hyalella azteca*, and the midge *Chironomus riparius*. A NOEL could not be established from the toxicity test results because all test organisms in all dilutions died before the end of the test. The average sediment concentration of WP in the lowest dilution (20 percent) was 194.5 mg/kg. The concentrations of total and dissolved WP in the overlying surface water decreased during the test from 23.7 micrograms per liter (µg/L) (total) and 14.7 µg/L (dissolved) to 2.54 µg/L (total) and 1.32 µg/L (dissolved), but these concentrations were still more than 1,000 times greater than those measured in the field over equally contaminated sediments. On the basis of this information, it was concluded that the sediment toxicity tests needed to be refined to more closely imitate conditions found in the field at ERF.

A second set of sediment toxicity tests was conducted in 1994 (Bouwkamp in Racine *et al.*, 1995; USAEHA, 1995) to refine the methodology used in the 1993 studies and to determine a sediment LC_{50}, NOEL, and LOEL for WP. Thirty-day toxicity tests on sediment containing *H. azteca* and *C. riparius* from Racine Island were conducted under the following treatment scenarios:

- Overlying water was renewed two times per week.
- Overlying water was not renewed and sediment was disturbed to mimic feeding ducks.

Two additional treatment scenarios were used for *C. riparius*:

- Sediments were spiked with 1 microliter (µL) of WP particles equivalent to 5 mg/kg.

- Sediments were spiked with 3 µL of WP particles equivalent to 14.25 mg/kg.

An LC_{50} chronic NOEL and a LOEL, as well as a survival NOEL and LOEL, were calculated from the results of the toxicity tests for each treatment scenario and test species. The results are presented in Table 3-20.

TABLE 3-20
Results of 30-Day Toxicity Tests

		Survival (µg/kg)		Chronic (µg/kg)	
Toxicity Test	LC_{50} (µg/kg)	NOEL	LOEL	NOEL	LOEL
H. azteca					
Renewal	9,101	7,100	16,000	1,500	3,800
Disturbed	6,850	3,800	7,100	3,800	7,100
C. riparius					
Renewal	256	26	41	1,600	2,300
Disturbed	485	41	1,600	41	1,600
1 µL of WP particles	16,212	10,000	20,000	0	5,000
3 µL of WP particles	not calculated	0	14,250	0	14,250

White phosphorus does not appear to adversely affect the macroinvertebrate community structure at Eagle River Flats.

Results were similar to those found in the 1993 study in that sediments from Racine Island were not toxic to organisms living in them in the field, but were toxic to laboratory organisms at diluted concentrations. The renewal of water versus nonrenewal of water and disturbance of sediments indicated few differences in toxicity and suggested that the amount of WP dissolved in the water column and the amount of WP at the sediment surface must reach equilibrium in a short time. *C. riparius* was more sensitive to WP than was *H. azteca*, and the lowest NOELs were 26 micrograms per kilogram (µg/kg) and 1,500 µg/kg, respectively.

Macroinvertebrate Community Structure. The macroinvertebrate community structure of ERF was evaluated to determine whether sediment or surface water concentrations of WP were affecting the aquatic food chain (Bouwkamp, in Racine *et al.*, 1994). Benthic macroinvertebrates were collected from 23 sites, including 14 ponded areas in ERF and Goose Bay, 7 from distributaries, and 2 from Eagle River (upstream and downstream of ERF). Results indicated that the numbers of species and species diversities were not significantly different among WP-contaminated sites. The number of organisms per unit area was significantly different at WP-contaminated sites and noncontaminated sites, but the number of organisms increased with

increasing sediment WP concentrations. From these results, it seems unlikely that WP was adversely affecting the aquatic community.

A similar macroinvertebrate community survey was conducted in 1994 (Bouwkamp, in Racine *et al.*, 1995). Macroinvertebrates were collected from 42 sites and analyzed for species density, diversity, and number of organisms per unit area. Results indicated that the macroinvertebrate community structure at WP-contaminated areas was not significantly different from that at reference locations for any parameter. From these results, it was concluded that there is no evidence that WP is adversely affecting benthic macroinvertebrate communities at ERF.

3.2.3 Literature

Toxicological information on the effects of WP on birds and other wildlife is limited. Much of the research on toxicity of WP has been conducted in conjunction with CRREL at Fort Richardson. Results of those studies were presented in the previous section. General toxicological information on ingestion of WP and research information reappearing in the open literature are presented below.

The toxic mechanisms of WP are not well documented because both organic and inorganic forms of phosphorus are normally used in a wide variety of functions within the animal body (Agency for Toxic Substances and Disease Registry [ATSDR], 1994). Organic phosphorus is used in energy storage and transfer, information transfer, protein synthesis, and carbohydrate metabolism. Inorganic phosphorus is found as phosphate in interstitial and intercellular fluids, as well as in the blood's buffering system.

Once an animal body is exposed to WP, the fate of the WP is not well understood. Because WP is lipid-soluble, it is likely that direct absorption can occur (ATSDR, 1994). However, it is hypothesized that some ingested WP is inorganically converted to other compounds before absorption. This inorganic conversion may occur as WP comes into contact with the moist surfaces of the mouth or moves through the acidic and basic portions of the gastrointestinal system. Inorganic conversion may also occur in the blood or interstitial fluids after WP has been absorbed, although this action has not been scientifically demonstrated (ATSDR, 1994).

The metabolic fate of white phosphorus is not well understood.

Inorganic conversions could include oxidation or hydrolysis to form orthophosphate, or hydrolysis in a highly alkaline environment to form a mixture of hypophosphite and phosphite (ATSDR, 1994). It is hypothesized that the jejunum of the mammalian gut could provide a sufficiently alkaline environment to conduct hydrolysis. The formation of orthophosphate is most likely because it is a stable end-product, and is the most common form of phosphorus found in the blood. During normal digestion, phosphate is released from phosphate-containing chemicals. It is primarily absorbed in the upper

small intestine, and to a lesser degree in the lower small intestine. Absorption of phosphate is affected by pH and is higher in acidic portions of the intestine than in basic portions. The differences in gastrointestinal pH for different wildlife species may affect the rate and amount of absorption of WP or the inorganic breakdown products (orthophosphate). Absorption of phosphate in the intestines is also decreased by high intake of calcium, magnesium, or iron, and by low intake of Vitamin D.

Adverse effects of white phosphorus toxicity include degeneration of bone structure, cardiac enlargement, central nervous system disorders, fatty degeneration of the liver, and tissue necrosis. Signs of toxicity vary among species.

Adverse effects observed in animals after exposure to acutely and chronically toxic concentrations of WP can include degeneration of bone structure, cardiac enlargement, central nervous system disorders, fatty degeneration of the liver, and tissue necrosis (Nam *et al.*, 1994). These adverse effects are manifested in the outward signs of toxicity, which vary among species. Signs of toxicity in small mammals (mice, rats, and rabbits) include vomiting, decrease in blood pressure, thirst, restlessness, delirium, and muscular weakness (Roebuck *et al.*, 1994). Signs in sheep include thirst, muscle weakness, lethargy, and coma. Signs of toxicity in dabbling ducks include thirst, muscle weakness, nervous activity, convulsions, and sudden death.

Toxicity of WP to birds has been studied primarily in association with ERF. The toxicity studies and results of those studies were discussed in Section 3.2.2. Other researchers have reported that dabbling ducks receiving WP doses ranging from 3 to 12 mg/kg-bw lived less than 1 day (Coburn *et al.*, 1950, as cited in Roebuck *et al.*, 1994). USFWS (1993) reported that ducks dosed with 1.5 mg/kg/day had weight loss, lethargy, anemia, and liver congestion. In addition, death occurred within 5 to 10 days. In the same study, ducks dosed with 12 mg/ kg/day died within 6 hours.

Toxicity studies with white phosphorus have been performed in small mammals.

Acute toxicity of WP in small mammals has been documented for laboratory rats and mice, and toxic levels have varied among investigations. Lethal doses (LD_{50} doses) for rats and mice given a single oral dose were 3.03 mg/kg-bw/day and 4.82 mg/kg-bw/day, respectively (Lee *et al.*, 1975, as cited in ATSDR, 1994). However, lowest observed adverse effect levels (LOAELs), based on adverse effects to the liver for rats given a single oral dose of WP, ranged from 6 mg/kg-bw/day (Barker *et al.*, 1963, as cited in ATSDR, 1994) to 10 mg/kg-bw/day (Pani *et al.*, 1972, as cited in ATSDR, 1994). Similarly, LOAELs for liver damage in mice given a single oral dose ranged from 5 mg/kg-bw/day to 7.5 mg/kg-bw/day (Hurwitz, 1972, as cited in ATSDR, 1994).

Intermediate and chronic exposure of laboratory rats resulted in cardiac, liver, and kidney LOAELs of 0.075 mg/kg-bw/day for pregnant rats exposed for 145 days (Bio/dynamics, 1991, as cited in ATSDR, 1994). Liver damage LOAELs for other laboratory animals ranged from 0.75 mg/kg-bw/day (guinea pigs dosed for 35 weeks) to

0.6 mg/kg-bw/day (pigs dosed for 4 to 16 weeks) (Ashburn *et al.*, 1948, and Peterson *et al.*, 1991, as cited in ATSDR, 1994).

Toxicity studies with white phosphorus have been performed in aquatic organisms.

WP toxicity in aquatic organisms is highly variable, but WP can be acutely toxic at concentrations less than 1 µg/L (Yon *et al.*, 1983). Bluegill sunfish (*Lepomis macrochirus*) and Atlantic salmon (*Salmo salar*) are the most sensitive fish species. Lethal concentrations (LC_{50} concentrations) for these two species were 2.4 µg/L and 2.3 µg/L, respectively for a 96-hour static toxicity test (Interagency Testing Committee [ITC], 1991; Zitko *et al.*, 1970). Lethal concentrations for other fish species have ranged up to 73 µg/L (ITC, 1991). In chronic aquatic toxicity tests, fathead minnows (*Pimephales promelas*) exposed to 0.4 µg/L had reduced hatchability and *P. promelas* exposed to 1.5 µg/L exhibited reduced survival. The daphnid (*Daphnia magna*) exhibited reduced survival at concentrations of 8.7 µg/L (ITC, 1991).

3.3 Uncertainties

This section presents the uncertainties and limitations of information used to conduct the exposure and ecological effects assessments. The primary uncertainties of the exposure assessment include errors in estimation of bird numbers and species at ERF and other UCI marshes; limitations on analyses of field collected birds; inter-study differences in methods of analysis for tissue concentrations; and limitations of data contained within the GIS database. The primary uncertainties of the ecological effects assessment include errors associated with field studies of birds (for example, mortality, telemetry, and observations of bird activities), intra- and inter-study variability, limitations of study design, and ability to match laboratory conditions to those observed in the field.

3.3.1 Uncertainties in Exposure Assessment

Ecosystem Characterization. In aerial bird population surveys, counts are based on observations made within short intervals during the day. Daytime activities in ERF (such as presence of investigators or hazing) may have caused birds to hide or leave the survey area before the aerial census took place.

Bird counts during aerial surveys depended on the numbers present within the line of sight along the airplane flight path. It is possible that bird numbers may have been under- or overestimated, especially when larger flocks were present. Some birds may not have flown from cover when the airplane passed overhead; others may have been outside the observer's field of vision. Because birds were counted by specific ERF areas, bird numbers could have been affected by the proximity of birds to the edge of the bird counting area. It also is possible that some birds were misidentified during the aerial census; misidentification would affect bird counts and species observed in a particular area. In particular, birds identified as "unidentified ducks"

Uncertainties in the exposure assessment include the following:

- *Population observations are made only during a short period of each day and/or only a few days each month.*
- *Population surveys are limited by bird movements and visibility.*
- *Only one field season of data was available for population data on marshes in other parts of UCI.*
- *No measurement of variability was available for the population surveys.*
- *A variety of methods was used for determining when to collect birds for tissue samples.*
- *Few predators were sampled.*
- *Tissue types analyzed varied among studies.*
- *Tissue samples were not consistently reported in the same units.*
- *Analytical detection limits varied, and sometimes were too high for evaluating ecological effects.*

probably included individual mallards, northern pintails, or green-wing teal that were not included in their species counts.

Bird counts done by aerial surveys are affected by the date of the survey and the distribution of surveys throughout the field season. To compensate for varying survey effort, the ERF bird counts by species group were normalized within each month by division of the bird counts for the total months by the number of surveys performed to obtain an average bird count per survey. This value was multiplied by the number of days in the month to estimate the bird-days for the month. The sum of the bird-days for the months from April to October was used to estimate the total bird use for that portion of the year.

For this method of approximating bird use, it is assumed that average monthly bird counts are representative of bird use for all days in a given month. If certain bird groups are not present in an area during nonsurvey days, this method would overestimate bird use. For these reasons, bird numbers from the aerial survey should be considered approximations. The population estimates only provide an index for comparing bird populations among different years and different areas.

Comparison of bird use among ERF and other surveyed UCI marshes is qualified by the fact that only one field season of data (1995) was available. As the yearly summaries for ERF have shown, there is considerable variation from year to year. Aerial surveys for some of the UCI marshes were conducted during the fall months of 1996. When these data were compared to data for the same marshes and time intervals from 1995, considerable variation was observed.

Ground surveys allow observation of bird flocks over a longer period of time during the day and thus allow a count of some birds that may leave their covers for limited periods. The primary limitation of ground surveys is that the observations take place from a single vantage point. Inevitably, some of the habitats are obscured from view by distance, topography, or vegetation so that some birds are not counted. Large bird flocks may also be difficult to count accurately.

Bird population estimates by ground and aerial surveys were not as well matched during the fall surveys as they were during the spring surveys. Because there was no measurement of variability for daily bird count estimates by either method, it was not possible to estimate confidence intervals for the measurements, or to determine which values were closer to actual bird populations. Bird numbers were used to normalize waterfowl transect mortality estimates, which constituted the assessment endpoint. Because there is uncertainty in bird population estimates used as the denominator to normalize mortality rates, there also is uncertainty in the mortality rate endpoint.

Differences between ground and aerial survey duck population estimates in the fall may have been a result of perspective; higher vegetation impairs ground surveyors' vision, but not aerial surveyors'

views. In addition, the estimates could be further affected by the time of day the surveys were conducted, the effect of hazing and human activity on ERF bird distributions, and the different areas that were viewed by each method.

Cummings *et al.* (in Racine *et al.*, 1996) also looked at the nesting success of bald eagles in ERF and in other marshes in UCI. For this information, uncertainty is associated with the fact that only a single field season was represented.

WP Tissue Analyses. The interpretation of WP tissue concentration data was affected by limitations in analysis of field-collected species and differences between studies conducted. These limitations and uncertainties are listed below:

- Some birds were collected live, whereas others were collected after they had died.
- Numbers of birds collected and analyzed were not uniform throughout the WP-affected areas.
- With the exception of one coyote and one bald eagle, analyses did not include predators.
- Sample size or number of animals analyzed was not presented for each study.
- In some studies, tissue analyses were conducted on a wet-weight basis; in other studies, a dry weight was used.
- Tissue types analyzed varied among studies. Some studies measured only a few tissues; others measured more tissues. The main tissues were not analyzed in all species collected.
- In some cases, analytical method detection limits were higher than desirable for evaluating ecological effects.
- Analyses performed varied among studies. Some measured both tissue concentrations and mass of WP in the gizzard, but most evaluated either one or the other.

The limitations and uncertainties listed above make it difficult to weigh results equally and determine average or median levels of WP present in tissues of various species. In addition, because of the study designs used, tissue concentrations associated with acute versus chronic exposures could not be determined.

Exposure Analysis. The analysis for areas of concern delineates areas of potential exposure by making use of existing data in the ERF GIS system. Therefore, any limitations of the studies used to generate data

or errors in the GIS database are reflected in the analysis. The following uncertainties were associated with the GIS database:

- The distribution of WP in ERF and the hazard presented by potential UXO made sampling and quantification of WP in sediments difficult. These factors contributed to uncertainty in characterizing the extent and distribution of WP in ERF.
- Lack of WP sediment samples in some areas may have resulted in these areas being omitted from consideration as areas of potential concern when WP concentrations actually may have been high.
- Given the irregular distribution of WP, it is possible that high-WP areas that were sampled did not represent the WP levels of the areas as a whole and an area may have been included for consideration as an area of potential concern when it should have been eliminated.
- Similar sampling uncertainties were encountered for OB/OD Pad contaminants because of the potential for burned UXO and lack of data on locations and types of material disposed there.

Uncertainties in the ecological effects assessment included:

- *Field surveys contributed human interference with natural behavior, human error, and equipment failure*
- *Intra- and inter-study variability*
- *Ability to match laboratory conditions to those observed in the field*

3.3.2 Uncertainties in Ecological Effects Assessment

Uncertainties about the field surveys of birds include human interference with natural behavior of the birds, human error, and equipment failure.

Disturbance by researchers may have scared birds from a study site or transect. In addition, the effects of hazing have been observed during the bird-use surveys. Hazing limits or reduces the numbers of birds within the area affected by the hazing. Cummings *et al.* (in Racine, *et al.*, 1994) found that movements of ducks in ERF were affected by hazing and the presence of researchers. The GIS data for the 1996 telemetry studies were not subjected to quality assurance (QA) and QC procedures by the time this report was produced.

As mentioned previously in Section 3.3.1, bird numbers may be under- or overestimated because of the observer and his or her sight line. Tall or dense vegetation may obscure birds, as well as the range of view of the observer. Identification of specimens is up to the individual observer; thus, some specimens may be inadvertently misidentified. Many female waterfowl of different species are similar in body shape and plumage.

Equipment failure is possible in telemetry studies. Transmitter units attached to study species may fall off or malfunction during the course of a study. No data can be recorded when birds outfitted with transmitters cannot be located or followed.

The primary uncertainties of the laboratory and toxicity tests used to evaluate potential ecological effects include intra- and inter-study

variability, limitations of study design, and ability to match laboratory conditions to those observed in the field.

Intra-study variability occurred for many of the laboratory and toxicity tests. Because laboratory tests conducted to determine clinical signs of toxicity exhibited wide variability among treatment groups, it was difficult to measure time of onset for various toxic signs as related to dose. The reasons for this variability are unknown but could have been related to small sample sizes or individual differences in the ducks' testes. The subchronic studies also had variability among the treatment groups, and dose-response relationships could not be generated for either mortality or gross pathological effects.

Inter-study variations occurred in the acute toxicity tests for birds. The acute laboratory and toxicity tests conducted in 1993 were unable to determine an LD_{50} for female mallards, and consequently there was a lack of dose-response relationship. Acute toxicity tests for female mallards were repeated in 1994, at which time the LD_{50} values could be calculated. The reasons for the failure of the 1993 studies and success of the 1994 studies are unknown.

Limitations in study design were encountered in toxicity tests in which NOELs were calculated for aquatic macroinvertebrates. In initial sediment toxicity studies, a WP NOEL for sediment macroinvertebrates could not be calculated because the sediments sampled were lethal to test organisms at all dilutions. Conclusions in this study were limited to use in redesigning the tests to more closely match field conditions.

The inability to match laboratory conditions with those observed in the field was most prevalent in the macroinvertebrate toxicity tests and community structure analysis. In sediment toxicity tests conducted in both 1993 and 1994, laboratory conditions could not be matched with those found in the field. Sediments collected from Racine Island were toxic to amphipods and midges tested in the laboratory, but they were not toxic to aquatic macroinvertebrates living in the same sediments in the field. In addition, the WP concentrations in the overlying surface water could not be adjusted to match those measured in the field and ranged from 100 to 1,000 times greater than concentrations measured at similarly contaminated field locations. Results of macroinvertebrate community analyses did not match the sediment toxicity test results for either test year.

4.0 Risk Characterization

In this section, the likelihood of adverse ecological effects occurring as a result of exposure to WP in ERF are evaluated. In the first part of risk characterization, the exposure assessment (Section 3.1) and the ecological effects assessment (stressor-response profile in Section 3.2)

are integrated. Uncertainties associated with use of data from previous studies are also summarized. The second part of risk characterization is the risk description, in which ecological risks are summarized, data gaps are identified, and an interpretation of the ecological significance of the risk is provided (USEPA, 1992a).

Waterfowl mortality is considered the only significant effect of white phosphorus on ecological resources.

4.1 Risk Estimation

Risk estimation consists of comparing the exposure and ecological effects assessment, as well as estimating and summarizing the associated uncertainties. For this EcoRA, waterfowl mortality is considered to be the only significant effect of WP on ecological resources.

4.1.1 Integration of Exposure Assessment and Ecological Effects Assessment

Physical characteristics associated with exposure were integrated in the analysis for areas of concern (Section 3.1.3). Characteristics such as habitat (vegetation, landform, and ponds), WP concentrations, and duck use were combined to identify areas where all these factors exist together (overlap). Hot areas have been identified in the sedge marshes, permanent ponds, and various meadows of Area C, Bread Truck, and Racine Island. Area C/D was also included because it has many of the same landcover types and is near Area C and Bread Truck.

Concentrations of white phosphorus in fat and skin samples from mallards collected in Eagle River Flats exceeded the corresponding maximum tissue concentrations in the acute toxicity laboratory studies. Ducks are ingesting enough white phosphorus to result in mortality.

To estimate risk, each area of ERF was evaluated to answer the following questions:

- If bird mortality was observed, how many dead birds were found and what were the WP levels in bird tissue (fat and gizzard)?
- Were levels in bird tissue in excess of those associated with lethal doses in laboratory studies?
- What percentage of time did birds use the area (as indicated by telemetry studies)?
- How many birds were estimated to use the area on an annual basis?

The areas of concern were evaluated to answer the following set of questions:

- What is the habitat type in the area of concern?
- How much area does the habitat include in the area of concern? What proportion of the total ERF habitat type is represented?
- What percentage of time did birds use the habitat type (as indicated by telemetry studies)?

White phosphorus concentrations were detected in a few fish samples from Area A and Racine Island. Detections in invertebrate samples from Racine Island were also noted.

- How many birds are estimated to use the habitat type on an annual basis?
- What percentage of time would birds use these habitat types?

Table 4-1 summarizes the results of WP analyses of biological tissues collected in ERF. The table shows that mallard, northern pintail, and green-winged teal carcasses or dying ducks were collected from Area A, Area C, Bread Truck, and Racine Island. Mallard carcasses or dying ducks were also collected from Area C/D. White phosphorus was detected in various tissues of these duck samples. In Area C, Area C/D, and Racine Island, WP levels in fat and skin samples were higher than the corresponding maximum tissue concentrations in mallard WP toxicity studies. This finding indicates that the ducks ingested enough WP in ERF to result in mortality. The maximum tissue levels from toxicological tests provide a conservative comparison of WP bird tissue levels.

Table 4-1 also summarizes the results of fish and invertebrate sampling and analysis for WP from surface waters in Areas A, B, C, and C/D, as well as in Bread Truck and on Racine Island. Positive WP results were noted for fish samples from Area A and Racine Island. Positive WP results were observed for invertebrate samples from Racine Island. WP was not observed above the detection limits in the other areas. Plants sampled in Area C did not show uptake of WP.

Most of the dead ducks were found in Area C, on Racine Island, in Area A, and in Bread Truck.

Duck mortality studies are summarized in Table 4-1. The table shows that the largest proportion of ERF dead or dying ducks was observed in Area C (37 percent), Racine Island (22 percent), Area A (22 percent), Bread Truck (12 percent), and Area C/D (6 percent). Of these areas, only Area A did not contain WP exposure area of concern (Section 3.1.3). No observations of dead or dying birds in the coastal areas (east or west) were recorded. Dead swans were also observed in Area C (44 percent), Areas A and D (25 percent), and Area C/D (6 percent).

The mortality ratio for ducks was calculated as the number of carcasses observed along the transect divided by an estimate of the bird exposure rate from ground surveys of bird populations (Steele and Reitsma, in Racine *et al.*, 1996). The data presented in Table 4-2 show that the mortality ratios appear to have declined from 1992 to 1995.

Duck use of the various areas was estimated by telemetry observations during periods when hazing was not occurring. The results of these analyses indicated the following relative use by ducks: Area A (26 percent), Area C (18 percent), Area C/D (12 percent), Coastal East (11 percent), Area B (10 percent), Bread Truck (5 percent), Coastal West (4 percent), Area D (3 percent), Racine Island (3 percent), and OB/OD Pad (1 percent). The apparent use of the coastal areas is an

TABLE 4-1
Assessment of Risk Based on Biological Tissue Data by ERF Area

Areas	Duck WP Tissue Concentrations[a]				Other Biota		
	Fat[b] (µg/g)	Skin[c] (µg/g)	Gizzard (µg/g)	Gizzard WP Mass (µg)	Fish (µg/kg)	Invertebrates (µg/kg)	Plants (µg/kg)
A	MLD: --- GWT: --- PIN: ---	MLD: --- GWT: 0.3 PIN: ---	MLD: --- GWT: --- PIN: ---	MLD: 0.231 GWT: --- PIN: 80.9	ND - 67.8	ND (<37)	---
B	---	---	---	---	ND (<90)	ND (<40)	---
C	MLD: ND GWT: --- PIN: ---	MLD: ND - **5.56** GWT: --- PIN: ---	MLD: 0.28 - 270 GWT: 0.08 - 0.56 PIN: 74	**MLD:** 0.273 - 21,400 GWT: ND - 0.592 PIN: ND - 111	ND (<25)	ND (<31)	ND[d]
C/D	MLD: **0.752 - 0.873** GWT: --- PIN: ---	MLD: --- GWT: --- PIN: ---	MLD: ND GWT: --- PIN: ---	MLD: ND GWT: --- PIN: 0.24	ND (<18)	ND (<15)	---
D	---	---	---	---	---	---	---
Bread Truck	MLD: --- GWT: --- PIN: ---	MLD: --- GWT: --- PIN: ---	MLD: --- GWT: --- PIN: ---	MLD: ND - 5.12 GWT: 0.444 - 11.4 PIN: ND - 0.606	ND (<18)	ND (<180)	---
Racine Island	MLD: 0.23 - **1.05** GWT: **0.96 - 19.06** PIN: ---	MLD: 0.12 - **20.5** GWT: **0.55 - 5.71** PIN: 0.32 - **2.64**	MLD: 0.21 - 628 GWT: 0.1 - 3,150 PIN: 24.4 - 96.9	MLD: 1.19 GWT: --- PIN: ---	ND - 82.3	ND - 67.6	---
Coastal East	---	---	---	---	---	---	---
Coastal West	---	---	---	---	---	---	---
All ERF	---	---	---	---	---	---	---

[a]MLD = mallard; GWT = green-winged teal; PIN = northern pintail.
[b]Compare field WP concentrations in fat to the following laboratory maximum tissue concentrations for mallard: WP in oil (dose range 6.1 mg/kg to 7.1 mg/kg) 0.562 to 1.78 µg/g; WP pellet form (dose 6.5 mg/kg bw) 0.313 µg/g.
[c]Compare field WP concentrations in skin to the following laboratory maximum tissue concentrations for mallard: WP in oil (dose range 6.1 mg/kg to 7.1 mg/kg) 0.408 to 0.458 µg/g.
[d]For aboveground portions of plants WP was detected in the roots of one sedge sample (*Carex lyngbyei*) at 2,270 mg/kg ww and in the rhizome of one bulrush sample (*Scirpus paludusus*) at 110 mg/kg ww.

Notes:
--- = data not available.
Boldface values exceed comparative fat or skin laboratory values for mallards.

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TABLE 4-2
Assessment of Risk Based on Duck Mortality Data by ERF Area

Areas	Contains Hot Areas?	Waterfowl Carcasses Observed?	Percent of Documented ERF Waterfowl Carcasses (ducks/swans)[a]	Percent of Duck Area Use[b]	Estimated Annual Duck Use[c] (bird-days)	Percent Carcasses Exceeds Percent Use?	Mortality Ratio[d] (Spring/Fall) 1992	1993	1994	1995
A	No	Yes	(22/25)	26	26,000	No	(0.0117/ 0.0544)	(0.0039/ 0.0044)	(0.0/ 0.0061)	(0.0/ 0.0052)
B	No	Yes	(0.2/---)	10	10,000	No	---	---	---	---
C	Yes	Yes	(37/44)	18	18,000	Yes	(0.0159/ 0.0312)	(0.0050/ 0.0031)	(0.0002/ 0.0047)	(0.0/ 0.0033)
C/D	Yes	Yes	(6/6)	12	12,000	No	---	---	---	---
D	No	Yes	(0.7/25)	3	3,000	No				
Bread Truck	Yes	Yes	(12/---)	5	5,000	Yes	(0.0205/ 0.0246)	(0.0070/ 0.0059)	(0.0/ 0.0065)	(0 0/ 0.0016)
Racine Island	Yes	Yes	(22/---)	3	3,000	Yes	---	---	---	---
Coastal East	No	No	(---/---)	11	11,000	---	---	---	---	---
Coastal West	No	No	(---/---)	4	4,000	---	---	---	---	---
All ERF	Yes	Yes	(100/100)	93	93,000	---	(0.0146/ 0.0443)	(0.0045/ 0.0039)	(0.0/ 0.0058)	(0.0/ 0.0031)
OB/OD Pad	No	No	(---/---)	1	1,000	---	---	---	---	--

[a]Waterfowl carcass percentages were calculated as number of dead birds found within area over all corresponding carcasses found in ERF (not including carcasses in woodlands adjacent to ERF).
[b]From telemetry ducks observations made during nonhazing periods. Twelve percent of observations on OB/OD Pad or unclassified.
[c]Calculated as the percent of area use times the average annual duck use from 1989 to 1996 (100,000 duck-days) from Table 3-1.
[d]From Steele and Reitsma, in Racine *et al.*, 1996.

Notes:
--- = data not available.

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artifact of the way the data in the ERF GIS were created (CH2M HILL, 1996a). Comparison of duck mortality to duck use indicated that highest mortality occurs in Area C, Bread Truck, and Racine Island.

Table 4-3 summarizes the information associated with the identified areas of concern in Areas C and C/D, Bread Truck, and Racine Island. These areas represented the following percentages of total ERF area for the corresponding habitat types: permanent ponds (29 percent), intermittent ponds (19 percent), and sedge marsh (51 percent). The actual percentage of bird use of these areas of concern, based on the corresponding habitat use, was calculated from telemetry observations during nonhazing periods as follows: permanent ponds (47 percent), intermittent ponds (31 percent), and sedge marsh (54 percent). In general, this finding indicated that bird use of the areas of concern was higher than would have been indicated by bird use based on the proportional area of the corresponding habitat. The percentage of bird use of areas of concern was much lower when compared to overall ERF use: permanent ponds (5 percent), intermittent ponds (2 percent) and sedge marsh (16 percent).

Major duck use during nonhazing periods occurred in Area C, Area C/D, and Area B. Bread Truck and Area C were used less. Area D and Racine Island had the lowest use.

Table 4-4 compares mallard mortality with estimated percent ERF area use from the 1996 telemetry studies (Cummings *et al.*, in Walsh *et al.*, 1997). The table shows that four ERF areas (C, C/D, Bread Truck, and Racine Island) had mallard mortality in excess of the proportional area use (indicated by telemetry hits). This information supports the conclusion that these are areas of concern for duck exposure to WP.

Table 4-5 summarizes information used to compare bird use of ERF with overall bird use of UCI marshes (after Eldridge and Robertson, in Racine *et al.*, 1996). This comparison was based on aerial surveys of bird populations conducted during the 1995 field season. In general, the table shows that approximately 3 to 5 percent of waterfowl (swans, geese, and ducks) use ERF wetlands. Higher percentages of eagles (between 9 and 52 percent) use ERF. Because this comparison was based on a single field season, the relative proportions of birds are expected to vary from year to year.

Approximately 3 to 5 percent of waterfowl in the UCI used Eagle River Flats in 1995.

In the mortality of ducks studied by Cummings *et al.* in bird telemetry studies between 1993 and 1995 (in Racine *et al.*, 1994, 1995, 1996), 19 ducks out of 120 ducks with transmitters were found dead in ERF. These numbers represent a mortality of about 16 percent for ducks in ERF. However, the 1996 telemetry studies were conducted on a larger sample of birds (107 mallards) and without hazing. The mortality from this study was conservatively 35 percent, a value probably more indicative of current risk at ERF without remediation. If it is conservatively assumed that about 5 percent of UCI ducks use ERF (3 to 4 percent was estimated in Table 4-5), the percentage of UCI ducks potentially affected (killed) by WP in ERF would be about 2 percent.

TABLE 4-3
Assessment of Risk in Areas of Concern by Habitat Type

Areas of Concern	Habitat Type	Area (ha/%) [a]	Percent Duck Use of Area (% Habitat/% of ERF) [b]	Estimated Area Duck Use [c] (bird-days)
Area C, Bread Truck, Racine Island	Permanent Ponds	15/29	47/5.4	5,400
	Intermittent Ponds	7/19	31/2.3	2,300
	Sedge Marsh	19/25	22/6.4	6,400
Area C/D	Sedge Marsh	20/26	32/9.1	9,100
Total	---	61/37	49/23	23,000

[a] Percent of total ERF area for this habitat.
[b] From telemetry duck observations made during nonhazing periods from 1993 to 1996.
[c] Calculated as percent of area of concern use (percent) times average annual duck use from 1989 to 1996 (100,000 duck-days) from Table 3-1.

TABLE 4-4
Comparison of Mallard ERF Area Use with Associated Mortality: 1996 Field Season[a]

	Telemetry Points		Mallard Mortality		Mortality
ERF Area	No.	Percent	No.	Percent	>Use?[b]
A	1,214	61	8	22	No
B	213	11	2	5	No
C	204	10	13	35	**Yes**
C/D	167	8.5	6	16	**Yes**
Coastal West	63	3.2	0	0	No
Racine Island	40	2.0	6	16	**Yes**
Coastal East	27	1.4	0	0	No
D	18	0.91	0	0	No
OB/OD Pad	16	0.81	0	0	No
Bread Truck	13	0.66	2	5	**Yes**
Total	1976	100	37	100	

[a]Source: *Cummings et al.*, in Walsh *et al.*, 1997
[b]Percent of mallard mortality is greater than percent of area use (as indicated by telemetry).

4.1.2 Uncertainty

This section summarizes the uncertainties related to the integration of the EcoRA studies. Discussions of uncertainties were presented in earlier sections of this report.

The mortality of dead or dying birds collected in ERF was attributed to the area where the birds or carcasses were collected. It was assumed that the birds did not travel a significant distance after ingesting the WP particles before becoming immobile.

TABLE 4-5
Assessment of Risk by Comparing ERF Bird Use to Use of Total UCI Marshes

Bird Group	Estimated Annual ERF Bird Use (bird-days[a])	Estimated 1995 ERF Bird Use[b] (bird-days)	Estimated 1995 UCI Bird Use[b] (bird-days)	ERF Bird Use Percentage of Total UCI Bird Use[c] (overall/1995)[c]
Swans	9,400	6,700	200,000	5/3
Geese	65,000	85,000	2,100,000	3/4
Ducks	100,000	110,000	3,200,000	3/3
Eagles	830	140	1,600	52/9

[a]Estimated annual bird use (average of 1989 to 1996) and estimated bird use for 1996 only from Table 3-1.
[b]After Eldridge and Robertson, in Racine *et al.*, 1996.
[c]ERF bird use as a percent of total estimated bird use in UCI marshes for estimated (8-year overall/1995) bird use.

Waterfowl mortality was estimated from counting of carcasses and feather piles along established transects within ERF. These transects were searched on a regular basis for dead or dying birds and were located in areas that had traditionally seen high levels of mortality. Areas that did not have transects were not searched on a regular basis so that mortality counts in those areas are expected to be lower than in areas with mortality transects.

Uncertainties in the integration of the ecological risk assessment include:

- *Travel distance after ingestion of a fatal dose of white phosphorus*
- *Representativeness of the transect results*
- *Population estimates*
- *Accuracy and representativeness of the telemetry data*
- *Representativeness of the 1995 population survey in UCI.*

The mortality ratio was based to a large degree on the accuracy of the bird exposure values that were made from ground survey counts. As discussed in Section 3.1.1, ground survey estimates did not match aerial survey population estimates for reasons associated with bird viewing. Because variability of daily bird counts was not measured, no confidence limits can be ascribed to the daily estimates that were averaged to estimate bird exposure values. It cannot be demonstrated that differences in the mortality ratio from year to year are due to factors other than normal variability of bird population estimates.

In some areas where WP was not detected in fish or invertebrate samples, the detection limit may have been too high to assess ecological risk. For example, the reported detection limit for fish sampled in Area B was 90 mg/kg, and for invertebrates it was 180 mg/kg.

Bird use of habitats and areas was estimated on the basis of observations from bird telemetry studies conducted from 1993 to 1996. With the ERF GIS, individual bird locations were matched to the landcover and vegetation type and ERF area designation. Only data that were recorded during periods when hazing was not occurring were used to estimate bird habitat preference. It was assumed that bird behavior was unaffected by other factors during the nonhazing periods.

Ingestion of white phosphorus particles by ducks and swans is the cause of increased mortality in Eagle River Flats. Sediment concentrations are high in Area C, in Bread Truck, and on Racine Island.

As indicated in the review of the GIS database (CH2M HILL, 1996c), the plotted bird locations from the 1995 field season showed radial lines that seemed to originate from the two radio receiver stations. This indicated that the tracking system may have been biased to particular compass headings. The database review also showed that bird observations extended into Knik Arm, well beyond the Coastal East area, which would tend to overestimate bird use by incorporating observations from a larger area. The opposite was true for the Coastal West area, which had observations over approximately one-half the surface area. For these reasons, the bird observation numbers by area or habitat should be considered approximate but useful for comparison between areas where full coverage was shown.

The largest potential source of error in the comparison of bird use at ERF to use at other UCI marshes was that the study was based on data from a single field season (1995) (after Eldridge and Robertson, in Racine *et al.*, 1996). As indicated in Section 3.1, there was considerable variation in bird populations from year to year in ERF. Bird populations in UCI marshes were also expected to vary, an expectation that was confirmed when aerial census figures were compared for the full time periods for selected UCI marshes.

4.2 Risk Description

Risk description consists of two primary elements: the ecological risk summary and an interpretation of ecological significance (USEPA, 1992a). For this baseline EcoRA, the risk description was focused on waterfowl mortality from WP ingestion.

Mortality transects combined with population surveys have provided an index of mortality over time.

4.2.1 Ecological Risk Summary

The weight of evidence indicates that ingestion of WP particles by ducks and swans is the cause of elevated waterfowl mortality in ERF. WP has been identified at elevated levels in the sediment of three ERF areas: Area C, Bread Truck, and Racine Island. Area C/D is adjacent to these areas and could also have high levels of WP that were not detected because of limited sediment sampling.

Tissues of waterfowl found dead or dying in ERF have tested positive for WP. The detected WP levels in bird tissues have been higher than corresponding WP levels in tissues from lethally dosed mallards in toxicity studies. This information suggests that waterfowl can ingest sufficient quantities of WP in ERF to result in death.

Bird population studies have provided useful insights into natural variation in bird populations using ERF, although the variation has not been quantified. Some data from population ground surveys have been used in conjunction with mortality transect data to develop a mortality ratio for ducks. This index was used to normalize observed mortality on the transect to the number of ducks using the corresponding ERF area. It has been suggested that the falling

mortality ratio in advance of full-scale remedial activities provides evidence that natural processes occurring in some parts of ERF are reducing WP exposure levels (Steele and Reitsma, in Racine *et al.*, 1996). The effect of bird hazing activities on ERF waterfowl exposure is another possible explanation for the falling mortality ratios.

Bird hazing has complicated the interpretation of mortality and location data.

Bird hazing activities make it difficult (if not impossible) to determine whether falling mortality ratios can be attributed to natural reductions in WP exposure levels (through attenuation or sedimentation). For this reason, bird hazing should be stopped while assessments of bird populations and mortality along transects are being conducted. Although, hazing was stopped during the 1996 field season, a census of mortality transects was not conducted because of health and safety considerations (Steele *et al.*, 1996, in Walsh *et al.*, 1997).

Reduced bird exposure levels from sediment deposition over the WP-contaminated sediments may provide a reduction in waterfowl mortality in the short and long term. It is also possible that these sediments may become subsequently reexposed by water or ice erosion.

Sediment deposition over contaminated materials may reduce waterfowl mortality over time. The contaminated sediments may become reexposed through water or ice erosion.

Studies of ecological impacts on birds in ERF were focused primarily on three species of waterfowl: mallards, northern pintails, and green-winged teals. These birds were chosen for detailed studies because they represent nearly 97 percent of all bird mortality observed in ERF (Racine *et al.*, 1993).

Telemetry studies conducted in the 1994, 1995, and 1996, field seasons did not indicate that predatory birds (represented by bald eagles) were being affected by WP contamination in ERF. No mortality was observed among 24 transmitter-equipped birds while they used ERF or within a 268-km radio contact area. Comparison of ERF eagle nesting success to eagle nesting success at Susitna and Chickaloon Flats did not indicate any significant differences (Cummings *et al.*, 1995, in Racine *et al.*, 1996).

4.2.2 Interpretation of Ecological Significance

As indicated in Section 4.1.1, only a small percentage of UCI waterfowl (3 to 4 percent) may be using ERF (based on 1 year of surveys). When the estimated in-ERF mortality of radio-equipped birds from the telemetry studies during 1993 to 1995 was analyzed, it was found that approximately 16 percent of the ducks died in ERF, presumably from WP poisoning or subsequent immobilization and predation. The 1996 telemetry studies were conducted on a larger sample of birds (107 mallards) and without hazing, however. The mortality from this study was 35 percent, a value probably more indicative of current risk at ERF without remediation. If it is conservatively assumed that approximately 5 percent of UCI

waterfowl use ERF, the estimated percentage of UCI waterfowl affected by WP in ERF would be about 2 percent.

Only about 3 to 4 percent of the waterfowl in UCI may be using Eagle River Flats. An estimated 2 percent of the UCI waterfowl are affected by white phosphorus in Eagle River Flats.

Data quality objectives (DQOs) for the waterfowl mortality assessment endpoint are described in Section 6 of the *RI/FS Management Plan* (CH2M HILL, 1996a). The DQO process is critical to obtaining data that RPMs can use in decisionmaking. Accurate and consistent measurement of waterfowl mortality is essential to the establishment of baseline conditions upon which future trends or remedial success at ERF can be compared.

Duck counts by aerial and ground surveys were compared in Section 3.1.2 of this report. A comparison of 1994 and 1995 data indicated that the correlation between the two survey methods was very weak (correlation coefficients of 0.31 and 0.52, respectively). The lack of correlation was attributed to a number of factors, including time interval of the surveys, visibility to observers, bird behavior (such as courtship and nesting), hazing, and weather. In addition, variations in bird counts by different observers or variations in daily bird count estimates were not determined. Because these factors were not quantified in the earlier studies, the uncertainty associated with the reported data could not be estimated.

The identified areas of concern represent a large proportion of areas used by ducks, as indicated by telemetry studies from 1993 to 1996. Overall duck use of permanent ponds (11.4 percent), intermittent ponds (7.4 percent), and sedge marsh (28.7 percent) accounted for a total of 47.5 percent of duck observations made within ERF.

Although field studies have not established a reliable estimate of bird mortality in the reference areas of UCI, the mortality rate of Eagle River Flats is much higher.

When use in the areas of concern was compared to overall use of the habitat type in ERF, the percent use of these areas represented 46.6 percent of permanent pond use, 31.4 percent of intermittent pond use, and 54.1 percent of sedge marsh use. Overall duck use of the areas of concern represented approximately 30 percent of all the duck observations within ERF. This finding indicates that the areas of concern represent significant habitat resources for ducks in ERF.

Field studies have not established a reliable estimate of bird mortality in reference UCI marshes; however, mortality in ERF is much higher than background mortality in the reference areas (Steele and Reitsma, in Racine *et al.*, 1996).

5.0 Conclusions and Data Gaps

5.1 Conclusions

This baseline risk assessment was performed for ERF in OUC with information from previous studies, principally those conducted by CRREL and its associates. Considerable research has shown strong evidence that WP from smoke obscurant shells is the primary cause of

the waterfowl mortality in ERF. WP exists as particulates in the sediment, and will persist in saturated or inundated sediments where oxygen (or other oxidizers) are absent. The particulate form and the spatial heterogeneity of the WP increases the difficulty in identifying area concentrations. Sedimentation may cover these particles and thus render them unavailable to feeding waterfowl or other birds. Particles may also be exposed by water or ice erosion.

Dabbling ducks and swans are the primary receptors for the WP-contaminated sediments.

The highest frequencies and concentrations of WP were detected in the sediments of Area C, Bread Truck, and Racine Island. Areas A and C/D had low frequencies of detection and concentrations. Areas B and D had no WP detections. Limited WP contamination has been detected in the gully sediments that are transported during ebb tide in tidal flooding cycles. WP has not been detected in the water of the gullies or the Eagle River.

Waterfowl ingest the WP particles, perhaps believing them to be food particles, which are about the same size. Dabbling ducks and swans are the primary receptors for the WP-contaminated sediments. Both feed on the bottom of ponded areas. Northern pintail, green-winged teal, and mallard have the highest incidence of mortality in ERF, with almost 97 percent of the recorded bird deaths associated with these three duck species. Plants, macroinvertebrates, fish, shorebirds, and predators have shown detectable levels of WP but account for a minor percentage of overall mortality in ERF. Therefore, dabbling ducklings will be the target species of concern in future remediation efforts. Table 5-1 summarizes the ecological effects of WP on the birds of ERF. It was estimated that the total bird mortality was 386 (95 percent confidence interval of 161 to 611) in the spring of 1993, and 144 in the fall. Hazing occurred during these seasons.

Aerial surveys were used to estimate the use of ERF by birds. Three dabbling duck species represent 64 percent of the duck use and 28 percent of all birds using ERF.

Aerial surveys were used to estimate the use of ERF by birds. On average, the total annual use, in bird-days, was about 100,000 for ducks and 9,400 for swans. Three dabbling duck species represent 64 percent of the duck use and 28 percent of all birds using ERF. The specific use figures vary from year to year. These birds are present during the two migration periods in the spring and fall. In general, elevated waterfowl counts were observed in the spring just after ice-out and again in the fall before the winter migration. The pattern of bald eagle populations was similar, with elevated numbers in the spring and fall.

During the 1995 field season, aerial surveys also were conducted at the following UCI marshes: Susitna Flats, Palmer Hay Flats, Goose Bay, Trading Bay, Redoubt Bay, and Chickaloon Flats. Use comparison among the marshes indicated that the birds at ERF are a small proportion (3 to 4 percent) of the total number of waterfowl using all UCI marshes.

Telemetry studies during nonhazing periods have found that the ducks spend about 22 percent of their time in Area C, 14 percent in Area C/D, and 10 percent in Area B. Ducks spent less than 10 percent of the time in each of the other areas (Bread Truck, Area A, Area D, and Racine Island).

Although data were obscured by the use of bird hazing in ERF, it appears that waterfowl mortality has been decreasing over the past 3 years.

Particular landcovers were preferred by ducks in these areas. During nonhazing periods, ducks spent 26 percent of their time in the sedge marshes, 13 percent in permanent ponds, and 11 percent in the Ramenski's sedge meadow. Halophytic herb meadow, interior sedge meadow, and intermittent ponds each had a use value of about 8 percent.

Table 5-1 also discusses measurement endpoints used in ERF. The water bird mortality was observed during use of standardized transects that were walked at regular intervals to discover carcasses and feather piles. Standard mortality transects were used in reference areas of UCI for only 1 year (1995), and only one carcass was found; therefore, a reliable estimate for a reference mortality with the transect method could not be established. Most of the bird carcasses and feather piles in ERF were observed in Area C, in Bread Truck, on Racine Island, and in Area A. Although data were obscured by the use of bird hazing in ERF, it appears that waterfowl mortality has been decreasing over the past 3 years.

Bird telemetry results over the past 3 years have suggested that the mortality is about 16 percent for ducks in ERF. The telemetry results in 1996 found a mortality rate in mallards of 35 percent. It has been estimated that about 0.8 percent of the UCI waterfowl may be affected by the WP in ERF.

5.2 Data Gaps

The review of available studies for the risk assessment has identified the following data gaps:

These data gaps have been identified:

- *Telemetry studies*
- *Reference area mortality*
- *Population reference areas*

- **Telemetry studies.** The 1996 field season represents the first complete year in which field studies were performed without hazing. These studies were intended to provide a baseline against which the effects of remedial activities could be measured. They also provide a way to monitor changes in bird preferential use of ERF areas.

- **Reference area mortality.** Censuses of in-ERF and out-of-ERF reference mortality transects were conducted only during the 1995 field season. To date, there has been no reliable estimate of reference area mortality (Steele and Reitsma, in Racine *et al.*, 1996). It now appears that monitoring of the on-ERF transects will no longer be feasible because of health and safety considerations (Steele *et al.*, 1997). These health and safety considerations

TABLE 5-1
Summary of Conclusions Concerning Ecological Effects and Endpoint Evaluation

Functional Group to Be Protected	Species Evaluated	Statement Tested and Interpretation	Measurement	Conclusions
Water birds (direct exposure through ingestion of WP particles)	Ducks (mallards, pintails, green-winged teals) and swans because of observed acute effects; shorebirds (dowitchers) because of potential exposure.	Mortality was not substantially different from that in reference areas. Areas of bird use have WP below significant mortality effects.	Duck mortality measured at ERF and reference areas. Observations of swan and shorebird mortality. Verification that hot spot remediation is successful.	Duck, swan, and shorebird mortality in ERF has been related to WP exposure while water birds feed among contaminated sediments. The WP particles seemingly are ingested incidentally while water birds forage for seeds or invertebrates. Duck mortality in ERF is higher than in reference areas, although it represents less than 1 percent of the ducks using UCI. Mortality values for swans and shorebirds have not been compared with those for swans and shorebirds in reference areas, but probably are higher than in those areas.
Terrestrial scavengers and predators (secondary exposure through feeding on dead water birds)	Bald eagles.	No significant morality or effect on reproduction was found.	No significant effects in telemetry studies; incidental observations of continuing no effect.	No confirmed direct effect from WP in the field was found, and likelihood of significant effects from contaminated birds is low. Secondary effect will disappear as water bird mortality decreases.
Other terrestrial species	None.	None.	Incidental observations.	No significant effects were observed, and exposure is expected to be low.
Plants (ERF and Knik Arm)	Miscellaneous wetland plants.	No significant bioaccumulation of WP was found.	Analysis of plant tissues.	Aquatic plants growing within contaminated sediments contained low levels of WP. Low mortality of waterfowl that feed mainly on vegetation (such as geese and wigeons) supports this conclusion.
Aquatic species in ERF	Benthic invertebrates and fish.	No significant bioaccumulation of WP and no effects on invertebrate community were found.	Analysis of fish and invertebrates for WP; toxicity testing of sediment with invertebrates; evaluation of invertebrate community composition and diversity in relation to WP exposure.	Sampling and analysis of fish and invertebrates did not reveal significant accumulations of WP. Laboratory studies showed that invertebrates were sensitive to WP, but field studies showed no evidence of adverse effects on macroinvertebrate communities at ERF.
Aquatic species in Knik Arm	None.	None.	None.	If aquatic species within ERF are not being affected, it is unlikely that adverse effects would occur in Knik Arm.

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preclude the utility of a continued effort to monitor background mortality with transects because any onsite/offsite comparisons must be made for the same time period. It would be useful to expand the proposed telemetry studies to monitor mallard mortality in an offsite reference area. Preferably, this could be done for more than 1 year to allow a comparison of ERF mortality to background mortality.

- **Population reference areas.** The populations of other marshes were observed in a thorough manner for only 1 year. During the 1996 field season, censuses were taken at the same UCI marshes (except Redoubt Bay and Trading Bay) only during the fall months (August to October). Another year or two of complete aerial surveys of UCI marshes would be useful for quantifying the proportion of bird use represented by ERF use.

6.0 Works Cited

Agency for Toxic Substances and Disease Registry (ATSDR). *Toxicological Profile for White Phosphorus, Draft.* U.S. Department of Health and Human Services, Public Health Service. June 1994.

Ashburn, L.L., A.J. McQueeney, and R.R. Faulkner. "Scarring and Precirrhosis of the Liver in Chronic Phosphorus Poisoning of Guinea Pigs." *Proc. Soc. Exp. Biol. Med.* 67:351-358. 1948.

Barker, E.A., E.A. Smuckler, and E.P. Benditt. "Effects of Thioacetamide and Yellow Phosphorus Poisoning on Protein Synthesis *in Vivo*." *Lab. Invest.* 12:955-960. 1963.

Bennett, A. *Fish and Wildlife Management, Part IV, Natural Resources Management Plan,* 172D Infantry Brigade (Alaska), Fort Richardson, Alaska. May 1982.

Bio/dynamics. *A One-Generation Reproduction Study in Rats with Elemental Phosphorus.* Final report. Vols. I and II. Report BD-89-153. U.S. EPA. Fiche No. OTS0518525-3, OTS0518525-4. 1991.

CH2M HILL. *Operable Unit C OB/OD Pad, Fort Richardson, Alaska, Site Investigation Work Plan.* Prepared for Department of the Army, U.S. Army Engineer District, Alaska. 1996b.

CH2M HILL. *Eagle River Flats Comprehensive Evaluation Report.* Prepared for U.S. Army Garrison, Alaska, Department of Public Works, and Department of the Army, U.S. Army Engineer District Alaska. July 1994.

CH2M HILL. *Operable Unit C Final Remedial Investigation/Feasibility Study Management Plan.* Prepared for U.S. Army, Alaska, Department of Public Works. April 1996a.

CH2M HILL. *Eagle River Flats GIS Database Review and Evaluation of Assessment Endpoints Approach*. Prepared for U.S. Army Garrison, Alaska, Department of Public Works. March 1996c.

CH2M HILL. *Evaluation of Field Studies to Support Assessment Endpoints Approach*. Prepared for U.S. Army Garrison, Alaska, Department of Public Works, and Department of the Army, U.S. Army Engineer District Alaska. April 1996d.

Coburn, D.R., J.B. DeWitt, V.J. Derby, and E. Ediger. "Phosphorus Poisoning in Waterfowl." *J. Am. Pharm. Assoc.* 39:151-158. 1950.

Eldridge, W.D. *Waterbird Utilization of Eagle River Flats–April-October 1990*. U.S. Fish and Wildlife Service, Anchorage, Alaska. December 1990.

Eldridge, W.D. *Waterbird Utilization of Eagle River Flats–April-October 1991*. U.S. Fish and Wildlife Service, Anchorage, Alaska. December 9, 1991.

Eldridge, W.D. *Waterbird Utilization of Eagle River Flats–April-October 1992*. U.S. Fish and Wildlife Service, Anchorage, Alaska. 1992.

Environmental Science and Engineering. *Eagle River Flats Expanded Site Investigation*. Fort Richardson, Alaska. Final Technical Report. Data Item A011. Prepared for the U.S. Army Toxic and Hazardous Material Agency. 1990.

Gossweiler, W.A. *Fort Richardson Natural Resource Plan*. U.S. Army. 1984.

Hurwitz, A. "Effects of Microsomal Enzyme Inducers on Animals Poisoned with Hepatotoxins." *Toxicol. Appl. Pharmacol.* 22:339-346. 1972.

Interagency Testing Committee (ITC). *Twenty-ninth Report of the Interagency Testing Committee to the Administrator, Environmental Protection Agency*. November 1991.

Lee, C.C., J.V. Dilley, J.R. Hodgson, *et al.* Mammalian Toxicity of Munition Compounds: Phase I, Acute Oral Toxicity, Primary Skin and Eye Irritation, Dermal Sensitization and Disposition and Metabolism. Environmental Protection Research Division, U.S. Army Medical Research and Development Command. Washington D.C. 1975.

Nam, S.I., B.D. Roebuck, and M.E. Walsh. Uptake and Loss of White Phosphorus in American Kestrels. *Environ. Toxicol. Chem.* Vol. 13, pp. 637-641. 1994.

Opresko, D.M., B.E. Sample, and G.W. Suter. Toxicological Benchmarks for Wildlife. Electronic Database V1.5. U.S. Department of Energy, Office of Environmental Restoration and Waste Management, Oak Ridge National Laboratory. 1996.

Pani, P., E. Gravela, C. Mazzarino, *et al.* "On the Mechanism of Fatty Liver in White Phosphorus-Poisoned Rats." *Exp. Mol. Pathol.* 16:201-209. 1972.

Peterson, T.C., C.N. Williams, and D.A. Malatjalian. "Monocyte aryl Hydrocarbon Hydroxylase (AHH) Activity Mimics Kupffer Cell and Hepatocyte AHH Activity in an Animal Model of Liver Disease." *Can. J. Physiol Pharmacol.* 69:1797-1803. 1991.

Racine, C.H., M.E. Walsh, C.M. Collins, D.J. Calkins, B.D. Roebuck, and L. Reitsma. *Waterfowl Mortality in Eagle River Flats, Alaska: The Role of Munition Residues.* Report 92-5. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). May 1992a.

Racine, C.H., M.E. Walsh, C.M. Collins, D. Lawson, K. Henry, L. Reitsma, B. Steele, R. Harris, and S.T. Bird. *White Phosphorus Contamination of Salt Marsh Sediments at Eagle River Flats, Alaska. Report I. Remedial Investigations. Report II, Treatability Studies.* U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). November 1993.

Racine, C.H., M.E. Walsh, B.D. Roebuck, C.M. Collins, D. Calkins, L. Reitsma, P. Buchl, and G. Goldfarb. "White Phosphorus Poisoning of Waterfowl in an Alaskan Salt Marsh." *Journal of Wildlife Diseases.* Vol. 2, No. 4, pp. 669-673. 1992b.

Racine, C.H., M.E. Walsh, C.M. Collins, D. Lawson, S. Bigl, K. Henry, C. Bouwkamp, J. Cummings, L. Clark, J. Davis, P. Pochop, P. O'Neil, C. Rossi, D. Sparling, R. Grove, L. Comerci, W. Eldridge, L. Reitsma, B. Steele, and S. Burson. *Interagency Expanded Site Investigation Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* Fiscal Year 1993 Final Report. C.H. Racine, ed. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). May 1994.

Racine, C.H., M.E. Walsh, C. Collins, D. Lawson, S. Bigl, B. Nadeau, L. Hunter, J. Bodette, E. Chacho, R. Haugen, K. Henry, M.R. Walsh, E. Chamberlain, D. Garfield, P. Weyrick, M. Brouillette, C. Bouwkamp, J. Cummings, L. Clark, J. Davis, P. Pochop, C. Yoder, R. Johnson, K. Gruver, K. Tope, J. Bourassa, R. Phillips, C. Rossi, D. Sparling, R. Grove, E. Hall, M. Gustafson, P. Klein, W. Eldridge, L. Reitsma, B. Steele, S. Burson, B. Roebuck, and S. Nam. *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination at Eagle River Flats, Alaska.* Fiscal Year 1994 Final Report. C.H. Racine and D. Cate, eds. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). May 1995.

Racine, C., M.E. Walsh, C. Collins, D. Lawson, S. Bigl, L. Hunter, E. Chaco, R. Haugen, M.R. Walsh, P. Robinson, R. Bailey, J. Mullen, J. Cummings, J. Davis, P. Pochop, C. Yoder, R. Johnson, K. Gruver, K. Tope, C. Rossi, W. Eldridge, L. Reitsma, B. Steele, and B. Roebuck.

Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska, FY 95 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory. September 1996.

Racine, C.H., M.E. Walsh, C.M. Collins, D.J. Calkins, B.D. Roebuck, and L.Reitsma. *Waterfowl Mortality in Eagle River Flats, Alaska: The Role of Munition Residues.* Report No. CETHA-IR-91008, U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). January 1991.

Roebuck, B.D., M.E. Walsh, C.H. Racine, L. Reitsma, B. Steele, and S.I. Nam. "Predation of Ducks Poisoned by White Phosphorus: Exposure and Risk to Predators." *Environ. Toxicol. Chem.* 13:1613-1618. 1994.

Roebuck, B. D. *Analysis of White Phosphorus (P_4) in Biota at Eagle River Flats, Fort Richardson, Alaska: 1995 Field Season.* Preliminary report. December 1, 1995.

Rosenberg, D.H. Alaska Department of Fish and Game. Personal communication. 1994.

Steele, B., L. Reitsma, and S. Burson. *Waterfowl Mortality on Eagle River Flats.* New England Institute for Landscape Ecology. 1997.

Suter, G.W., II., M.E. Will, and C. Evans. *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Terrestrial Plants.* ES/ER/TM-85. Oak Ridge National Laboratory, Environmental Sciences Division, under the direction of the Environmental Restoration Risk Assessment Council. 1993.

Tweten, R. *Eagle River Flats Waterfowl Mortality Investigation Progress Report.* U.S. Fish and Wildlife Service, Anchorage, Alaska. 1989.

U.S. Army Corps of Engineers (COE). *Risk Assessment Handbook.* Volume II, Environmental Evaluation. EM-200-1-6. November 1995a.

U.S. Army Corps of Engineers (COE). *Risk Assessment Handbook.* Volume I, Human Health Evaluation. EM-200-1-4. 1995b.

U.S. Army Environmental Hygiene Agency (USAEHA). *Receiving Water Biological Study No. 32-24-H1ZV-93: Water, Sediment, Macroinvertebrate and Fish Sampling, Eagle River Flats, Fort Richardson, Alaska, 12-23 July 1993.* Final report. March 1994.

U.S. Army Environmental Hygiene Agency (USAEHA). *Receiving Water Biological Study No. 32-24-H37Y-94: Evaluation of White Phosphorus Effects on the Aquatic Ecosystem, Eagle River Flats, Fort Richardson, Alaska, 8-17 May, 22 August - 9 September 1994.* Final report. April 1995.

U.S. Environmental Protection Agency (USEPA). *Developing a Work Scope for Ecological Assessments.* EPA ECO Update, Vol. 1, No. 4, Publication 9345.0-05I. May 1992b.

U.S. Environmental Protection Agency (USEPA). *Ecological Assessment of Hazardous Waste Sites*. 1991c.

U.S. Environmental Protection Agency (USEPA). *Ecological Assessment of Superfund Sites: An Overview*. EPA ECO Update, Vol. 1, No. 2, Publication 9345.0-05I. December 1991a.

U.S. Environmental Protection Agency (USEPA). *Ecological Significance and Selection of Candidate Assessment Endpoints*. EPA ECO Update, Vol. 3, No. 1, Publication 9345.0-11. January 1996a.

U.S. Environmental Protection Agency (USEPA). *Ecotox Thresholds*. EPA ECO Update, Vol. 3, No. 2, Publication 9345.0-12. January 1996b.

U.S. Environmental Protection Agency (USEPA). *Briefing BTAG: Initial Description of Setting, History, and Ecology of a Site*. EPA ECO Update, Vol. 1, No. 5, Publication 9345.0.051. August 1992d.

U.S. Environmental Protection Agency (USEPA). *Field Studies for Ecological Risk Assessment*. EPA ECO Update, Vol. 2, No. 3, Publication 9345.0-05I. September 1994a.

U.S. Environmental Protection Agency (USEPA). *Framework for Ecological Risk Assessment*. EPA/630/R-92/001. February 1992a.

U.S. Environmental Protection Agency (USEPA). *Risk Assessment Guidance for Superfund*. Volume II, Environmental Evaluation Manual. Office of Emergency and Remedial Response, Washington, D.C. March 1989.

U.S. Environmental Protection Agency (USEPA). *The Role of BTAGs in Ecological Assessment*. EPA ECO Update, Vol. 1, No 1, Publication 9345.0-05I. September 1991b.

U.S. Environmental Protection Agency (USEPA). *The Role of Natural Resource Trustees in the Superfund Process*. EPA ECO Update, Vol. 1, No. 3, Publication 9345.0-05I. March 1992c.

U.S. Environmental Protection Agency (USEPA). *Selecting and Using Reference Information in Superfund Ecological Risk Assessments*. EPA ECO Update, Vol. 2, No. 4, Publication 9345.0-05I. September 1994b.

U.S. Environmental Protection Agency (USEPA). *Wildlife Exposure Factors Handbook*. Office of Research and Development, Washington D.C. EPA/600/R-93/187a. December 1993.

U.S. Fish and Wildlife Service (USFWS). Endpoints for Eagle River Flats, letter to Mr. William Gossweiler, U.S. Army 6th Infantry Division, Directorate of Public Works, Environmental Resources Branch, Fort Richardson, Arkansas. January 8, 1997.

U.S. Fish and Wildlife Service (USFWS). *Proposal to Assess the Toxicology of White Phosphorus in Waterfowl and Other Species Using ERF, Alaska.* Patuxent Wildlife Research Center. 1993.

Walsh, M.E., C. Racine, C. Collins, M.R. Walsh, Maj. M. Meeks, R. Bailey, J. Cummings, R. Johnson, K. Gruver, P. Pochop, J. Davis, C. Rossi, W. Eldridge, L. Reitsma, B. Steele, and S. Burston, III. *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* Fiscal Year 1996 Draft Report. Charles M. Collins and David W. Cate, eds. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). March 1997.

Yon, R.L., R.S. Wentsel, and J.M. Bane. *Programmatic Life Cycle Environmental Assessment for Smoke/Obscurants - Red, White, and Plasticized White Phosphorus.* Vol. 2. Prepared for Project Manager for Smoke/Obscurants. USAAMCC, Environmental Technology Division, Aberdeen Proving Ground. July 1983.

Zitko, V., D.E. Aikens, S.N. Tibbo, K.W.T. Besch, and J.M. Anderson. "Toxicity of yellow phosphorus to herring (*Clupea harengus*), Atlantic salmon (*Salmo salar*), lobster (*Homarus americanus*) and beach flea (*Gammarus oceanicus*)." *J. Fish Red. Ed. Canada.* 27:21-29. 1970.

Attachment 1
White Phosphorus Concentrations in Nonhuman Tissues

Attachment 1
White Phosphorus Tissue Concentrations in Birds and Mammals
OUC Ecological Risk Assessment
Fort Richardson, Alaska

Specimen (date collected)	Sample Size	Area	Type of Tissue	Mass of Tissue (g - ww)	Mass of White Phosphorus (µg)	Concentration of White Phosphorus in Tissue (µg/g)	Source	Type Study	Form of WP
Waterfowl									
Pintail		Area C	Heart	1.7	0	0	Racine et al. 1991	In field	In situ
Pintail		Area C	Liver	7.1	0.351	0.049	Racine et al. 1991	In field	In situ
Pintail		Area C	Gizzard contents	1.5	111	74	Racine et al. 1991	In field	In situ
Pintail		Area C	Intestinal contents	1.3	1.07	0.82	Racine et al. 1991	In field	In situ
Pintail-male (5/7/95)		E. side Pond @ BTP (Bread Truck Pond)	Gizzard contents		0.0493		Roebuck, 1995	In field	In situ
Pintail-female (5/11/95)		E. side pond @ BTP	Gizzard contents		ND		Roebuck, 1995	In field	In situ
Pintail-female (8/10/95)		200 ft. from C tower	Gizzard contents		2.71		Roebuck, 1995	In field	In situ
Pintail-female (8/18/95)		South of area C tower	Gizzard contents		ND		Roebuck, 1995	In field	In situ
Pintail-male (8/31/95)		Area A	Gizzard contents		80.9		Roebuck, 1995	In field	In situ
Pintail-male (9/2/95)		Canoe Pt. Channel	Gizzard contents		0.132		Roebuck, 1995	In field	In situ
Pintail-female (9/6/95)		North pond of C Pond	Gizzard contents		2.08		Roebuck, 1995	In field	In situ
Pintail-female (9/7/95)		BTP	Gizzard contents		0.606		Roebuck, 1995	In field	In situ
Pintail-male (5/26/93)		BTP	Skin			Det. ww	Sparling et al., in Racine et al. 1994	In field	In situ
Pintail-male (5/26/93)		BTP	Gizzard contents			0.24 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Pintail-male (8/24/93)		Racine Island	Skin			2.64 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Pintail-male (8/24/93)		Racine Island	Liver			0.17 ww	Sparling et al., in Racine et al. 1994	In field	In situ
ıtail-male (8/24/93)		Racine Island	Gizzard contents			24.4 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Pintail-male (8/26/93)		Racine Island	Skin			0.32 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Pintail-male (8/26/93)		Racine Island	Liver			0 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Pintail-male (8/26/93)		Racine Island	Gizzard contents			96.9 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Pintail - male	1		Wing tissue			0.017 ww	Roebuck et al., 1994	In field	In situ
Blue-winged teal-male (5/25/93)		C Pond	Skin			Det. ww	Sparling et al., in Racine et al., 1994	In field	In situ
Green-winged teal-male (9/11/90)		Area C	Liver	4.6	0.047	0.010	Racine et al. 1991	In field	In situ
Green-winged teal-male (9/11/90)		Area C	Kidney	2.9	0	0	Racine et al. 1991	In field	In situ
Green-winged teal-male (9/11/90)		Area C	Gizzard contents	0.53	0.295	0.56	Racine et al. 1991	In field	In situ
Green-winged teal-male (9/11/90)		Area C	Intestinal contents	not weighed	0.081	NA	Racine et al. 1991	In field	In situ
Green-winged teal-male (9/11/90)		Area C	Intestines	10.4	9.8	0.94	Racine et al. 1991	In field	In situ
Green-winged teal-female (9/12/90)		Area C	Blood	1.7	0	0	Racine et al. 1991	In field	In situ
Green-winged teal-female (9/12/90)		Area C	Liver	6.3	0.91	0.144	Racine et al. 1991	In field	In situ
Green-winged teal-female (9/12/90)		Area C	Heart	2.1	0.159	0.076	Racine et al. 1991	In field	In situ
Green-winged teal-female (9/12/90)		Area C	Kidney	1.1	0.015	0.014	Racine et al. 1991	In field	In situ
ɜen-winged teal-female (/12/90)		Area C	Gizzard contents	0.15	0.012	0.08	Racine et al. 1991	In field	In situ
Green-winged teal-female (9/12/90)		Area C	Intestines	not weighed	6.16	NA	Racine et al. 1991	In field	In situ

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Specimen (date collected)	Sample Size	Area	Type of Tissue	Mass of Tissue (g - ww)	Mass of White Phosphorus (µg)	Concentration of White Phosphorus in Tissue (µg/g)	Source	Type Study	Form of WP
Green-winged teal-male (9/12/90)		Area C	Heart	2	0.389	0.19	Racine et al. 1991	In field	In situ
Green-winged teal-male (9/12/90)		Area C	Blood	4.4	0	0	Racine et al. 1991	In field	In situ
Green-winged teal-male (9/12/90)		Area C	Liver	8.7	0.411	0.049	Racine et al. 1991	In field	In situ
Green-winged teal-male (9/12/90)		Area C	Kidney	2.2	0.043	0.019	Racine et al. 1991	In field	In situ
Green-winged teal-male (9/12/90)		Area C	Gizzard contents	0.17	0.022	0.13	Racine et al. 1991	In field	In situ
Green-winged teal-male (9/12/90)		Area C	Intestines	16	7.9	0.494	Racine et al. 1991	In field	In situ
Green-winged teal-collected live, survived 9.5 hours (9/15/90)		Area C	Pectoral muscle	35.6	0.059	0.0016	Racine et al. 1991	In field	In situ
Green-winged teal-collected live, survived 9.5 hours (9/15/90)		Area C	Heart	4	0	0	Racine et al. 1991	In field	In situ
Green-winged teal-collected live, survived 9.5 hours (9/15/90)		Area C	Liver	10.4	0	0	Racine et al. 1991	In field	In situ
Green-winged teal-collected live, survived 9.5 hours (9/15/90)		Area C	Intestines	14.7	0.08	0.005	Racine et al. 1991	In field	In situ
Green-winged teal-collected live, survived 9.5 hours (9/15/90)		Area C	Kidney	3.5	0	0	Racine et al. 1991	In field	In situ
Green-winged teal-collected live, survived 9.5 hours (9/15/90)		Area C	Brain	2	0	0	Racine et al. 1991	In field	In situ
Green-winged teal-collected live, survived 9.5 hours (9/15/90)		Area C	Fat	8.8	0.4	0.045	Racine et al. 1991	In field	In situ
Green-winged teal-collected live, survived 9.5 hours (9/15/90)		Area C	Gizzard muscle	11.8	trace	trace	Racine et al. 1991	In field	In situ
Green-winged teal-collected live, survived 9.5 hours (9/15/90)		Area C	Gizzard contents	0.67	0.08	0.12	Racine et al. 1991	In field	In situ
Green-winged teal male (8/19/95)		4 m. South of Stake #5, on C-edge transect	Gizzard contents		ND		Roebuck, 1995	In field	In situ
Green-winged teal male (8/31/95)		W end of C pond	Gizzard contents		0.592		Roebuck, 1995	In field	In situ
Green-winged teal female (9/8/95)		BTP	Gizzard contents		11.4		Roebuck, 1995	In field	In situ
Green-winged teal female (9/14/95)		BTP North West corner	Gizzard contents		0.444		Roebuck, 1995	In field	In situ
Green-winged teal female (8/19/93)		Area A	Skin			0.30ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal female (8/19/93)		Area A	Liver			0.16 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal female (8/24/93)		Racine Island	Skin			1.25 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal female (8/24/93)		Racine Island	Liver			0.15 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal female (8/24/93)		Racine Island	Gizzard contents			1.00 ww	Sparling et al., in Racine et al. 1994	In field	In situ

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Green-winged teal female (8/24/93)		Racine Island	Skin			1.50 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal female (8/24/93)		Racine Island	Liver			0.15 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Fat			0.96 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Skin			0.55 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Liver			0.17 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Gizzard contents			0.74 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Fat			1.37 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Skin			1.23 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Liver			0.17 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Fat			2.49 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Skin			2.16 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Liver			0.15 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Gizzard contents			2.15 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Fat			1.15 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Skin			1.01 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Liver			Det. ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Gizzard contents			0.10ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal U (8/24/93)		Racine Island	Skin			2.09 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal U (8/24/93)		Racine Island	Liver			0.16 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal U (8/24/93)		Racine Island	Gizzard contents			2.96 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal U (8/24/93)		Racine Island	Skin			1.12 ww	Sparling et al., in Racine et al. 1994	In field	In situ

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Green-winged teal U (8/24/93)		Racine Island	Gizzard contents			0 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Fat			19.06 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Skin			5.71 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Liver			2.70 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/24/93)		Racine Island	Gizzard contents			3150 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal female (8/24/93)		Racine Island	Fat			4.86 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal female (8/24/93)		Racine Island	Skin			3.10 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal female (8/24/93)		Racine Island	Liver			0.19 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/26/93)		Racine Island	Fat			1.49 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/26/93)		Racine Island	Skin			0.94 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/26/93)		Racine Island	Liver			0 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/26/93)		Racine Island	Gut			0 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal male (8/26/93)		Racine Island	Liver			0.17 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal female (8/31/93)		Racine Island	Fat			1.53 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal female (8/31/93)		Racine Island	Skin			2.05 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal female (8/31/93)		Racine Island	Liver			0 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal female (8/31/93)		Racine Island	Gizzard contents			11.58 ww	Sparling et al., in Racine et al. 1994	In field	In situ
Green-winged teal			Digestive tract		3		Roebuck & Nam in Racine et al., 1995	In field	In situ
Green-winged teal			Digestive tract		ND		Roebuck & Nam in Racine et al., 1995	In field	In situ
Teal - male	8		Gizzard contents		0.021-1,310 (median = 0.48)		Roebuck et al., 1994	In field	In situ
Teal - male	5		Abdominal fat			0.052-1.80 ww (median = 0.187)	Roebuck et al., 1994	In field	In situ
Teal - male	9		Skin			0.012-6.34 ww (median = 0.0733)	Roebuck et al., 1994	In field	In situ
Teal - male	8		Breast muscle			0.001-0.022 ww (median = 0.007)	Roebuck et al., 1994	In field	In situ

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Teal - female	3		Gizzard contents		37.8-8,820 (median = 1,084)		Roebuck et al., 1994	In field	In situ
Teal - female	3		Abdominal fat			0.235-5.92 ww (median = 2.04)	Roebuck et al., 1994	In field	In situ
Teal - female	3		Skin			0.142-1.37 ww (median = 0.214)	Roebuck et al., 1994	In field	In situ
Teal - female	3		Breast muscle			0.006-0.560 ww (median = 0.010)	Roebuck et al., 1994	In field	In situ
Teal - male	1		Unknown tissue			0.521 ww	Roebuck et al., 1994	In field	In situ
Shoveler - female	1		Gizzard contents		0.751		Roebuck et al., 1994	In field	In situ
Shoveler - female	1		Abdominal fat			0.047 ww	Roebuck et al., 1994	In field	In situ
Shoveler - female	1		Skin			0.067 ww	Roebuck et al., 1994	In field	In situ
Shoveler - female	1		Breast muscle			ND	Roebuck et al., 1994	In field	In situ
Shoveler - male	1		Muscle			0.060 ww	Roebuck et al., 1994	In field	In situ
Mallard-male		Area C	Gizzard contents	3.1	60.5	19.5	Racine et al. 1991	In field	In situ
Mallard-male		Area C	Fat	0	NA	NA	Racine et al. 1991	In field	In situ
Mallard-male		Area C	Gizzard contents	5.4	1.5	0.28	Racine et al. 1991	In field	In situ
Mallard-male		Area C	Fat	2.6	0	0	Racine et al. 1991	In field	In situ
Mallard-male (8/21/95)		West A pond	Gizzard contents		0.231		Roebuck, 1995	In field	In situ
Mallard-female (8/24/95)		Racine Island	Gizzard contents		1.19		Roebuck, 1995	In field	In situ
Mallard-male (8/25/95)		Area C	Gizzard contents		1.29		Roebuck, 1995	In field	In situ
Mallard-female (8/26/95)		Lawson's Pond stake # 9	Gizzard contents		125		Roebuck, 1995	In field	In situ
Mallard-female (8/26/95)		Area C near Clunie Creek in pond	Gizzard contents		0.273		Roebuck, 1995	In field	In situ
Mallard-female (8/26/95)		CD area near CD bluff	Gizzard contents		ND		Roebuck, 1995	In field	In situ
Mallard-female (8/29/95)		CD channel N of Clunie Creek	Gizzard contents		ND		Roebuck, 1995	In field	In situ
Mallard-chick (9/14/95)		BTP, North west corner	Gizzard contents		5.12		Roebuck, 1995	In field	In situ
Mallard-male (10/7/95)		20 m E of mid E-W UTM Stake on BTP rectangle	Gizzard contents		ND		Roebuck, 1995	In field	In situ
Mallard-male (10/13/95)		Mid C pond	Gizzard contents		21,400		Roebuck, 1995	In field	In situ
Mallard-male (10/14/95)		15 m South of Lawson's pond transect stake #1 between C-pond & Clunie Creek	Gizzard contents		49.5		Roebuck, 1995	In field	In situ
Mallard-male (8/24/93)		Racine island	Skin			3.99 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/24/93)		Racine island	Liver			0.31 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/24/93)		Racine island	Gizzard contents			628 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-female (8/24/93)		Middle of area C	Skin			5.56 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-female (8/24/93)		Middle of area C	Liver			0.47 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-female (8/24/93)		Middle of area C	Gizzard contents			270 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/25/93)		Middle of area C	Skin			0 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/25/93)		Middle of area C	Liver			0 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/25/93)		Middle of area C	Gizzard contents			Det. ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-female (8/25/93)		Middle of area C	Liver			0 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-female (8/26/93)		Racine island	Skin			1.26 ww	Sparling et al., in Racine et al., 1994	In field	In situ

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Mallard-female (8/26/93)		Racine island	Liver			0.21 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-female (8/26/93)		Racine island	Gizzard contents			113 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-female (8/26/93)		Racine island	Skin			0.12 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-female (8/26/93)		Racine island	Liver			21.4 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-female (8/26/93)		Racine island	Gizzard contents			4.1 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/26/93)		Racine island	Skin			1.67 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/26/93)		Racine island	Liver			0.27 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/26/93)		Racine island	Gizzard contents			170 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/26/93)		Racine island	Skin			20.5 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/26/93)		Racine island	Liver			1.3 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/26/93)		Racine island	Skin			1.23 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/26/93)		Racine island	Liver			Det. ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/26/93)		Racine island	Gizzard contents			7.67 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/26/93)		Racine island	Skin			1.54 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/26/93)		Racine island	Liver			0.19 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/26/93)		Racine island	Gizzard contents			8.33 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-female (8/26/93)		Racine island	Skin			1.60 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-female (8/26/93)		Racine island	Liver			0.13 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-female (8/26/93)		Racine island	Gizzard contents			269 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/31/93)		Racine island	Fat			0.23 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/31/93)		Racine island	Skin			1.33 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (8/31/93)		Racine island	Liver			0 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (9/9/93)		Racine island	Fat			1.05 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (9/9/93)		Racine island	Skin			0.71 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (9/9/93)		Racine island	Liver			0 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-male (9/9/93)		Racine island	Gizzard contents			0.21 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-female (9/9/93)		Racine island	Skin			0.41 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard female (9/9/93)		Racine island	Liver			0.16 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard-female (9/9/93)		Racine island	Gizzard contents			36.0 ww	Sparling et al., in Racine et al., 1994	In field	In situ
Mallard - male	1		Gizzard contents		1.32		Roebuck et al., 1994	In field	In situ
Mallard - male	1		Abdominal fat			0.42 ww	Roebuck et al., 1994	In field	In situ
Mallard - male	1		Skin			0.06 ww	Roebuck et al., 1994	In field	In situ
Mallard - male	1		Breast muscle			0.004 ww	Roebuck et al., 1994	In field	In situ

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Mallard (introduced)	4		Skin/Fat			0.406-2.35 ww	Roebuck et al., 1994	In field	In situ
Mallard (introduced)	4		Brain			<0.5 ww	Roebuck et al., 1994	In field	In situ
Mallard (introduced)	4		Breast muscle			<0.5 ww	Roebuck et al., 1994	In field	In situ
Mallard (introduced)	4		Thigh muscle			<0.5 ww	Roebuck et al., 1994	In field	In situ
Mallard (introduced)	4		Liver			<0.5 ww	Roebuck et al., 1994	In field	In situ
Mallard (introduced)	4		Heart			<0.5 ww	Roebuck et al., 1994	In field	In situ
Mallard (introduced)	4		Kidney			<0.5 ww	Roebuck et al., 1994	In field	In situ
Mallard (introduced)	4		Spleen			<0.5 ww	Roebuck et al., 1994	In field	In situ
Mallard			Fat			0.90 ww	Sparling et al., in Racine et al., 1994	Lab. expenment dose level - 7.1 mg WP/kg-body weight (bw)	Dissolved in oil
Mallard			Fat			0.97ww	Sparling et al., in Racine et al., 1994	Lab. expenment dose level - 7.1 mg WP/kg-bw	Dissolved in oil
Mallard			Fat			1.78 ww	Sparling et al., in Racine et al., 1994	Lab. expenment dose level - 7.1 mg WP/kg-bw	Dissolved in oil
llard			Skin			0.6-0.7 ww	Sparling et al., in Racine et al., 1994	Lab. expenment	Dissolved in oil
Mallard	5 survived		Fat			0 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 0 mg WP/kg-bw
Mallard	5 survived		Skin			0 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 0 mg WP/kg-bw
Mallard	6 survived		Liver			0 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 0 mg WP/kg-bw
Mallard	1 died		Fat			0.275 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose<6.1mg WP/kg-bw
Mallard	8 survived		Fat			0.001ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose<6.1mg WP/kg-bw
Mallard	1 died		Skin			0.132 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose<6.1mg WP/kg-bw
Mallard	8 survived		Skin			0 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose<6.1mg WP/kg-bw
Mallard	1 died		Liver			0 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose<6.1mg WP/kg-bw
Mallard	8 survived		Liver			0 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose<6.1mg WP/kg-bw
Mallard	2 died		Fat			0.562 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 6.1mg WP/kg-bw
Mallard	4 survived		Fat			0 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 6.1mg WP/kg-bw
Mallard	2 died		Skin			0.408 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 6.1mg WP/kg-bw
Mallard	5 survived		Skin			0 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 6.1mg WP/kg-bw
Mallard	2 died		Liver			0.014 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 6.1mg WP/kg-bw
Mallard	4 survived		Liver			0 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 6.1mg WP/kg-bw
Mallard	4 died		Fat			1.054 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 7.1mg WP/kg-bw
lard	3 survived		Fat			0.022 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 7.1mg WP/kg-bw
Mallard	4 died		Skin			0.458 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 7.1mg WP/kg-bw

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Specimen (date collected)	Sample Size	Area	Type of Tissue	Mass of Tissue (g - ww)	Mass of White Phosphorus (µg)	Concentration of White Phosphorus in Tissue (µg/g)	Source	Type Study	Form of WP
Mallard	3 survived		Skin			0.004 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 7.1mg WP/kg-bw
Mallard	4 died		Liver			0.006 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 7.1mg WP/kg-bw
Mallard	3 survived		Liver			0 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 7.1mg WP/kg-bw
Mallard	4 died		Fat			0.632 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 8.0mg WP/kg-bw
Mallard	1 survived		Fat			0.004 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 8.0mg WP/kg-bw
Mallard	5 died		Skin			0.463 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 8.0mg WP/kg-bw
Mallard	1 survived		Skin			0 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 8.0mg WP/kg-bw
Mallard	5 died		Liver			0.001 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 8.0mg WP/kg-bw
Mallard	1 survived		Liver			0 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 8.0mg WP/kg-bw
Mallard	4 died		Fat			0.442 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 9.1mg WP/kg-bw
Mallard	2 survived		Fat			0.007 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 9.1mg WP/kg-bw
Mallard	4 died		Skin			0.199 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 9.1mg WP/kg-bw
Mallard	2 survived		Skin			0 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 9.1mg WP/kg-bw
Mallard	4 died		Liver			0.002 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in oil Dose 9.1mg W
Mallard	2 survived		Liver			0 ww	Sparling et al., in Racine et al., 1994	Toxicological study	Dissolved in Dose 9.1mg WP/kg-bw
Domestic Mallard	6		Fat			0.39 - 3.52	Racine et al., 1992c	Lab toxicity study	Dose 12 mg WP /kg-bw Dissolved in oil
Domestic Mallard	2		Breast muscle			0.013 - 0.052	Racine et al., 1991 and 1992b	Lab toxicity study	Dose 12 mg WP /kg-bw
Domestic Mallard	2		Brain			ND - 0.007	Racine et al., 1991 and 1992b	Lab toxicity study	Dose 12 mg WP /kg-bw
Domestic Mallard	6		Liver			0.01 - 0.68	Racine et al., 1992c	Lab toxicity study	Dose 12 mg WP /kg-bw Dissolved in oil
Domestic Mallard	5		Skin			0.59 - 2.23	Racine et al., 1992c	Lab toxicity study	Dose 12 mg WP /kg-bw Dissolved in Oil
Mallard	10 survived		Fat			0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Dose 0 mg pelletized WP /kg
Mallard	10 survived		Liver			0 ww	Sparling et al., in Racine et al., 1995	Toxicological study.	Dose 0 mg pelletized WP /kg
Mallard	7 survived		Fat			0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Dose 2.4 mg pelletized WP /k
Mallard	3 died		Fat			0.657 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Dose 2.4 mg pelletized WP /k
Mallard	7 survived		Liver			0.003 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Dose 2.4 mg pelletized WP /k
Mallard	3 died		Liver			0.005 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Dose 2.4 mg pelletized WP /k
Mallard	4 survived		Fat			0.039 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Dose 3.4 mg pelletized WP /k
Mallard	6 died		Fat			0.187 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Dose 3.4 mg pelle /k

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Mallard	4 survived		Liver			0.003 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Dose 3.4 mg pelletized WP /kg
Mallard	6 died		Liver			0.940 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Dose 3.4 mg pelletized WP /kg
Mallard	2 survived		Fat			0.313 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Dose 6.5 mg pelletized WP /kg
Mallard	12 died		Fat			0.312 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Dose 6.5 mg pelletized WP /kg
Mallard	2 survived		Liver			0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Dose 6.5 mg pelletized WP /kg
Mallard	12 died		Liver			0.001 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Dose 6.5 mg pelletized WP /kg
Mallard (1 year old males) (avg)			Fat			0.001ww	Sparling et al., in Racine et al., 1995	Toxicological study	Control
Mallard (1 year old males) (avg)			Kidney			0.003 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Control
Mallard (1 year old males) (avg)			Liver			0.001 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Control
Mallard (1 year old males) (avg)			Fat			0.178 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 4mg/kg pelletized WP suspended in distilled water
Mallard (1 year old males) (avg)			Kidney			0.007 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 4mg/kg pelletized WP suspended in distilled water
Mallard (1 year old males) (avg)			Liver			0.001 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 4mg/kg pelletized WP suspended in distilled water
Mallard (1 year old males) (avg)			Fat			0.054 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletized WP suspended in distilled water - sampled 3 hr. after dose
Mallard (1 year old males) (avg)			Kidney			0.001 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletized WP suspended in distilled water - sampled 3 hr. after dose
Mallard (1 year old males) (avg)			Liver			0.003 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletized WP suspended in distilled water - sampled 3 hr. after dose
Mallard (1 year old males) (avg)			Fat			0.074 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletized WP suspended in distilled water - sampled 6 hr. after dose
Mallard (1 year old males) (avg)			Kidney			0.001ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletized WP suspended in distilled water - sampled 6 hr. after dose
Mallard (1 year old males) (avg)			Liver			0.0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletized WP suspended in distilled water - sampled 6 hr. after dose
Mallard (1 year old males) (avg)			Fat			0.030 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletized WP suspended in distilled water - sampled 12 hr. after dose

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Mallard (1 year old males) (avg)			Kidney			0.0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletize WP suspended in distilled water - sampled 12 hr. after dose
Mallard (1 year old males) (avg)			Liver			0.001 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletize WP suspended in distilled water - sampled 12 hr. after dose
Mallard (1 year old males) (avg)			Fat			0.015 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletize WP suspended in distilled water - sampled 24 hr. after dose
Mallard (1 year old males) (avg)			Kidney			0.001 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletize WP suspended in distilled water - sampled 24 hr. after dose
Mallard (1 year old males) (avg)			Liver			0.0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletize WP suspended in distilled water - sampled 24 hr. after dose
Mallard (1 year old males) (avg)			Fat			0.001ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletize WP suspended in distilled water - sampled 96 hr. after dose
Mallard (1 year old males) (avg)			Kidney			0.001ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletize WP suspended in distilled water - sampled 96 hr. after dose
Mallard (1 year old males) (avg)			Liver			0.0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg WP suspended in distilled water - sampled 96 hr. after dose
Mallard (1 year old males) (avg)			Fat			0.001ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletize WP suspended in distilled water - sampled 240 hr. after dose
Mallard (1 year old males) (avg)			Kidney			0.0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletize WP suspended in distilled water - sampled 240 hr. after dose
Mallard (1 year old males) (avg)			Liver			0.0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 1mg/kg pelletize WP suspended in distilled water - sampled 240 hr. after dose
Mallard (1 year old males) (avg)			Fat			0.083 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletize WP suspended in distilled water - sampled 3 hr. after dose
Mallard (1 year old males) (avg)			Kidney			0.011 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletize WP suspended in distilled water - sampled 3 hr. after dose
Mallard (1 year old males) (avg)			Liver			0.010 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletize WP suspended in distilled water - sampled 3 hr. after dose
Mallard (1 year old males) (avg)			Fat			0.077 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletize WP suspended in distilled water - sampled 6 hr. after dose
Mallard (1 year old males) (avg)			Kidney			0.0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletize WP suspended in distilled water - sampled 6 hr. after dose

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Specimen (date collected)	Sample Size	Area	Type of Tissue	Mass of Tissue (g - ww)	Mass of White Phosphorus (µg)	Concentration of White Phosphorus in Tissue (µg/g)	Source	Type Study	Form of WP
Mallard (1 year old males) (avg)			Liver			0.001 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletized WP suspended in distilled water - sampled 6 hr. after dose
Mallard (1 year old males) (avg)			Fat			0.113 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletized WP suspended in distilled water - sampled 12 hr. after dose
Mallard (1 year old males) (avg)			Kidney			0.0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletized WP suspended in distilled water - sampled 12 hr. after dose
Mallard (1 year old males) (avg)			Liver			0.001 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletized WP suspended in distilled water - sampled 12 hr. after dose
Mallard (1 year old males) (avg)			Fat			0.012 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletized WP suspended in distilled water - sampled 24 hr. after dose
Mallard (1 year old males) (avg)			Kidney			0.005 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletized WP suspended in distilled water - sampled 24 hr. after dose
Mallard (1 year old males) (avg)			Liver			0.0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletized WP suspended in distilled water - sampled 24 hr. after dose
Mallard (1 year old males) (avg)			Fat			0.001 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletized WP suspended in distilled water - sampled 96 hr. after dose
Mallard (1 year old males) (avg)			Kidney			0.0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletized WP suspended in distilled water - sampled 96 hr. after dose
Mallard (1 year old males) (avg)			Liver			0.0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletized WP suspended in distilled water - sampled 96 hr. after dose
Mallard (1 year old males) (avg)			Fat			0.028 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletized WP suspended in distilled water - sampled 240 hr. after dose
Mallard (1 year old males) (avg)			Kidney			0.004 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletized WP suspended in distilled water - sampled 240 hr. after dose
Mallard (1 year old males) (avg)			Liver			0.001 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Single dose 2mg/kg pelletized WP suspended in distilled water - sampled 240 hr. after dose
Mallard			Unabsorbed WP in Digestive tract		over 3,500		Roebuck & Nam, in Racine et al., 1995	Toxicity study	Dose 12 mg WP/kg-bw. WP in small particle form
Mallard (mean ± SEM)	6		Residual WP in digestive tract		544 ± 251		Roebuck & Nam, in Racine et al., 1995	Toxicity study	Dose 12 mg WP/kg-bw. WP dissolved in oil (1.57 mg WP/mL oil)
Mallard (mean ± SEM)	6		Residual WP in digestive tract		1,887 ± 473		Roebuck & Nam, in Racine et al., 1995	Toxicity study	Dose 12 mg WP/kg-bw. WP in small particle form
Mallard (mean ± SEM)	6		Residual WP in digestive tract		962 ± 275		Roebuck & Nam, in Racine et al., 1995	Toxicity study	Dose 12 mg WP/kg-bw. WP in large particle form

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Mallard	9		Bile of gall bladder:			ND-0.242 (bile)	Roebuck & Nam, in Racine et al., 1995	Toxicity study	Dose 12 mg WP/kg-bw 3 ducks, WP in large particl- form, 3 ducks, WP dissolvec oil (1.57 mg WP/mL oil), 3 ducks, WP in small particl- form
Mallard		Area C	In entire digestive tract		1,100		Roebuck & Nam, in Racine et al., 1995. Sparling et al., in Racine et al., 1994	Pen enclosures of DWRC at ERF	Not specified
Mallard		Area C	In entire digestive tract		2,000		Roebuck & Nam, in Racine et al., 1995. Sparling et al., in Racine et al., 1994	Pen enclosures of DWRC at ERF	Not specified
Mallard		Area C	In entire digestive tract		36		Roebuck & Nam, in Racine et al., 1995. Sparling et al., in Racine et al., 1994	Pen enclosures of DWRC at ERF	Not specified
Mallard		Area C	In entire digestive tract		109		Roebuck & Nam, in Racine et al., 1995. Sparling et al., in Racine et al., 1994	Pen enclosures of DWRC at ERF	Not specified
Mallard		Area C	In entire digestive tract		2		Roebuck & Nam, in Racine et al., 1995. Sparling et al., in Racine et al., 1994	Pen enclosures of DWRC at ERF	Not specified
Mallard		Area C	fat			ND	Roebuck & Nam, in Racine et al., 1995. Sparling et al., in Racine et al., 1994	Pen enclosures of DWRC at ERF	Not specified
Mallard		Area C	fat			ND	Roebuck & Nam, in Racine et al., 1995. Sparling et al., in Racine et al., 1994	Pen enclosures of DWRC at ERF	Not specified
Mallard		Area C	fat			1.504	Roebuck & Nam, in Racine et al., 1995. Sparling et al., in Racine et al., 1994	Pen enclosures of DWRC at ERF	Not specified
Mallard		Area C	fat			ND	Roebuck & Nam, in Racine et al., 1995. Sparling et al., in Racine et al., 1994	Pen enclosures of DWRC at ERF	Not specified
Mallard		Area C	fat			0.269	Roebuck & Nam, in Racine et al., 1995. Sparling et al., in Racine et al., 1994	Pen enclosures of DWRC at ERF	Not specified
Duck			In digestive tract		0.115		Roebuck & Nam, in Racine et al., 1995	In field	In situ
Duck			In digestive tract		0.032		Roebuck & Nam, in Racine et al., 1995	In field	In situ
Duck		Area CD	In digestive tract		0.169		Roebuck & Nam, in Racine et al., 1995	In field	In situ
Duck			fat			0.292	Roebuck & Nam, in Racine et al., 1995	In field	In situ
Duck			fat			ND	Roebuck & Nam, in Racine et al., 1995	In field	In situ
Duck			fat			2.846	Roebuck & Nam, in Racine et al., 1995	In field	In situ
Duck		Area CD	fat			0.752	Roebuck & Nam, in Racine et al., 1995	In field	In situ
Duck		Area CD	fat			0.873	Roebuck & Nam, in Racine et al., 1995	In field	In situ
Duck (2 green-winged teal, 1 pintail)	3		Skin/Fat			0.018-1.57 ww	Roebuck et al., 1994	In field	In situ

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Duck (2 green-winged teal, 1 pintail)	3		Brain			ND-0.060 ww	Roebuck et al., 1994	In field	In situ
Duck (2 green-winged teal, 1 pintail)	3		Breast muscle			<0.5 ww	Roebuck et al., 1994	In field	In situ
Duck (2 green-winged teal, 1 pintail)	3		Thigh muscle			<0.5 ww	Roebuck et al., 1994	In field	In situ
Duck (2 green-winged teal, 1 pintail)	3		Liver			<0.5 ww	Roebuck et al., 1994	In field	In situ
Duck (2 green-winged teal, 1 pintail)	3		Heart			<0.5 ww	Roebuck et al., 1994	In field	In situ
Duck (2 green-winged teal, 1 pintail)	3		Kidney			<0.5 ww	Roebuck et al., 1994	In field	In situ
Duck (2 green-winged teal, 1 pintail)	3		Spleen			<0.5 ww	Roebuck et al., 1994	In field	In situ
Tundra swan-adult		Area C	Gizzard contents	4.4	0.24	0.054	Racine et al., 1991	In field	In situ
Tundra swan-adult			Fat	6.9	0	0	Racine et al., 1992b	In field	In situ
Tundra swan-adult			Blood serum	not weighed	0	0	Racine et al., 1992b	In field	In situ
Tundra swan-adult			Whole blood	not weighed	0	0	Racine et al., 1992b	In field	In situ
Tundra swan- immature		Area C	Gizzard contents	10.7	0.24	0.022	Racine et al., 1991	In field	In situ
Tundra swan- immature		Area C	Fat	6.3	2.03	0.32	Racine et al., 1991	In field	In situ
Tundra swan- immature		Area C	Gizzard contents	53.1	11,000	206	Racine et al., 1991	In field	In situ
Tundra swan- immature		Area C	Fat	6.6	19.2	2.9	Racine et al., 1991	In field	In situ
Tundra swan-adult		Area C	Gizzard contents	1.4	0.085	0.061	Racine et al., 1991	In field	In situ
Tundra swan-adult		Area C	Fat	9.1	0.93	0.102	Racine et al., 1991	In field	In situ
Tundra swan- male (5/2/95)		W. of A pond within 200 meters of A tower	Gizzard contents		0.0238		Roebuck, 1995	In field	In situ
Tundra swan (10/2/95)		Area D ponded area	Gizzard contents		positive		Roebuck, 1995	In field	In situ
Tundra swan (10/2/95)		Area D ponded area	Gizzard contents		positive		Roebuck, 1995	In field	In situ
Tundra swan (10/2/95)		Area D ponded area	Gizzard contents		positive		Roebuck, 1995	In field	In situ
Tundra swan (10/2/95)		Area D ponded area	Gizzard contents		positive		Roebuck, 1995	In field	In situ
Wild swan	3		Skin			0.01 - 0.14	Racine, et al., 1992c	In field	In situ
Nonwaterfowl									
Northern Phalarope-female (5/28/93)		Boardwalk near transition zone between areas C and D	Skin			0 ww	Sparling et al, in Racine et al., 1994	In field	In situ
Northern Phalarope-female (5/28/93)		Boardwalk near transition zone between areas C and D	Crop and gizzard			0 ww	Sparling et al, in Racine et al., 1994	In field	In situ
Northern Phalarope	8		Skin			ND	Sparling et al, in Racine et al., 1994	Shot in field	In situ
Northern Phalarope	8		Crop contents			ND	Sparling et al, in Racine et al., 1994	Shot in field	In situ
Lesser Yellowlegs - female (8/19/93)		Area A	Skin			0 ww	Sparling et al, in Racine et al., 1994	In field	In situ
Red-necked phalarope	6		Gizzard contents		0.051-15,500 ww (median = 1.17)		Roebuck et al., 1994	In field	In situ
Red-necked phalarope	6		Skin			0.451-3.190 (median = 0.593)	Roebuck et al., 1994	In field	In situ
Red-necked phalarope	3		Yolk from yolk sacs			0.031-0.106 (median = 0.080)	Roebuck et al., 1994	In field	In situ
Red-necked phalarope	1		Intestine remains			4.565 ww	Roebuck et al., 1994	In field	In situ
Lesser Yellowlegs - female (8/19/93)		Area A	Liver			0 ww	Sparling et al, in Racine et al., 1994	In field	In situ
Lesser Yellowlegs	5		Skin			ND	Sparling et al, in Racine et al., 1994	Shot in field	In situ
sser Yellowlegs	5		Crop contents			ND	Sparling et al, in Racine et al., 1994	Shot in field	In situ

Attachment 1
White Phosphorus Tissue Concentrations in Birds and Mammals
OUC Ecological Risk Assessment
Fort Richardson, Alaska

Specimen (date collected)	Sample Size	Area	Type of Tissue	Mass of Tissue (g - ww)	Mass of White Phosphorus (µg)	Concentration of White Phosphorus in Tissue (µg/g)	Source	Type Study	Form of WP
Greater Yellowlegs male (6/17/93)		C tower	Skin			0.40 ww	Sparling et al. in Racine et al., 1994	In field	In situ
Greater Yellowlegs	3		Skin			ND	Sparling et al, in Racine et al., 1994	Shot in field	In situ
Greater Yellowlegs	3		Crop contents			ND	Sparling et al, in Racine et al., 1994	Shot in field	In situ
Arctic Tern	11		Skin			ND	Sparling et al, in Racine et al., 1994	Shot in field	In situ
Arctic Tern	11		Crop contents			ND	Sparling et al, in Racine et al., 1994	Shot in field	In situ
Mew Gull	16		Skin			ND	Sparling et al, in Racine et al., 1994	Shot in field	In situ
Mew Gull	16		Crop contents			ND	Sparling et al, in Racine et al., 1994	Shot in field	In situ
Dowitcher	9		Skin			ND	Sparling et al, in Racine et al., 1994	Shot in field	In situ
Dowitcher	9		Crop contents			ND	Sparling et al, in Racine et al., 1994	Shot in field	In situ
Sandhill Crane - (5/10/95)		South end of horseshoe-shaped pond beneath Cole Pt. toward Racine island	Gizzard contents		ND		Roebuck, 1995	In field	In situ
Pectoral sandpiper	1		Gizzard			12.35	Roebuck et al., 1994	In field	In situ
Pectoral sandpiper	1		Skin			0.33	Roebuck et al., 1994	In field	In situ
Pectoral sandpiper	1		Fat			0.555	Roebuck et al., 1994	In field	In situ
Kestrel avg			Fat			0.0 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Control - fed uncontaminate poultry chicks
Kestrel avg			Fat			0.009 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Fed WP contaminated poult chicks with upper digestive system removed - avg WF residue in chick 0.134 mg/g tissue ww
Kestrel avg			Fat			0.079 ww	Sparling et al., in Racine et al., 1995	Toxicological study	Fed intact contaminated poultry chicks with 1.1 mg W pellet implanted in crop - ave WP residue - chick less uppe digestve system - 0.134 (S. + 0.109) mg/g tissue ww, - upper digestive system - 0.62 (S.D.+ 0.644) mg/g tissue
Kestrel			Whole gizzard			0.08	Nam et al., in Racine et al., 1993	Laboratory study	7 day exposure to WP containing food - avg daily intake WP 70 mg
Kestrel			Thigh muscle			0.03	Nam et al., in Racine et al., 1993	Laboratory study	7 day exposure to WP containing food - avg daily intake WP 70 mg
Golden eagle			Fat			0.02 ww	Sparling et al., 1994	Found dead in field	In situ
Golden eagle			Liver			Negative	Sparling et al., 1994	Found dead in field	In situ

Attachment 1
White Phosphorus Tissue Concentrations in Birds and Mammals
OUC Ecological Risk Assessment
Fort Richardson, Alaska

Specimen (date collected)	Sample Size	Area	Type of Tissue	Mass of Tissue (g - ww)	Mass of White Phosphorus (µg)	Concentration of White Phosphorus in Tissue (µg/g)	Source	Type Study	Form of WP
Golden eagle			Muscle			Negative	Sparling et al., 1994	Found dead in field	In situ
Bald eagle - immature female	1		Fat			0.060 ww	Roebuck et al., 1994	In field	In situ
Bald eagle - immature female	1		Skin			0.010 ww	Roebuck et al., 1994	In field	In situ
Controls (Collected from Susitna Flats)									
Green-winged teal-male			Gizzard contents	1.34	0	0	Racine et al., 1991	In field	In situ
Green-winged teal-male			Fat	4.99	0	0	Racine et al., 1991	In field	In situ
Green-winged teal-female			Gizzard contents	1.68	0	0	Racine et al., 1991	In field	In situ
Green-winged teal-female			Fat	6.35	0	0	Racine et al., 1991	In field	In situ
Green-winged teal-male			Gizzard contents	2.13	0	0	Racine et al., 1991	In field	In situ
Green-winged teal-male			Fat	2.95	0	0	Racine et al., 1991	In field	In situ
Green-winged teal-male			Gizzard contents	1.95	0	0	Racine et al., 1991	In field	In situ
Green-winged teal-male			Fat	3.21	0	0	Racine et al., 1991	In field	In situ
Green-winged teal-female			Gizzard contents	1.55	0	0	Racine et al., 1991	In field	In situ
Green-winged teal-female			Fat	4.05	0	0	Racine et al., 1991	In field	In situ
Eggs									
Chicken eggs from 5 hens			egg			0.025-0.04 (egg)	Roebuck & Nam, in Racine et al., 1995	Toxicological study	Gavaged with 1 mg WP/kg WP dissolved in oil
ring gull egg	1		Entire egg contents			0.003	Roebuck et al., 1994	In field	In situ
Mammals									
Coyote (5/4/95)		Behind Canoe Pt. Tower in woods	Leg muscle		ND		Roebuck, 1995	In field	In situ

Notes:
0 = WP was either not detected or was below detection limits.
NA = Not available
ND = Not detected
Det = Detected, but not reported.
WP = White phosphorous
ww = wet weight
Concentration of white phosphorus in tissue for toxicological studies referenced are average values for the number of birds listed.

Appendix B
Human Health Risk Assessment

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Contents, Continued

Abbreviations

ADFG	Alaska Department of Fish and Game
bw	body weight
COE	U.S. Army Corps of Engineers
ERF	Eagle River Flats
FS	feasibility study
g	gram
HI	hazard index
HQ	hazard quotient
IRIS	Integrated Risk Information System
kg	kilograms
LD_{50}	lethal dose for 50 percent mortality
LOAEL	lowest observed adverse effect level
m	meters
µg/g	micrograms per gram
mg/kg	milligrams per kilogram
mg/kg-bw/day	milligrams per kilogram of body weight per day
OB/OD	Open Burning/Open Detonation
OUC	Operable Unit C
P_4	elemental phosphorus
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
SRC	Syracuse Research Corporation
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
UXO	unexploded ordnance
WP	white phosphorus

APPENDIX B

Human Health Risk Assessment

The objective of this assessment is to use the latest information to determine current and potential future risk to human health at Eagle River Flats.

This section presents the results of the baseline risk assessment for Operable Unit C (OUC). The purpose of the baseline risk assessment is to characterize the potential human health risks if no remedial action is performed (the no-action alternative). The baseline risk assessment process has four steps:

- Data identification, which identifies the chemicals present at the site and focuses on the chemicals of potential concern.
- Exposure assessment, which identifies the potential pathways by which exposure can occur and characterizes the potentially exposed populations, and the frequency and duration of these exposures.
- Toxicity assessment, which identifies the types of hazards or health effects associated with exposures to site chemicals.
- Risk characterization, which integrates the information from the exposure and toxicity assessments to address the potential for adverse effects for each exposure scenario, and includes a discussion of the uncertainty in the assessment.

Guidance documents from the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency were used to develop the methodology for this assessment.

This appendix is organized to cover the last three steps because Sections 1 through 6 of the remedial investigation (RI) report cover the first step. Agency guidance for this report was obtained from the U.S. Army Corps of Engineers (COE) (COE, 1995) and the USEPA (1989a).

Sections 1 through 3 discuss the conditions and assessment for Eagle River Flats (ERF). Section 4 provides the assessment for Open Burning/Open Detonation (OB/OD) Pad. Section 5 discusses the implications of uncertainty. Section 6 provides the works cited.

1.0 Introduction to ERF

In 1991, the U.S. Army (Bird *et al.*, 1991) conducted a risk evaluation of hunters who may eat contaminated ducks from ERF. The assessment was based on the analytical results of tissue samples (breast and thigh muscle, and skin) from seven wild teals observed to die in ERF. It was concluded that a person would have to consume 3,333 teal at a single sitting to consume a lethal dose, using the lowest recorded lethal dose of white phosphorus (WP) as a result of accidental poisoning, 1.4 milligrams per kilogram (mg/kg). By using the U.S. Environmental Protection Agency (USEPA) reference dose of 2×10^{-5} mg/kg-body weight (bw)/day, it was calculated that a person

would have to consume 17.6 teals per year to exceed a dose that is felt to be protective for continued exposure over a lifetime.

Previous assessments of human health risks from the ingestion of contaminated duck concluded that a significant effect was very unlikely.

In 1991, M.H. Weeks, chief of the Toxicology Division, advised, "Based on this information [probability of a hunter taking a large number of contaminated birds in a season, and the toxicology of white phosphorus], and the very limited data on tissue P_4 [white phosphorus] levels from wild and farm reared birds, it is very unlikely that hunters or their families could ingest quantities of P_4 that would result in an actual toxic effect" (Weeks, 1991).

This opinion was also supported by Dr. John Middaugh, Alaska State Epidemiologist, who stated, "While the risk of adverse health effects from potential exposure to elemental phosphorus in waterfowl cannot be said to be zero, based on the evidence from available scientific data and findings of the ongoing investigation, the risk can be said to be so low as to constitute no basis for public health concern" (Middaugh, 1991). He also stated that the potential for any adverse health effect to a hunter or person consuming waterfowl obtained by hunters is extremely low because of the following key factors:

- Relatively small numbers of waterfowl are affected, compared to all the waterfowl in the area.
- The data indicate that poisoned waterfowl are incapacitated or die in a relatively short time after ingestion of elemental phosphorus.
- Levels of elemental phosphorus found in the tissues of dead birds are low.
- Exposure calculations based on sample data indicate that a human lethal dose would require consumption of 3,333 teals.

The offsite hunter and onsite recreation scenarios were the only human exposure scenarios considered, based on the assumption that the Army will maintain control over Eagle River Flats.

It is assumed that the Army will maintain control over the land into the foreseeable future, and that current land uses will not change. Table 1-1 summarizes the factors that were considered in determining reasonable human exposure scenarios to WP from ERF. The offsite hunter scenario is one exposure scenario that has been retained for additional assessment. Hunting is banned at ERF. It appears, however, that the time between ingestion of WP and death of a duck is sufficient to allow it to fly off ERF to another wetland area. Indeed, two mallards with detectable WP were found in two offsite areas: Clunie and Gwen lakes (Bird *et al.*, 1991). Because ERF is accessible from Knik Arm and upstream on Eagle River, the onsite recreation scenario also is retained. The other scenarios have been screened out on the basis of the factors discussed in the table.

TABLE 1-1
Potential Human Exposure Scenarios

Scenario	Description	Assessment	Assessment Justification
Offsite hunter	Hunter is offsite in Upper Cook Inlet, but consumes ducks that have been on ERF.	Yes	WP contamination detected in ducks. Human duck consumption will be assessed.
Offsite fisherman	Fisherman is offsite, but consumes fish that passed through Eagle River.	No	Little WP contamination detected in onsite fish or water. Therefore, no basis for assessing this offsite scenario.
Offsite boater	Incidental contact with water off ERF.	No	Very low WP concentrations in onsite water, so offsite water concentrations expected to be much less.
Onsite recreation	Onsite recreational activities, including hunting and fishing. May be authorized or unauthorized activities.	Yes	ERF will remain as a firing range under Army control. Other onsite activities will be prohibited, but access is possible.
Onsite development (commercial or industrial)	Includes roads, buildings. Onsite exposure could come during occupational use of the buildings.	No	ERF will remain as a firing range under Army control. Other onsite activities will be prohibited.
Onsite investigations	Potential exposures to unexploded ordnance (UXO) and WP by workers during site investigation.	No	ERF is currently a firing range under Army control. Workers operate under a health and safety plan to limit their exposures.
Onsite remediation	Potential exposures to UXO and WP by workers during site remediation.	No	Exposure scenarios will be addressed in the feasibility study (FS), not the RI.

2.0 Offsite Hunter Scenario for ERF

This section discusses the exposure, toxicity, and risk characterization for the offsite hunter scenario.

2.1 Exposure Assessment

Exposure is defined as the contact of an organism with a chemical or physical agent. In this assessment, exposure is normalized for time and body weight and is expressed as milligrams of chemical per kilogram of body weight per day (mg/kg-bw/day). The exposure of chemicals for noncancer health effects is estimated over an averaging time dependent on the assessed toxic effect. For each exposure scenario, the noncancer risk is evaluated for a target receptor, the group that receives the reasonable maximum exposure or intake of a chemical.

An exposure pathway is the route by which a contaminant moves from a source to a receptor. A complete exposure pathway has five elements:

- Contaminant source
- Mechanisms for contaminant release
- Environmental transport medium
- Exposure point (receptor location)
- Feasible route of exposure (ingestion, inhalation, dermal absorption)

If a pathway is not complete, there is no exposure.

The exposure to WP is calculated for this scenario as

$$E = C * F * M * D / (1{,}000 * 365 * BW) \qquad \text{(Eq. 1)}$$

where:

E = exposure (mg/kg-bw/day)
C = WP tissue concentration of contaminated duck (micrograms per gram) (µg/g)
F = fraction of consumed ducks that are contaminated with WP
M = meals of duck consumed per year
D = meal portion of duck (g/meal)
BW = human body weight (kg)

Data on the duck hunting harvest were obtained from the Alaska Department of Fish and Game, with data collected by other federal and state agencies.

The remainder of this section discusses the basis for the exposure factors used in this assessment. USEPA guidance states that actions at Superfund sites should be based on an estimate of the "reasonable maximum exposure" (RME) expected to occur under current and future land use conditions. The RME is defined as the "highest exposure that is reasonably expected to occur at a site" (USEPA, 1989a). The intent of the RME is to estimate a conservative exposure case (well above the average case) that is still within the range of possibilities.

2.1.1 Background on Hunting

The Alaska Department of Fish and Game (ADFG) provides summaries of the duck harvest in the Gulf Coast Zone, which contains Cook Inlet. To estimate the harvest, ADFG combines information from state and federal harvest surveys and duck stamp sales. The U.S. Fish and Wildlife Service (USFWS) tallies the number of Migratory Bird Hunting Stamps sold in each state and subtracts the estimated proportion sold to non-hunting stamp collectors. USFWS also conducts a nationwide mail questionnaire survey of federal duck stamp buyers at certain post offices to estimate hunter activity and harvests in each state. Because the survey does not ask hunters to report the species of ducks they harvest, the USFWS Federal Parts Collection Survey asks a sample of hunters to send in one wing from each duck and tails of geese. These are later classified by species, sex, and age of ducks.

The ADFG also conducts a mail questionnaire. Two of every five buyers of the state duck stamps are given a card at the time of purchase to record their hunting activity and harvests. Hunters are asked to mail the postage-paid cards at the end of their seasonal hunting.

The current duck bag limits for the Gulf Coast Zone are eight daily and 24 in possession. The 5-year (1989 to 1995, with no data from 1991 to 1992) average dabbler and diving duck harvest in Cook Inlet is 23,249 birds (ADFG, 1996). An estimate of the total annual dabbling ducks taken by active hunters was made by using data from the ADFG 1994 to 1995 report (ADFG, 1996):

- The 5-year (1990 to 1995) statewide average of active waterfowl hunters was 7,088. It has been estimated that 20 percent of them are very active (Crowley, 1996). This results in an estimate of 1,418 very active hunters.
- Assume Cook Inlet has the same proportion of very active hunters and hunter days (the number of days hunters spend in the field) as the entire state. The 5-year averages for hunter days are 14,481 and 37,308 for Cook Inlet and the state, respectively. The ratio of hunter days in Cook Inlet to the state (14,481/37,308) is 39 percent. Thus, the very active hunters in Cook Inlet (39 percent of 1,418) number 550.
- The 5-year average proportion of dabbling ducks to total ducks is about 67 percent statewide. Applying this percentage to the 5-year average number of harvested ducks in Cook Inlet results in an estimate (67 percent of 23,249) of 15,600 dabbling ducks harvested in Cook Inlet.

The annual average (based on 5 years) number of dabbling ducks harvested in Cook Inlet was 23,249, and the average number of active hunters is 7,088. It was estimated that the very active hunters harvest 23 ducks for family consumption each year. It is assumed that one duck was consumed per meal.

- Assume the very active hunters harvest an estimated 80 percent of the dabbling ducks (Crowley, 1996), which is a total (15,600 of 80 percent) of 12,500 dabbling ducks.
- Therefore, the very active hunter subpopulation harvests (12,500/550) 23 dabbling ducks per very active hunter per year.

It is further assumed that a hunter and family obtain one meal per duck.

2.1.2 Human Duck Consumption Rate

The estimated median duck consumption was 90 and 112 g/meal for children and adults, respectively.

The USEPA, having recently reviewed the available studies on food consumption (USEPA, 1996a), recommends using food consumption data from Pao *et al.* (1982). For chicken, the median and upper 90th percentile consumption rates were 112 and 224 grams (g) per meal, respectively. Age-specific data suggest that a child around 10 years of age would consume about 80 percent of an adult portion (USEPA, 1996a). No data are available specifically for duck, so it has been assumed that a meal of duck would consist of the same weight of meat as the values for chicken.

2.1.3 Exposure Point Concentration

In September 1991, researchers collected more than 300 gizzards from ducks harvested by hunters in nearby Cook Inlet marshes as a check on the potential for contaminated birds to migrate offsite. For most birds, a sample of skin or fat also was taken for later analysis if WP were detected in the gizzards. There were no detectable levels of WP in the gizzards. Because the gizzard is most likely to have the highest WP concentration compared to other tissues, the other bird tissue samples were not analyzed (Racine *et al.*, 1992a). This suggests that the fraction of contaminated birds harvested offsite is fairly small.

The probability that a duck harvested in Upper Cook Inlet is a contaminated bird from Eagle River Flats was estimated as 0.005.

The mortality rate was about 16 percent from the telemetry studies of 1993 to 95 and 35 percent in 1996 when no hazing occurred (from Section 4.1.1 of Appendix A). The time ducks spent offsite before hazing was 32, 20, and 40 percent for the mallards, northern pintails, and green-winged teal, respectively (Cummings *et al.*, in Racine *et al.*, 1996). Therefore, it was assumed that 35 percent of the ducks from the flats are contaminated and are offsite 30 percent of the time. With ERF duck population about 5 percent of the Upper Cook Inlet population (from Section 3.1.2 of Appendix A), the probability of a harvested duck being a contaminated bird from ERF can be approximated as 0.005.

Table 2-1 summarizes the WP concentrations in edible duck tissues from five birds that dies at ERF. These five ducks died with symptoms of WP poisoning in ERF in August 1991. By using the most commonly consumed portions of duck, an estimate was made of the amount of

WP that could be ingested by eating contaminated birds (Racine *et al.*, 1993).

TABLE 2-1
Estimate of Total WP in Edible Tissues From Five Ducks That Died in ERF

	Tissue	Total tissue mass (g)	Conc. of WP (µg/g)	Total WP (µg)
Green-winged teal	Breast muscle	62.1	0.0923	5.7
	Thigh muscle	12.0	0.277	0.03
	Fat	3.1	1.57	4.9
	Skin	53.6	0.891	47.8
	Total			61.7
Green-winged teal	Breast muscle	56.5	0.00792	0.4
	Thigh muscle	12.3	0.036	0.4
	Fat	3.7	0.0901	0.3
	Skin	41.5	0.0344	1.4
	Total			2.7
Pintail	Breast muscle	129.2	0.0169	2.2
	Thigh muscle	30.3	0.0234	0.7
	Fat	26.6	0.269	7.1
	Skin	115.3	0.176	20.3
	Total			30.3
Pintail	Breast muscle	129.8	0.00867	1.1
	Thigh muscle	28.2	0.049	1.4
	Fat	13.7	0.289	4.0
	Skin	109.4	0.211	23.1
	Total			29.5
Pintail	Breast muscle	143.0	0.0128	1.8
	Thigh muscle	35.2	0.031	1.1
	Fat	1.2	0.475	0.6
	Skin	160.6	0.0108	1.7
	Total			5.2
Average per duck				25.9

Source: Racine *et al.*, 1993

The white phosphorus concentrations in the consumed duck were estimated from the available tissue measurements.

On the basis of information on the fate and transport of WP that shows that WP is stable in anaerobic, saturated conditions, it has been assumed that the WP concentration in the duck remains constant over the years. Data also indicate, though, that WP concentrations are declining in some areas of ERF.

It has been assumed that a serving portion of duck consists of 5 percent skin, 10 percent fat, and 85 percent breast muscle, and the

concentration of the average consumed portion was calculated as 0.12 µg/g wet weight.

One study (Dyer *et al.*, 1972) examined the effect of tissue preparation on WP concentrations. Holding a WP-contaminated cod for 4 hours at 15°C, with a further 20 hours in ice after gutting, produced a higher, but not statistically significant, average concentration. Frozen storage of fillets resulted in a WP loss of 39 percent after 14 weeks and 54 percent after 43 weeks at temperatures of -26°C and -18°C. Losses were somewhat greater at -10°C. In the same study, the effect of cooking on WP concentrations was variable, suggesting that cooking time may be a factor influencing the loss of WP in tissue. Fillets baked for 25 to 26 minutes at 260°C lost 61 percent of WP, but there was no reduction following 8 minutes of either boiling or baking. It was conservatively assumed in this risk assessment, however, that there were no changes in WP concentration during holding, frozen storage, thawing, preparation, and cooking of duck.

2.1.4 Body Weight

An adult body weight of 70 kg (USEPA, 1989a) and a child body weight of 36 kg (USEPA, 1989c) have been used in this assessment.

Body weights of child and adult used in this assessment were 36 and 70 kg, respectively.

2.2 White Phosphorus Toxicity Assessment

Information for this assessment was obtained from the toxicological profile on WP prepared by the Syracuse Research Corporation (SRC) (SRC, 1994).

In regard to potential acute effects, no deaths were reported in children treated with 0.026 to 0.158 mg/kg per day of white phosphorus. The mortality rate was 30 percent in Wistar rats treated by gavage with 6 mg/kg. The oral lethal dose for 50 percent mortality (LD_{50}) for Charles River rats was 3.03 and 3.76 mg/kg for females and males, respectively. The LD_{50} was 4.82 and 4.85 mg/kg in female and male mice, respectively. Table 2-2 summarizes the systemic effects from oral ingestion. It should be noted that most of the effects have been reported following acute exposures.

The U.S. Environmental Protection Agency has established a chronic oral reference dose of $2x10^{-5}$ mg/kg-bw/day for WP.

USEPA has classified WP as a D carcinogen, meaning that it is not classifiable for human carcinogenicity, on the basis of no data in humans or animals (USEPA, 1996c). No cancer slope factor is available.

USEPA has established a chronic oral reference dose (RfD) of 2×10^{-5} mg/kg-bw/day from a critical effect of parturition mortality and forelimb hair loss in a reproductive rat study where the lowest observed adverse effect level (LOAEL) was 0.07 mg/kg/day. An uncertainty factor of 1,000 was used to develop the RfD from the

LOAEL. The confidence is low for the study, data base, and RfD (USEPA, 1996c).

TABLE 2-2
Systemic Effects of White Phosphorus

System	Systemic Effects
Cardiovascular	Damage to myocardium; fatty infiltration of muscle
Gastrointestinal	Vomiting following high dose (2 to 23 mg/kg); abdominal cramps or pain; no effects reported in children receiving 0.026 to 0.158 mg/kg-bw/day
Hematological	Inconsistent effects reported for erythrocyte and hemoglobin levels; hemorrhages observed in specific tissues.
Musculoskeletal	Phossy jaw. Bone effects observed in children and young animals following acute (14 days or less) and intermediate (15 to 364 days) exposures.
Hepatic	Impaired liver function. Alterations in enzyme levels. Necrosis. Degeneration. Fatty infiltration. Increased liver weight. Decreased protein synthesis. Cirrhosis.
Renal	In acute cases: proteinuria, albuminuria, acetonuria, increased urobilinogen, increased blood levels of urea and/or nitrogen, increased blood creatinine levels, altered kidney function. No renal effects observed in rats exposed to 0.075 mg/kg-bw/day for intermediate periods (15 to 364 days).
Immunological	Some evidence that the immune system is a target.
Neurological	Some reports of neurological effects following a single dose.

Source: SRC, 1994.

The reference dose is an estimate, with an uncertainty spanning perhaps an order of magnitude or greater, of a daily exposure to the human populations, including sensitive subpopulations, that is likely to be without an appreciable risk of harmful effects during a lifetime. Using the exposure calculated from Equation 1, the noncancer risks are evaluated as a hazard quotient, which is calculated as follows:

$$HQ = E / RfD \qquad \text{(Eq. 2)}$$

where:

HQ = hazard quotient
E = exposure (mg/kg-bw/day)
RfD = reference dose (mg/kg-bw/day)

If the exposure is greater than the reference dose, and therefore the hazard quotient is greater than one, there is a potential for health concern.

2.3 Risk Characterization

The risk characterization integrates the exposure and toxicity assessments to estimate the risk. The results for the offsite hunter scenario are summarized in Table 2-3. The hazard quotients for the child and adult from the consumption of duck in the offsite hunter scenario are 0.002 and 0.001, respectively. If the upper 90th percentile consumption rate is used, the hazard quotients would double, leaving them still considerably below the value of one; therefore, there is little likelihood of significant chronic effects in this defined scenario. As summarized in Section 4, there are several uncertainties and judgments that are included in this assessment, but it is generally believed that these results likely overestimate the actual risks associated with this scenario. Because the principal risk equations, Equations 1 and 2, are linear, a change in any one of the parameters will produce a proportional change in the calculated hazard quotient.

The hazard quotients for the child and adult from the consumption of duck in the offsite hunter scenario are 0.002 and 0.001, respectively. There is, therefore, little potential for significant human health effects in this scenario. Although there are a number of uncertainties, it is unlikely that other reasonable combinations of exposure factors could lead to a hazard quotient greater than one.

TABLE 2-3
Noncancer Risks in Offsite Duck Hunter Scenario

	White Phosphorus Concentration (µg/g)	Meat Portion (g/meal)	Meals per year	Exposure (mg/kg/day)	Hazard Quotient
Child	0.12	90	23	7.5×10^{-8}	0.005
Adult	0.12	112	23	6.0×10^{-8}	0.003

Oral RfD is 2×10^{-5} mg/kg-bw/day (USEPA, 1996a).
Additional assumptions:
Body weight: 36 kg for child, and 70 kg for adult (USEPA, 1989a, 1989b).
0.5 percent of consumed ducks were those contaminated by WP at ERF.

At a concentration of 0.12 µg/g, consumption of about 4,300 g of contaminated duck would lead to an exceedance of the oral RfD. With an adult meal consumption rate of 112 g/meal, this is equivalent to a consumption of 39 meals of contaminated duck per year. If the upper 90th percentile consumption rate is used, then this is reduced to about 20 ducks. The calculated hazard quotients in Table 2-3 are low because it was concluded that only a small proportion of contaminated duck, less than one-tenth of a duck per hunting season, would be in a hunter's harvest.

3.0 Onsite Recreation Scenario for ERF

There are no physical barriers that prevent access, although currently prohibited, to ERF from Knik Arm, or from upstream on the Eagle River. People on rafts or other boats on the river may go under the Observation Point Bravo Bridge if they go beyond the boat takeout,

which is located approximately 700 m upstream from the bridge. No trespassers, however, have been observed on ERF in recent times.

As discussed previously, ERF is an artillery impact zone, and thus contains an unknown quantity of UXO. For the possible occasional trespasser on ERF, the UXO represents a much greater potential hazard than the possible exposure to white phosphorus. Thus, the greatest potential risk associated with unauthorized access in the onsite recreation scenario is contact with UXO that produces an explosion, which may result in a serious physical injury.

At an average concentration in duck tissue of 0.12 µg/g, it would take a consumption of 4,300 g of contaminated duck to lead to an exceedance of the oral reference dose. This is equivalent to about 39 meals of contaminated duck per year. Even if the consumption is increased to the 90th percentile rate, this would still require about 20 contaminated ducks.

The potential period of exposure is not known. If an unauthorized visitor were on the flats, it would presumably be for a short period only during a few days of the summer. Exposure during the winter, when ERF is frequently covered with ice and snow, would be less to UXO and WP because of the covering.

The probability of explosions is not known. Past artillery use on ERF was discussed by CH2M HILL (1994). Over the past few years of site investigations, areas and pathways have been cleared of metal debris, including UXO. Each winter, when ERF ices over, the area is used for artillery impact, potentially leaving a new load of UXO on the Flats. Thus, the location, quantity, and types of UXO vary from year to year. If an explosion occurs while someone is nearby (perhaps caused by the pressure of a footstep), then the magnitude of the injury could be very substantial, including the possible loss of life. The injuries will vary with the explosive force, and the position of the receptor at the time.

The greatest risk in the onsite recreation scenario is physical injury from an explosion of unexploded ordnance on ERF.

Although no unauthorized visitors have been observed at the site, a upper-bound risk assessment was calculated for the possible exposure to WP in the recreational scenario. For purposes of this analysis, it was assumed that the exposure would be for a few hours for 10 days in a year, which is very likely an overestimate given that recent trespassing has not been observed. It was further assumed that the exposure concentration of WP was 10 µg/g in sediment, which exceeds the mean detected concentrations of all areas except the sampled areas of Racine Island (from Table 4-1 of the RI report). It was also assumed that children and adults might ingest 200 and 100 mg, respectively, during each of these visits from, for example, contact with the hands and subsequent hand to mouth touching. The value for the sediment ingestion rate was derived for the soil and dust intake rate for the residential exposure scenario (USEPA, 1991), and thus probably overestimates likely exposures.

The hazard quotients for a child and an adult recreational exposure scenario are 0.08 and 0.02, respectively, which are below the level of concern of one.

Exposure to soil is calculated as follows:

$$E = C * IR * EF * ED/(1{,}000{,}000 * BW * AT) \qquad \text{(Eq. 3)}$$

where:

E = exposure (mg/kg-bw/day)
C = soil concentration (µg/g)
IR = soil ingestion rate (mg/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = days averaging time (365 * ED for noncancer effects and 25,550 for cancer effects)

With the exposure assumptions, the calculated child and adult hazard quotients are 0.08 and 0.02, respectively, using Equations 2 and 3. The product of the exposure parameter values would have to increase by a factor of 13 and 50 for the hazard quotient to equal one, which is the level of concern for noncancer risks (USEPA, 1989a). This bounding risk assessment calculation reinforces the low likelihood that exposure to WP in this scenario would be of concern.

4.0 OB/OD Pad

Although currently prohibited, people on rafts or other boats might gain access to OB/OD Pad by going under the Observation Point Bravo Bridge on Eagle River or coming upstream from Knik Arm and hiking across ERF. Pad access is also possible by a road, but there is a gate with warning signs. No trespassers have been observed at OB/OD Pad, however.

Of those potential exposure scenarios in Table 1-1, only the onsite recreational scenario was considered for OB/OD Pad. In this scenario, exposure to surface soil would occur, and could result in soil ingestion. Groundwater exposure would not be anticipated because it is far from the surface. OB/OD Pad still may contain UXO, and this would represent a significant risk to humans.

The onsite recreational scenario was assessed for OB/OD Pad. This includes adult and child exposure to soil, but not to groundwater.

Figures 6-3 and 6-4 of the RI report summarize the detected concentrations in the surface soil. The same exposure assumptions were used for the Pad as in the ERF onsite recreation scenario. A child was assumed to weigh 36 kg, ingest 200 mg of soil per visit, and visit the pad 10 times per year for 10 years. An adult was assumed to weigh 70 kg, ingest 100 mg of soil per visit, and visit the pad 10 times per year for 20 years. These appear to be conservative values given that no trespasser has been observed at the Pad. The soil ingestion rate is consistent with a residential exposure (USEPA, 1991). For the calculation of exposure, the surface soil samples were considered individually. If multiple or duplicate samples were available, then the

individual chemical concentrations were averaged. If one sample had a detected concentration, and a replicate did not, then one-half the detection limit was used for the undetected quantity. Equation 3 was used to estimate the exposure under these assumptions.

Table 4-1 summarizes the toxicological characteristics from USEPA's 1996 Integrated Risk Information System (IRIS) database for the detected chemicals. Because IRIS does not have information on two of the detected chemicals, 2-amino-4,6-DNT and 4-amino-2,6-DNT, they are not included in the table. The bottom of the table contains a description of several of the included chemical characteristics. Because the valence state of chromium was not measured, it was conservatively assumed that it was +6. The HQs were calculated as in Equation 2, and the individual HQs were summed across chemicals to estimate the hazard index (HI). This is conservative because the HQs should only be summed across chemicals with a common effect or endpoint, and not all the chemicals with reference doses have the same effect or endpoint.

Quantitative toxicity values were obtained from the USEPA Integrated Risk Information System. Noncancer hazard index and cancer risks were calculated.

The cancer risk was calculated from:

$$R = E * SF \qquad \text{(Eq. 4)}$$

where:

R = cancer risk (excess lifetime cancer risk)
E = exposure (mg/kg-bw/day)
SF = oral slope factor (kg-day/mg)

Excess lifetime cancer risk is the incremental increase in the risk of getting cancer over and above the rate one would have if not exposed to the conditions of the defined exposure scenario. As an example, an excess lifetime cancer risk of 1×10^{-6} means an increased probability of 1 in one million of getting cancer above the probability of getting cancer if not exposed to the conditions of the exposure scenario. The individual chemical cancer risks were summed across chemicals to estimate the risk associated with a simultaneous exposure to multiple chemicals.

The cancer risks and noncancer hazard indices were below USEPA risk criteria for hazardous waste sites in the OB/OD Pad recreational scenario.

Table 4-2 summarizes the calculated risks. The calculated cancer risks are about 10^{-7} for the child and adult at all sampling locations, with the major contribution from the arsenic concentrations. Note that reference values for arsenic discussed in Section 6 of the RI report suggest that the concentrations of arsenic in OB/OD Pad are similar to other surrounding non-contaminated areas. If arsenic is excluded from the cancer risk estimate, then the calculated cancer risks decrease by about an order of magnitude.

TABLE 4-1
Toxicological Parameters

Chemical	Noncancer Effects						Cancer Effects	
	Oral Reference Dose (mg/kg/day)	Uncertainty Factor	Modifying Factor	Confidence in Study	Confidence in Database	Confidence in Value	Weight of Evidence	Oral Slope Factor (kg-day/mg)
Arsenic	0.0003	3	1	medium	medium	medium	A	1.5
Barium	0.07	3	1	medium	medium	medium		
Chromium III	1	100	10	low	low	low		
Chromium VI	0.005	500	1	low	low	low	A	
Lead							B2	
Mercury							D	
Zinc	0.3	3	1	medium	medium	medium	D	
2,4,6-TNT	0.0005	1,000	1	medium	medium	medium	C	0.03
2,4-DNT	0.002	100	1	high	high	high		
2,6-DNT	0.001	3,000						
Di-n-buytlphthalate	0.1	1,000	1	low	low	low		
N-nitrosodiphenylamine							B2	0.0049

Modifying factor—An uncertainty factor which is greater than zero and less than or equal to 10; the magnitude of the MF depends upon the professional assessment of scientific uncertainties of the study and database not explicitly treated with the standard uncertainty factors (e.g., the completeness of the overall data base and the number of species tested); the default value for the MF is 1.

Uncertainty factor—One of several, generally 10-fold factors, used in operationally deriving the reference dose (RfD) from experimental data. UFs are intended to account for (1) the variation in sensitivity among the members of the human population; (2) the uncertainty in extrapolating animal data to the case of humans; (3) the uncertainty in extrapolating from data obtained in a study that is of less-than-lifetime exposure; and (4) the uncertainty in using lowest-observed adverse effect data rather than no-observed adverse effect data.

Weight-of-evidence for carcinogenicity—The extent to which the available biomedical data support the hypothesis that a substance causes cancer in humans. A: Human carcinogen. B1: Probable human carcinogen, indicating that limited human data are available. B2: Probable human carcinogen, sufficient evidence in animals, and inadequate or no evidence in humans. C: Possible human carcinogen. D: Not classifiable as to human carcinogenicity. E: Evidence of noncarcinogenicity for humans.

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TABLE 4-2
Summary of Risks in the Onsite Recreational Scenario

Location	Hazard Index		Cancer Risk	
	Adult	Child	Adult	Child
MW-1	0.0003	0.001	1×10^{-7}	2×10^{-7}
MW-2	0.0008	0.003	1×10^{-7}	2×10^{-7}
MW-3	0.003	0.01	1×10^{-7}	2×10^{-7}
MW-4	0.0002	0.008	1×10^{-7}	2×10^{-7}
MW-5	0.0003	0.001	8×10^{-8}	2×10^{-7}
MW-6	0.0002	0.0008	9×10^{-8}	2×10^{-7}
MW-7	0.0004	0.001	1×10^{-7}	2×10^{-7}

The onsite recreational scenario is a potential future scenario, because there is no evidence that it is occurring today. It involves assumptions of representative concentrations, soil ingestion rates, and frequency and duration of visits.

The HIs range from 0.0008 to 0.01 for the child, and 0.0002 to 0.003 for the adult, with the major contribution from chromium concentrations (with the assumption of chromium VI) at all locations. At Well MW-2, 2,4-DNT is also a significant contributor. At Well MW-3, 2,4,6-TNT is a significant contributor. As discussed in Section 6 of the RI report, the chromium concentrations measured at OB/OD Pad are similar to reference values in surrounding non-contaminated areas. If chromium is excluded from the assessment, then all HIs decrease by different amounts depending on the relative contribution of chromium to the HI.

In considering the value of the cancer risk, USEPA has used a cancer risk level of 1×10^{-6} or less as acceptable for hazardous waste sites. Under the recreational scenario at all sampling locations, the cancer risks in Table 4-2 are about 10^{-7}, which is less than the cancer risk criterion, and the noncancer HIs also are considerably under their criterion of one.

5.0 Uncertainties

The level of uncertainty in the risk results is a function of both site-specific characteristics and the risk assessment process in general. Site-specific contributions include the following:

- WP concentrations in tissue were available from a variety of sampling events over a period of several years, and little data were available for muscle, which would be anticipated to be the major tissue ingested by humans.

The level of uncertainty in the risk results is a function of both site-specific characteristics and the risk assessment process in general.

- Measured concentrations were assumed to be representative of the future, which likely overestimates the risk given the likelihood of chemical losses over time in areas of ERF that occasionally become dry.
- Several judgments, which were designed to be conservative and therefore will lead to an overestimate of the risk, had to be made for the exposure scenarios.
- The location and explosive potential of onsite UXO are not known.

General contributions from the risk assessment process include the following:

- The current and potential future-use scenarios assume specific land use activities that may not accurately reflect future conditions, that may lead to an over- or under-estimate of the risk.
- The parameter values may not accurately represent current or future conditions, that may lead to an over- or underestimate of the risk. In particular, this scenario has not considered hunters who may subsist on duck during the hunting season. Their consumption rate may be up to 10 times greater than that assumed in the offsite hunter scenario. It should be noted, however, that the calculated HQ was 0.001 for the adult consumer in the offsite hunter scenario, and an additional exposure factor of 10 times would still leave the HQ substantially below one.
- Toxicity valves were not available for all chemicals, which will tend to underestimate the risk.
- Toxicity parameters are generally designed to be conservative, which will likely lead to an overestimate of the risk.

These uncertainties and judgments are reasonably typical of most human health risk assessments.

6.0 Works Cited

Alaska Department of Fish and Game (ADFG). *Alaska Wildlife Harvest Summary, 1994-1995*. March 6, 1996.

Bird, S.T., R. York, C.H. Racine, M.E. Walsh, C. Collins, D. Calkins, B.D. Roebuck, L.W. Metker, G. Leach, and R. Newsome. Waterfowl Mortality in Eagle River Flats, Alaska: The Role of Munitions Compounds and Human Health Risk Assessment. Presented at the Caribbean Haztech International Conference and Exhibition, San Juan, Puerto Rico. November 13-15, 1991.

CH2M HILL. *Eagle River Flats Comprehensive Evaluation Report*. Prepared for U.S. Army Garrison, Alaska, Department of Public

Works, and Department of the Army, U.S. Army Engineer District Alaska. July 1994.

CH2M HILL. *Operable Unit C Final Remedial Investigation/Feasibility Study Management Plan.* Prepared for U.S. Army, Alaska, Department of Public Works. April 1996.

Crowley, D.W. Letter to David Lincoln, Decision Risk Management. May 2, 1996.

Dyer, W.J., D.F. Hiltz, R.G. Achman, J. Hingley, G.L. Fletcher, and R.F. Addison. "Stability Of Elemental Phosphorus In Edible Muscle Tissue Of Cod During Processing Including Icing, Freezing and Thawing, Frozen Storage, Salting, and Cooking." *J. Fisheries Research Board of Canada.* Vol. 29, pp. 1053-1060. 1972.

Middaugh, J., Alaska State Epidemiologist. Letter to John Toones, Directorate of Engineering and Housing (DEH). August 28, 1991.

Pao, E.M., K.H. Fleming, P.M. Guenther, and S.J. Mickle. *Foods Commonly Eaten by Individuals: Amount Per Day and Per Eating Occasion.* U.S. Department of Agriculture, Home Economics Report No. 44. 1982.

Racine, C., M.E. Walsh, C. Collins, D. Lawson, S. Bigl, L. Hunter, E. Chacho, R. Haugen, M.R. Walsh, P. Robinson, R. Bailey, J. Mullen, J. Cummings, J. Davis, P. Pochop, C. Yoder, R. Johnson, K. Gruver, K. Tope, C. Rossi, W. Eldridge, L. Reitsma, B. Steele, and B. Roebuck. *Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* Fiscal Year 95 Final Report. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). September 1996.

Racine, C.H., M.E. Walsh, C.M. Collins, S. Taylor, B.D. Roebuck, L. Reitsma, and B. Steele. *Remedial Investigation Report: White Phosphorus Contamination of Salt Marsh Sediments at Eagle River Flats, Alaska.* Report No. CETHA-IR-CR92004. Prepared for U.S. Army Toxic and hazardous Materials Agency. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). March 1992a.

Racine, C.H., M.E. Walsh, C.M. Collins, S. Taylor, B.D. Roebuck, L. Reitsma, and B. Steele. *White Phosphorus Contamination of Salt Marsh Pond Sediments at Eagle River Flats, Alaska.* U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). Report 93-17. Prepared for U.S. Army Environmental Center. October 1993.

Syracuse Research Corporation (SRC). *Toxicological Profile for White Phosphorus and White Phosphorus Smoke.* Draft. Prepared for the Agency for Toxic Substances and Disease Registry. June 1994.

U.S. Army Corps of Engineers (COE). *Risk Assessment Handbook.* Volume I, Human Health Evaluation. EM-200-1-4. 1995.

U.S. Environmental Protection Agency (USEPA). *Human Health Evaluation Manual, Supplemental Guidance.* "Standard Default Exposure Factors." OSWER Directive 9285.6-03. March 25, 1991.

U.S. Environmental Protection Agency (USEPA). *Ecological Significance and Selection of Candidate Assessment Endpoints.* EPA ECO Update, Vol. 3, No. 1, Publication 9345.0-11. January 1996a.

U.S. Environmental Protection Agency (USEPA). *Exposure Factors Handbook.* EPA/600/8-89/043. March 1989c.

U.S. Environmental Protection Agency (USEPA). *Integrated Risk Information System.* 1996c.

U.S. Environmental Protection Agency (USEPA). *Risk Assessment Guidance for Superfund. Volume I, Human Evaluation Manual,* Part A. EPA/540/1-89/002. December 1989a.

U.S. Environmental Protection Agency (USEPA). *Risk Assessment Guidance for Superfund.* Volume II, Environmental Evaluation Manual. Office of Emergency and Remedial Response, Washington, D.C. March 1989b.

Weeks, M.H., Chief, Toxicology Division. Waterfowl Deaths at Eagle River Flats (ERF)–Possible Human Health Hazard. Memorandum to MAJ Legg. June 28, 1991.

Appendix C
Site Studies for Chemicals Other Than White Phosphorus

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APPENDIX C

Site Studies for Chemicals Other Than White Phosphorus

This appendix provides a summary of the three field studies of environmental contamination of chemicals other than white phosphorus at Eagle River Flats (ERF). Each section discusses the sampling location and results. The individual reports should be referred to for more details.

In the 1989 ESE study, sediment and water were sampled at 26 locations, and were analyzed for volatiles, semivolatiles, metals, and explosives. Of the detected quantities, maximum concentrations were usually only a few parts per billion.

1.0 1989 Investigation

In 1989, Environmental Science and Engineering (ESE) collected surficial sediment and surface water samples at 26 locations (Figures C-1A and C-1B).[1] At one location, only a surface water sample was collected. The samples were analyzed for volatile, semivolatile, and inorganic compounds on the target compound list of the U.S. Environmental Protection Agency, and several munitions and explosives.

Figures C-2 and C-3 identify the sediment sample locations and inorganic analytes that exceeded the geometric mean concentration times one geometric standard deviation for that analyte, which was used in the report as a measure of elevated concentrations. Figures C-4 and C-5 identify the surface sediment samples with detected organic analytes. As can be seen, the highest concentrations are only a few parts per million (ppm) in concentration.

Figures C-6 and C-7 summarize the locations and analytes in surface water that exceeded the geometric mean concentration times one geometric standard deviation for that analyte. Finally, Figures C-8 and C-9 identify the concentrations of the detected organic analytes, which in the surface water were usually only a few parts per billion (ppb).

2.0 1990 and 1993 Investigations

In the spring of 1990, researchers from the Cold Regions Research and Engineering Laboratory (CRREL) collected 93 surface sediment and water samples in craters or other features along 100-meter (m) transects. Field screen testing and liquid chromatographic procedures were used to identify munitions. The field screening was used to identify hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) and

[1] Figures in this appendix are taken from previous reports. A list of figure sources is provided at the end of this document.

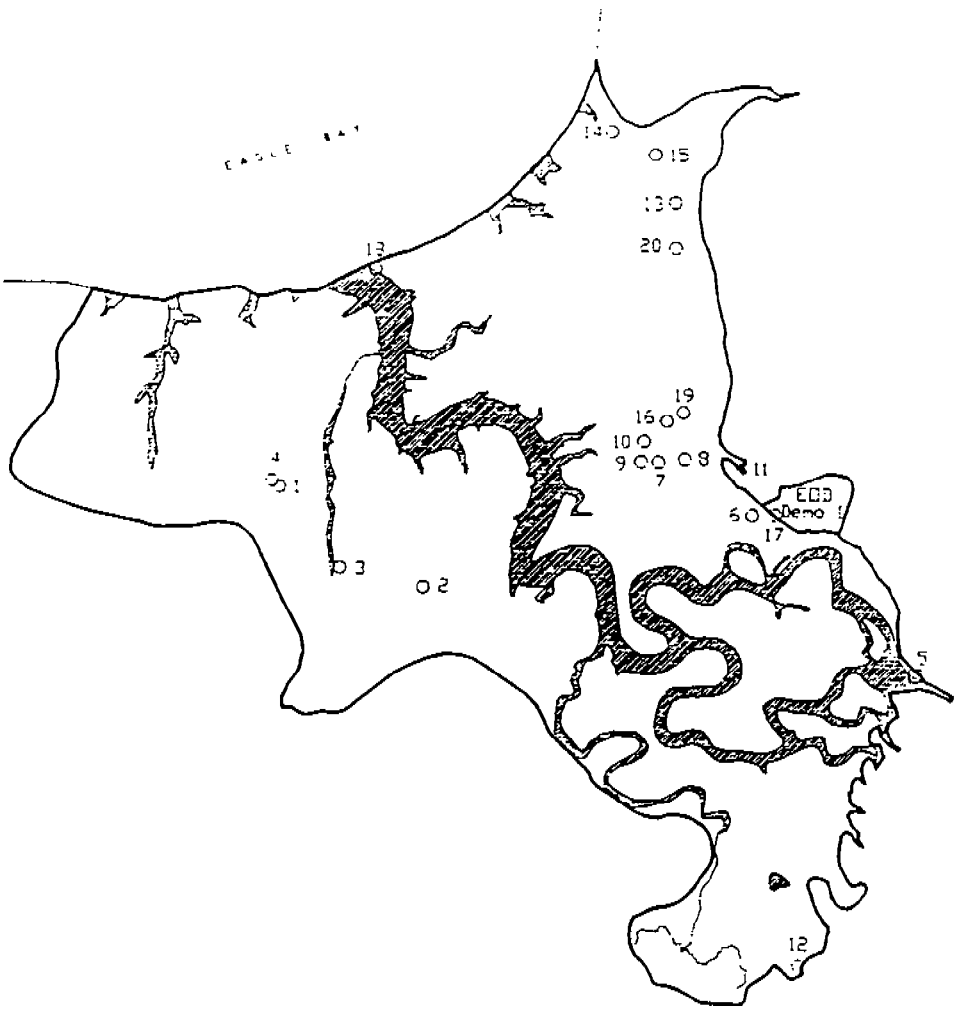


Figure 3-7 EAGLE RIVER FLATS
WATER AND SEDIMENT SAMPLE LOCATIONS
AUGUST 2-11, 1989
SOURCE: HUNTER/ESE, INC., 1989

Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland



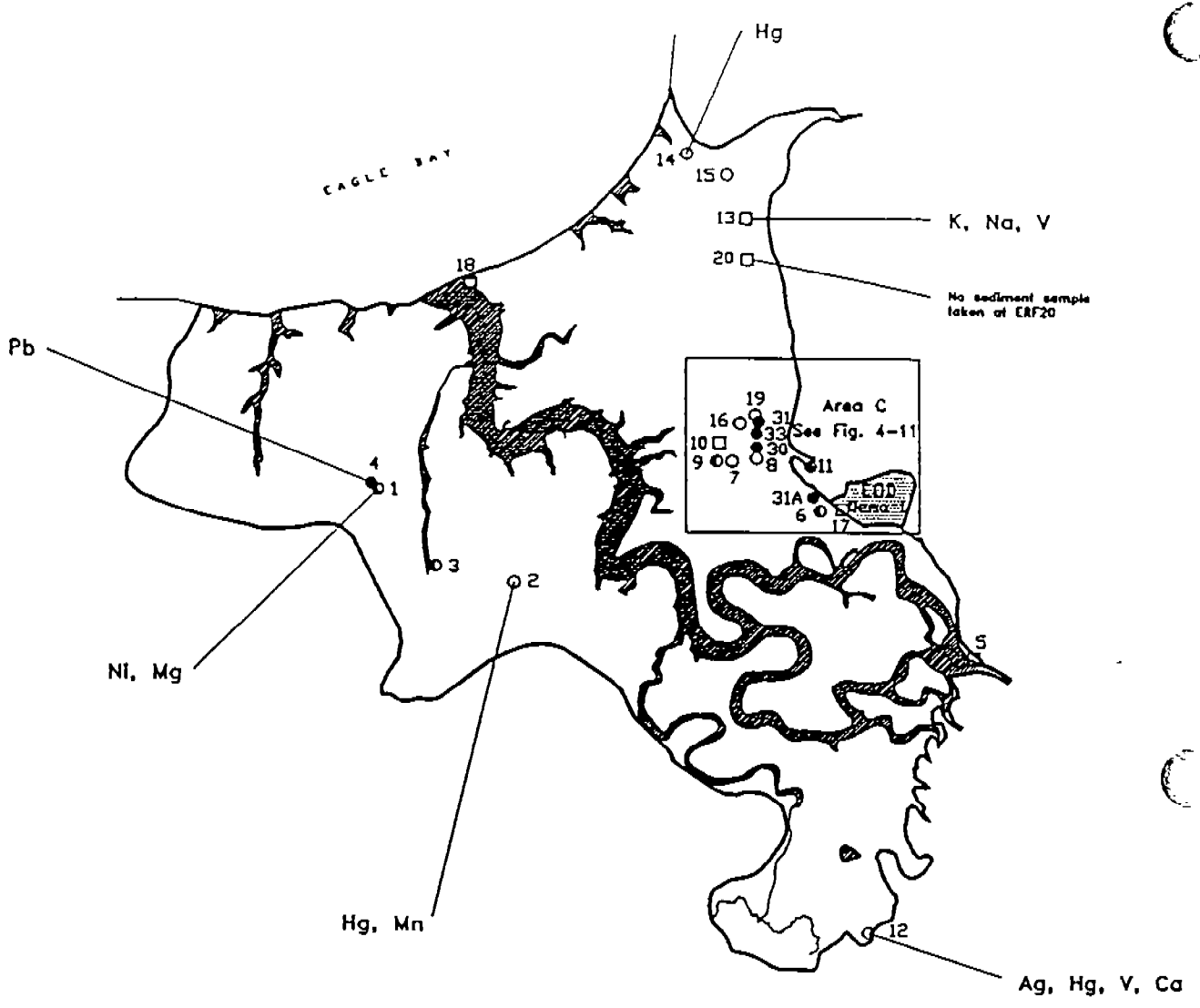
O Sample location

N

0 3000 Feet

Figure 3-8 EAGLE RIVER FLATS
WATER AND SEDIMENT SAMPLE LOCATIONS
OCTOBER 1-13, 1989
SOURCE: HUNTER/ESE, INC., 1989

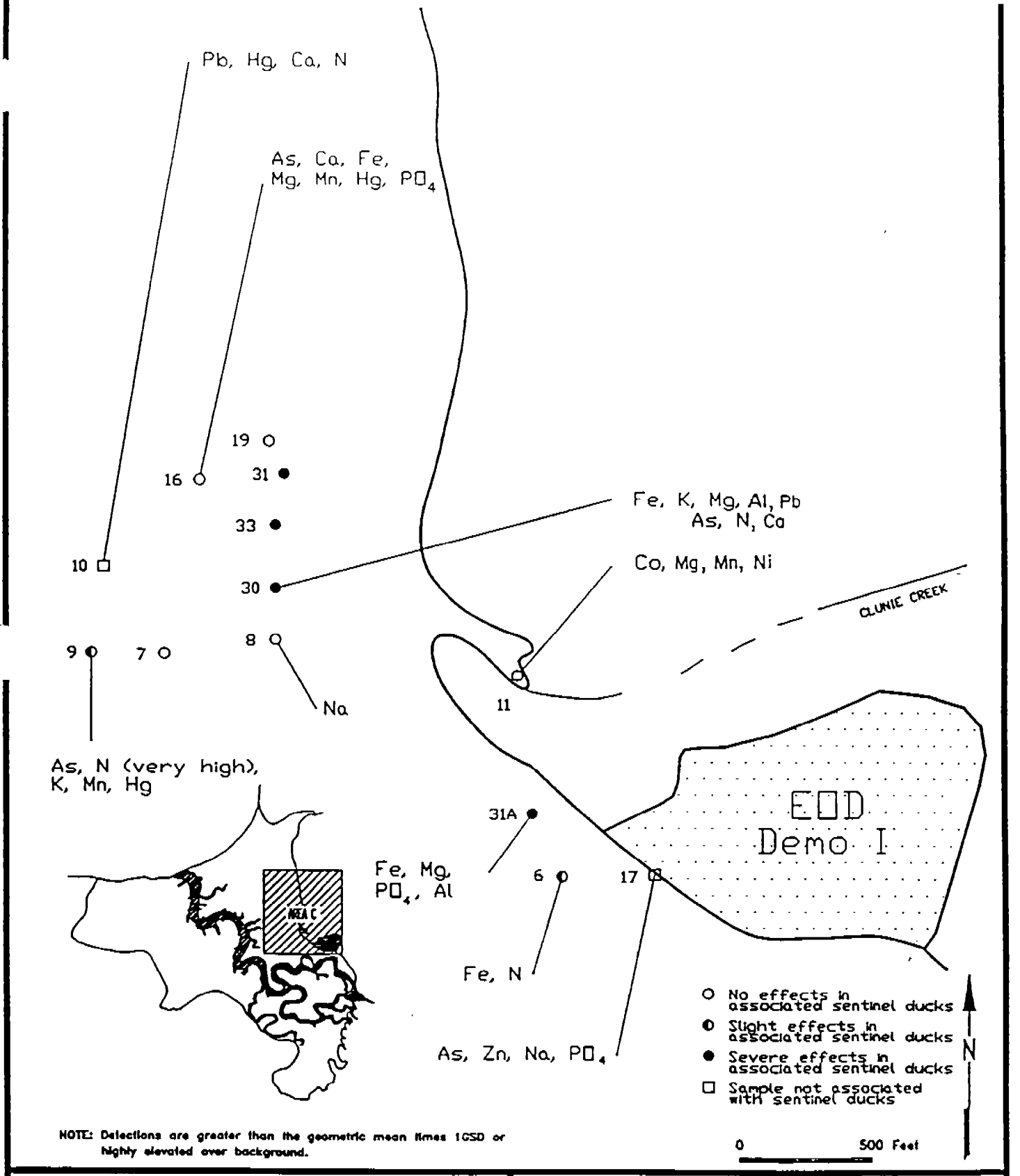
Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland



NOTE: Detections are greater than the geometric mean times 1GSD or highly elevated over background.

Figure 4-10 EAGLE RIVER FLATS
ELEVATED INORGANIC ANALYTE DETECTIONS
SURFACE SEDIMENT SAMPLES
SOURCE: HUNTER/ESE, INC., 1989

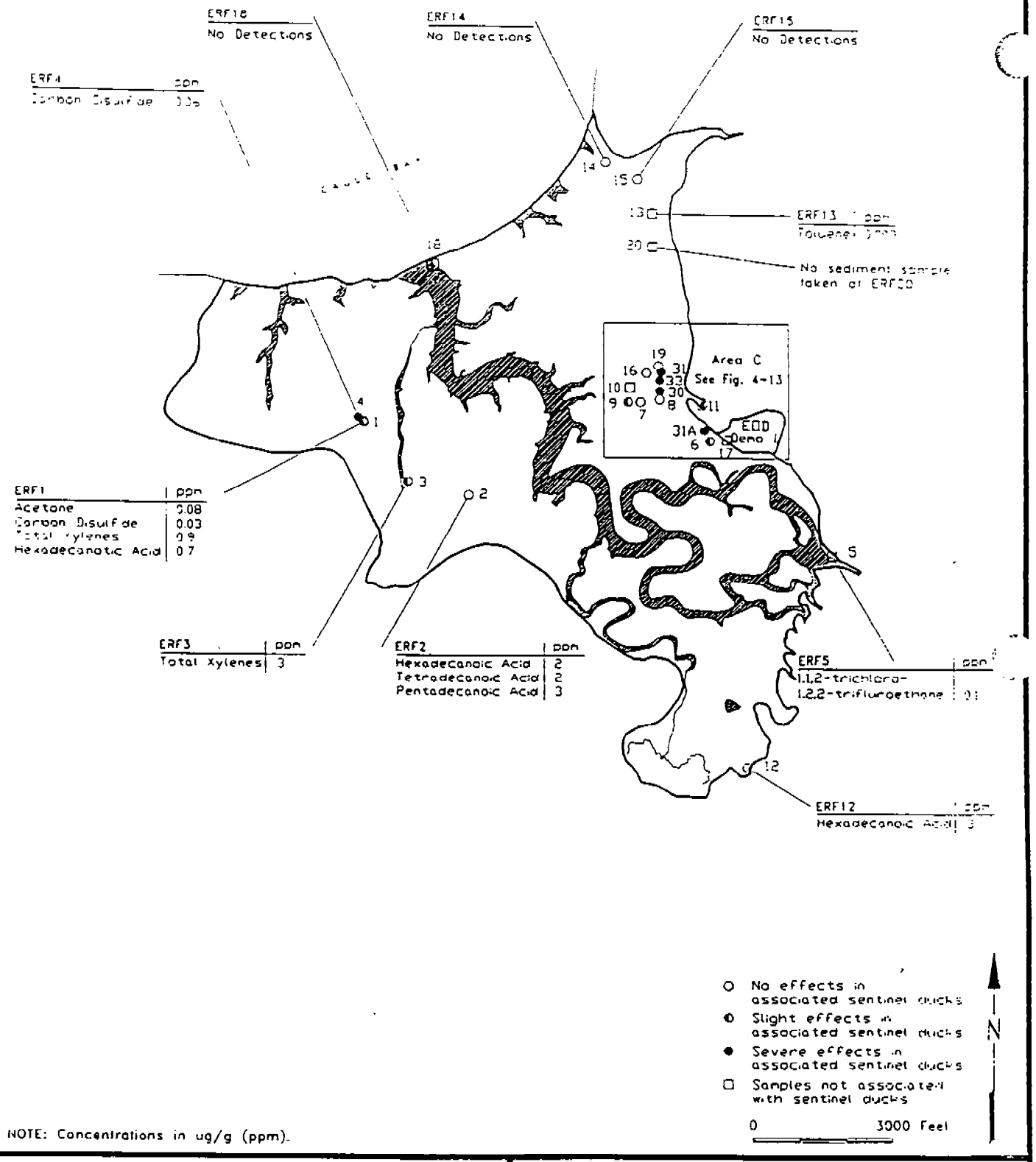
Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland



NOTE: Detections are greater than the geometric mean times 1GSD or highly elevated over background.

Figure 4–11 ERF STUDY AREA C
ELEVATED INORGANIC ANALYTE DETECTIONS
SURFACE SEDIMENT SAMPLES
SOURCE: HUNTER/ESE. INC., 1989

Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland



NOTE: Concentrations in ug/g (ppm).

Figure 4-12 EAGLE RIVER FLATS
ORGANIC ANALYTES
SURFACE SEDIMENT SAMPLES
SOURCE: HUNTER/ESE, INC., 1989

Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland

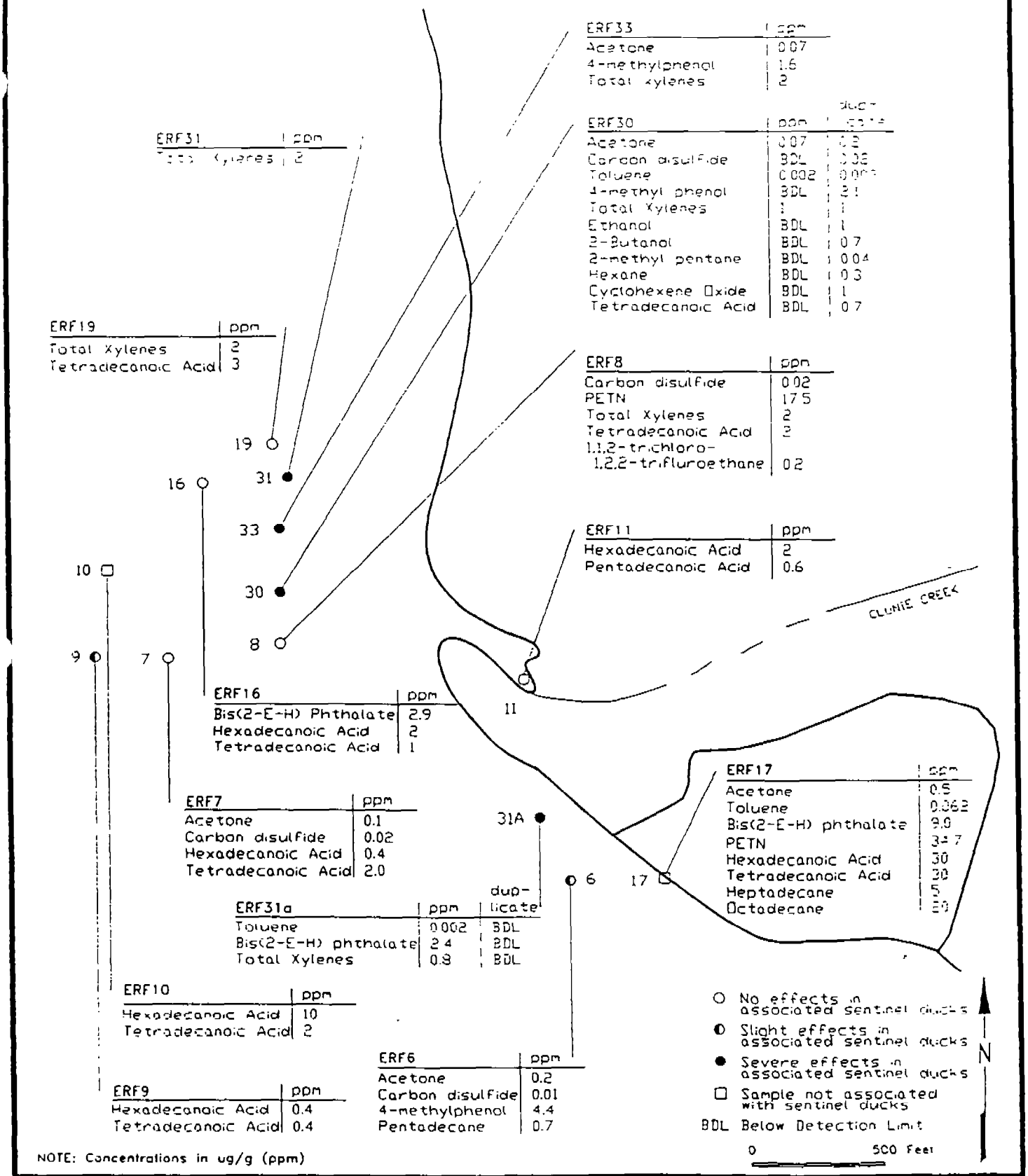
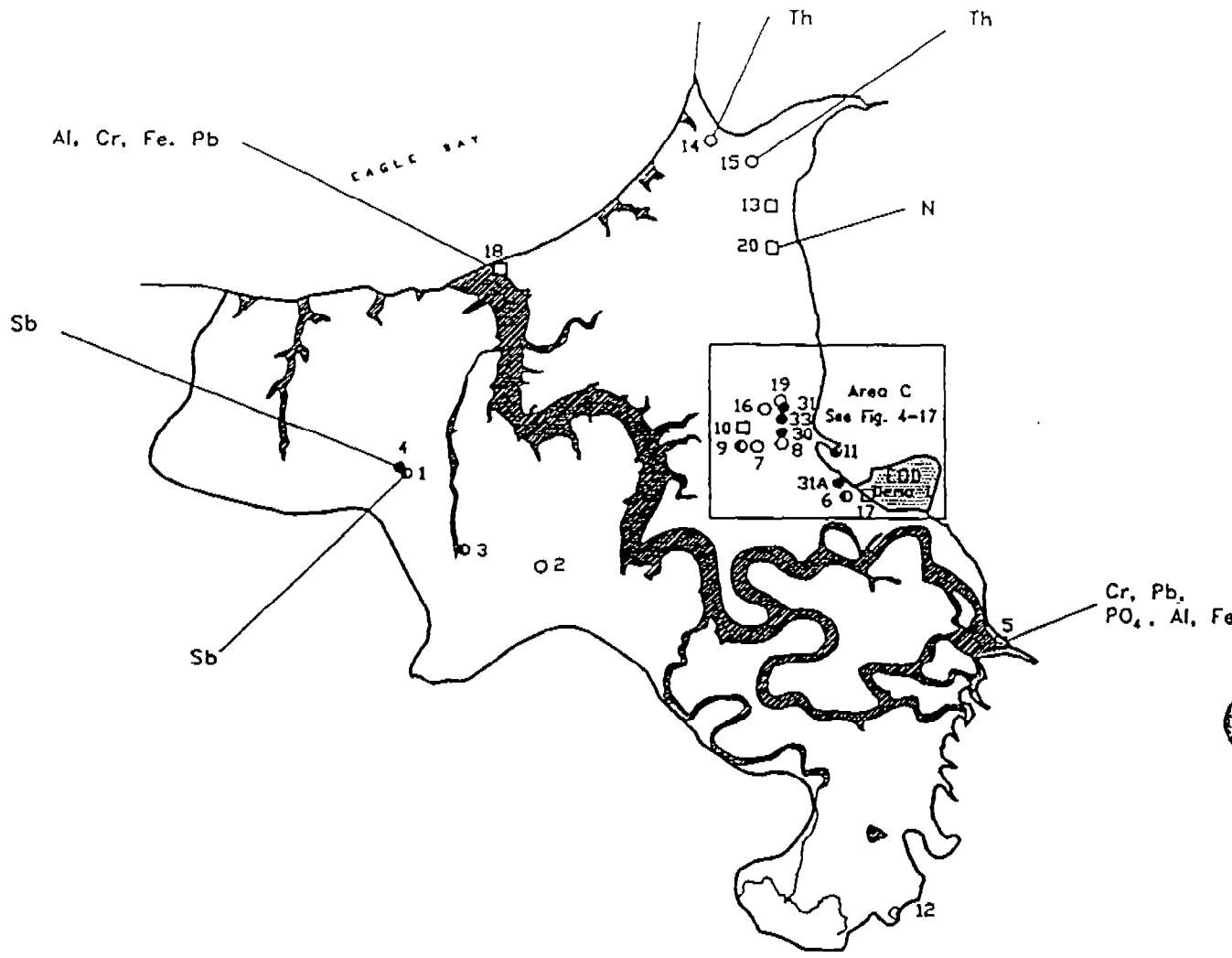


Figure 4-13 ERF STUDY AREA C
ORGANIC ANALTYES
SURFACE SEDIMENT SAMPLES
SOURCE: HUNTER/ESE, INC., 1989

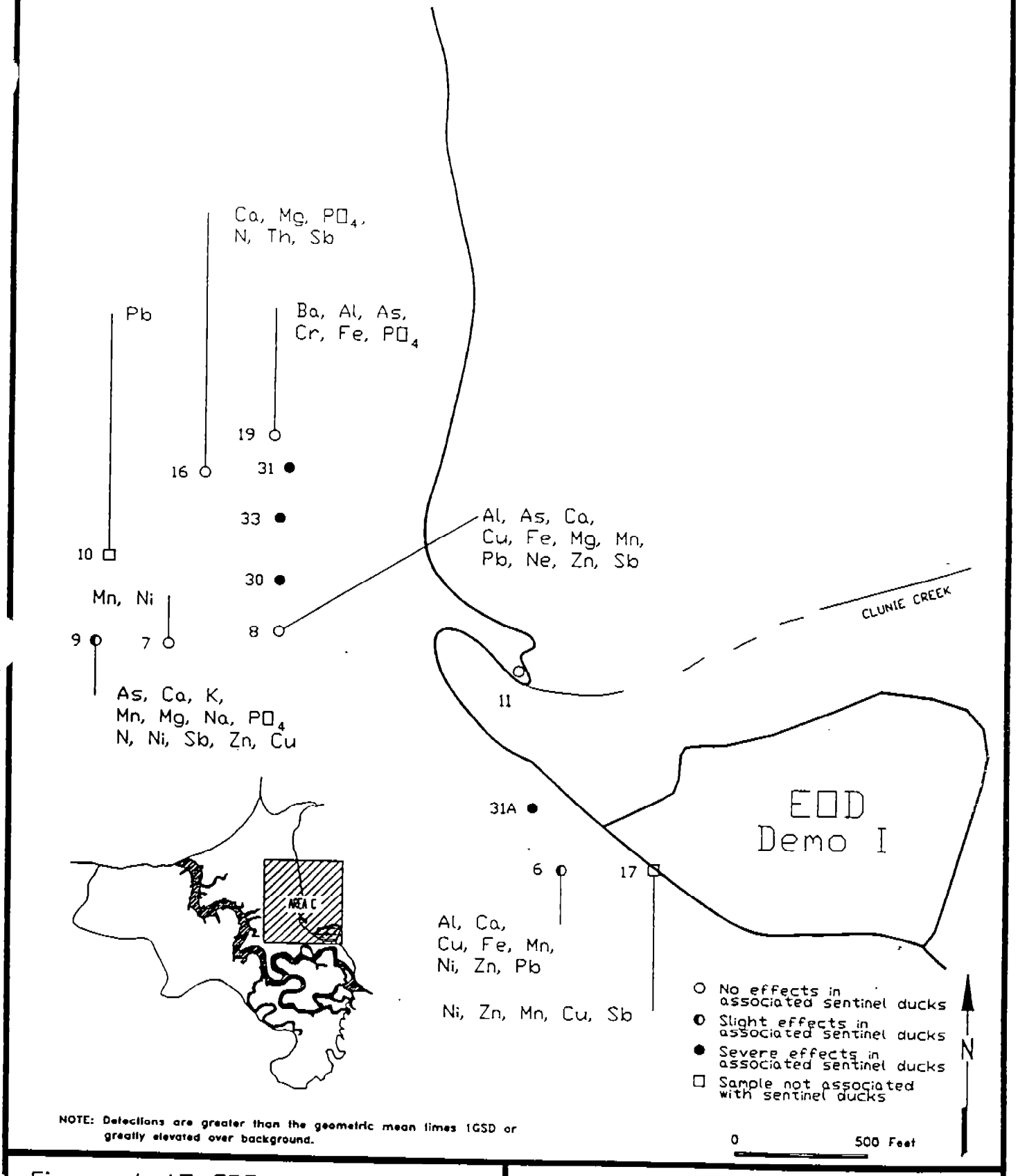
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Aberdeen Proving Ground, Maryland



NOTE: Detections are greater than the geometric mean times 1GSD or greatly elevated over background.

Figure 4-16 EAGLE RIVER FLATS
ELEVATED INORGANIC ANALYTE DETECTIONS
SURFACE WATER SAMPLES
SOURCE: HUNTER/ESE, INC., 1989

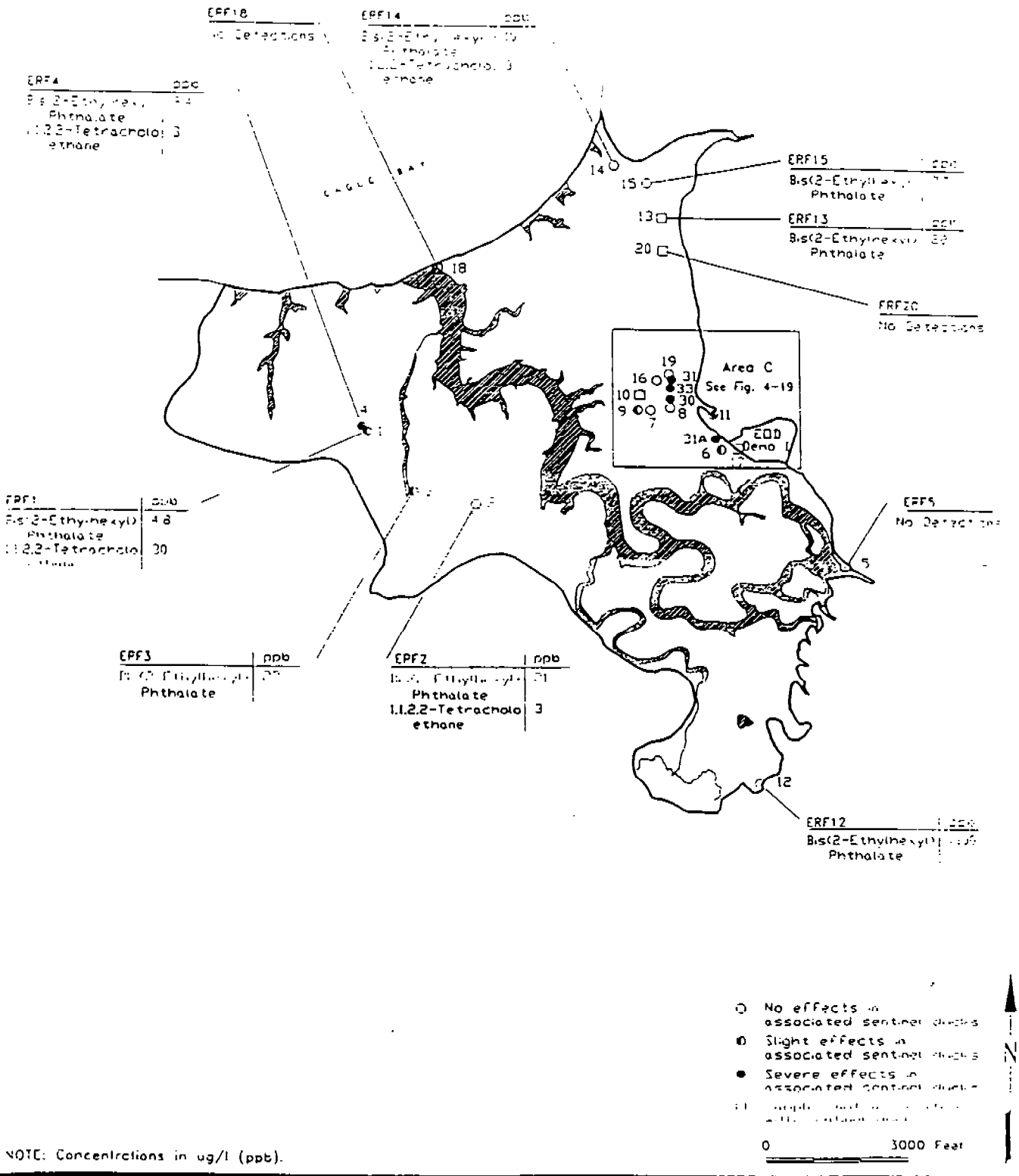
Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland



NOTE: Detections are greater than the geometric mean times 1GSD or greatly elevated over background.

Figure 4-17 ERF STUDY AREA C
ELEVATED INORGANIC ANALYTE DETECTIONS
SURFACE WATER SAMPLES
SOURCE: HUNTER/ESE, INC., 1989

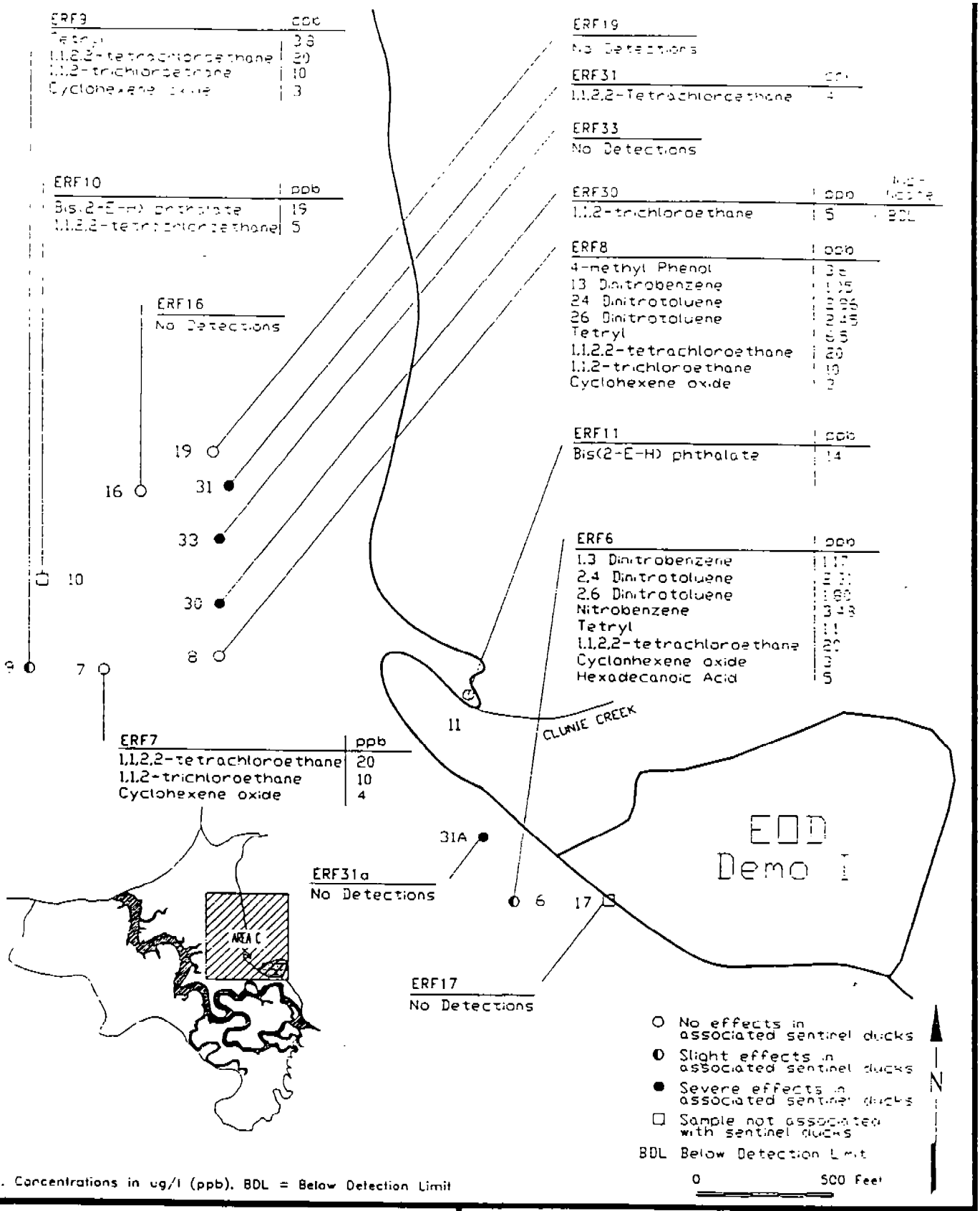
Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland



NOTE: Concentrations in ug/l (ppb).

Figure 4-18 EAGLE RIVER FLATS
ORGANIC ANALYTES
SURFACE WATER SAMPLES
SOURCE: HUNTER/ESE, INC., 1989

Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland



NOTE. Concentrations in ug/l (ppb). BDL = Below Detection Limit

Figure 4-19 ERF STUDY AREA C
ORGANIC ANALTYES
SURFACE WATER SAMPLES
SOURCE: HUNTER/ESE, INC., 1989

Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland

2,4,6-trinitrotoluene (TNT), but none of the samples had detectable quantities. The liquid chromatography did identify three sediment samples next to OB/OD Pad that had 2,4-dinitrotoluene (2,4-DNT). The locations of the transects and the samples with detected chemicals are shown in Figure C-10. Three additional samples were analyzed to reconfirm these results, but only trace amounts were detected.

In the 1990 CRREL study, sediment samples had low detectable quantities of 2,4-DNT, 2,6-DNT, and TNT along the base of the marsh adjacent to OB/OD Pad.

Because only samples near OB/OD Pad had detected concentrations in the spring sampling, sediment sampling that was performed in the fall focused on the area adjacent to the Pad. Of the 172 samples, 62 contained detectable 2,4-DNT. All of these samples with detected quantities were along the base of, or in the salt marsh adjacent to, OB/OD Pad. When concentrations of 2,4-DNT exceeded 1 microgram per gram (µg/g), the presence of 2,6-DNT and TNT was also detected, but at much lower concentrations. Also present in some samples were trace amounts of TNT biotransformation products 2-amino-4,6-dinitrotoluene and 4-amino-2,6-DNT. The sample locations and concentrations of 2,4-DNT are shown in Figure C-11.

In July 1993, water and sediment samples were collected from 21 sites, including two duplicate samples (see Figure C-12). The samples were analyzed for metals, explosives, organics, and pesticides. The nonmetal inorganic compounds were the results "expected in a dynamic tidal wetland with a glacial-fed river and estuarine tides that flood the wetlands." The metals in the water were within freshwater criteria based on site-specific hardness.

Analysis of water and sediment samples in 1993 from 21 sites found no detectable explosives, pesticides/PCBs, volatiles, and only one detection each of bis(2-ethylhexyl)phthalate and methylene chloride.

There were no volatile or base/neutral/acid extractable analytes detected in any of the sediment or water samples except for one detection of bis(2-ethylhexyl)phthalate (360 micrograms per kilogram) and one detection of methylene chloride. Both of these analytes are laboratory contaminants, so their association with ERF is questionable. There were no pesticides/polychlorinated biphenyls (PCBs) or explosives including breakdown products detected in any of the sediment or water samples.

3.0 Works Cited

Bouwkamp, C., Army Environmental Health Agency. "Contaminant Inventory." In C.H. Racine, M.E. Walsh, C.M. Collins, D. Lawson, S. Bigl, K. Henry, C. Bouwkamp, J. Cummings, L. Clark, J. Davis, P. Pochop, P. O'Neil, C. Rossi, D. Sparling, R. Grove, L. Comerci, W. Eldridge, L. Reitsma, B. Steele, and S. Burson. *Interagency Expanded Site Investigation Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska.* Fiscal Year 1993 Final Report. C.H. Racine, ed. U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). May 1994.

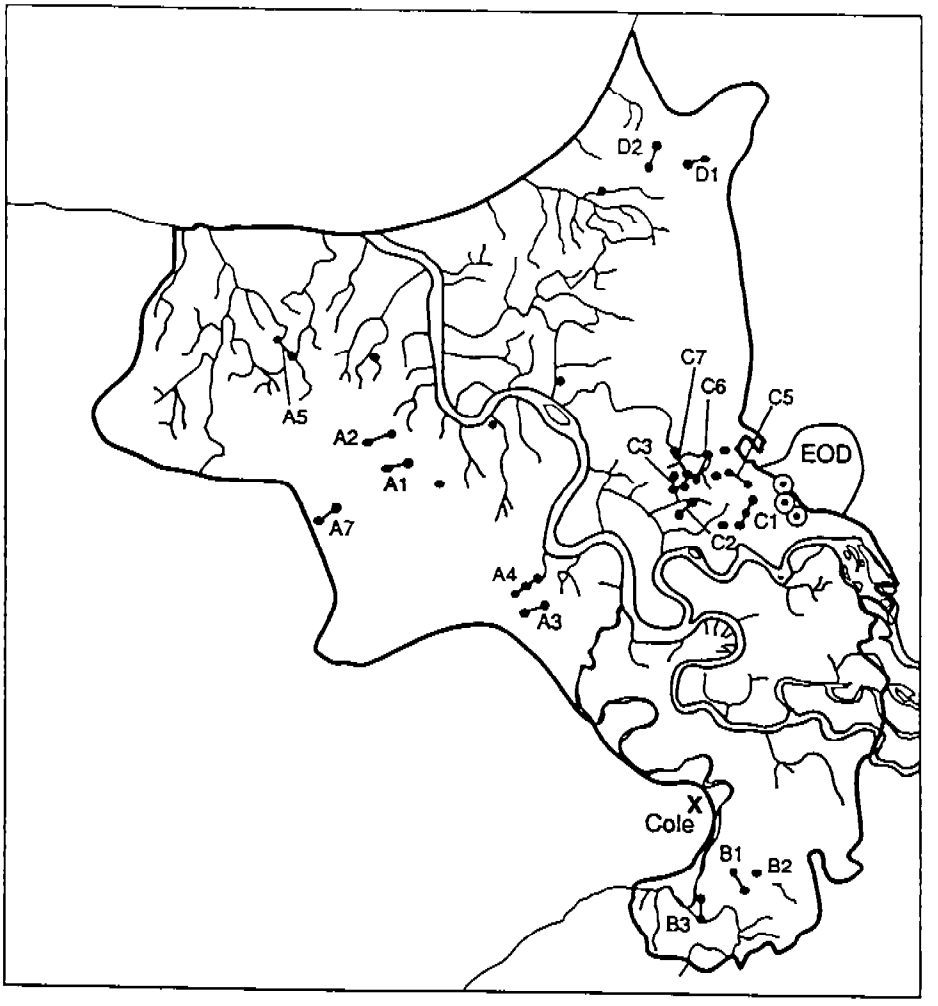


Figure 12. Spring sediment sample transects and three locations where 2,4-DNT was detected (circled dots).

OUC Remedial Investigation Figure C-10

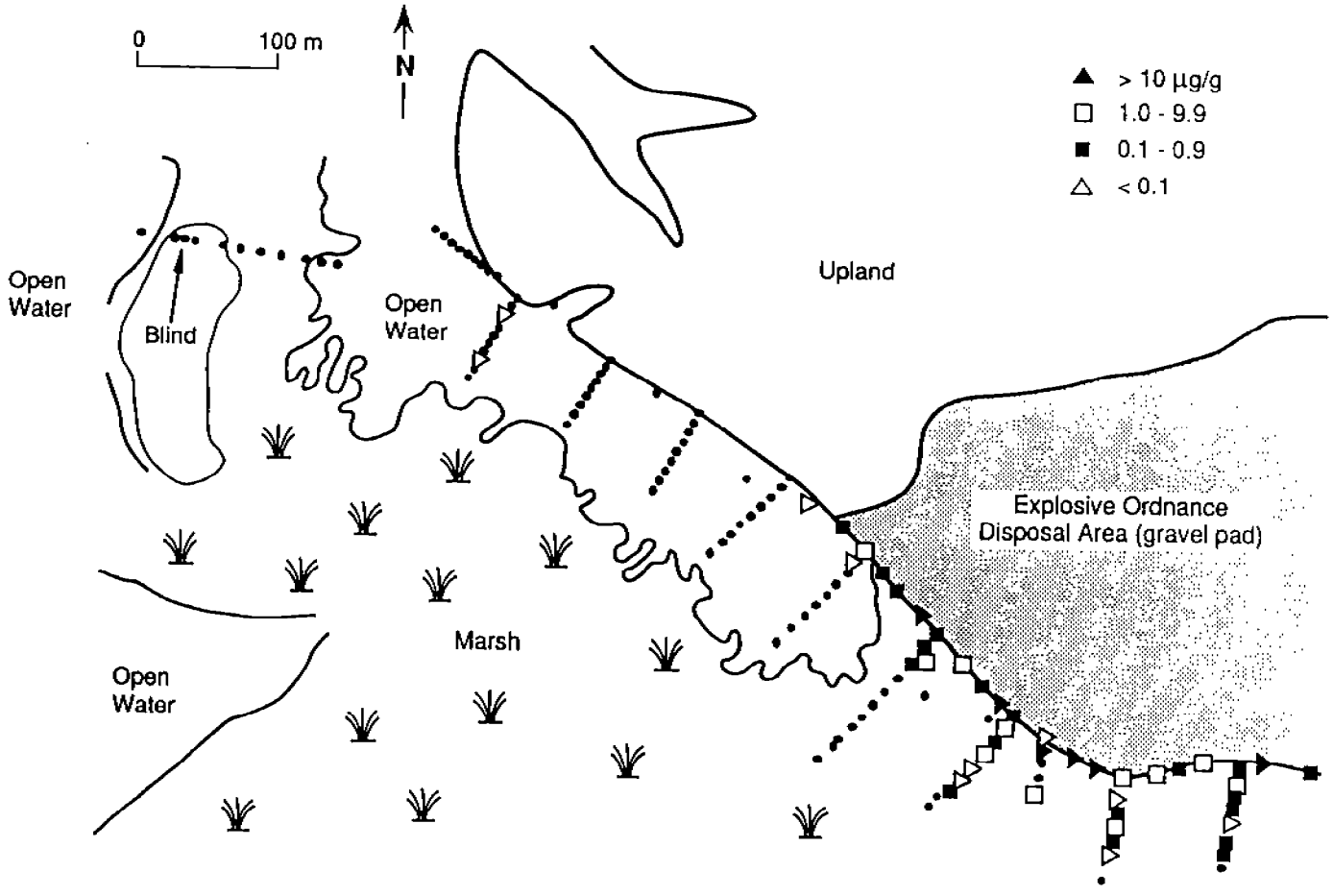


Figure 15. Area C sediment sample sites in relation to the detection of various levels of 2,4-DNT.

OUC Remedial Investigation Figure C-11

OUC 0029643

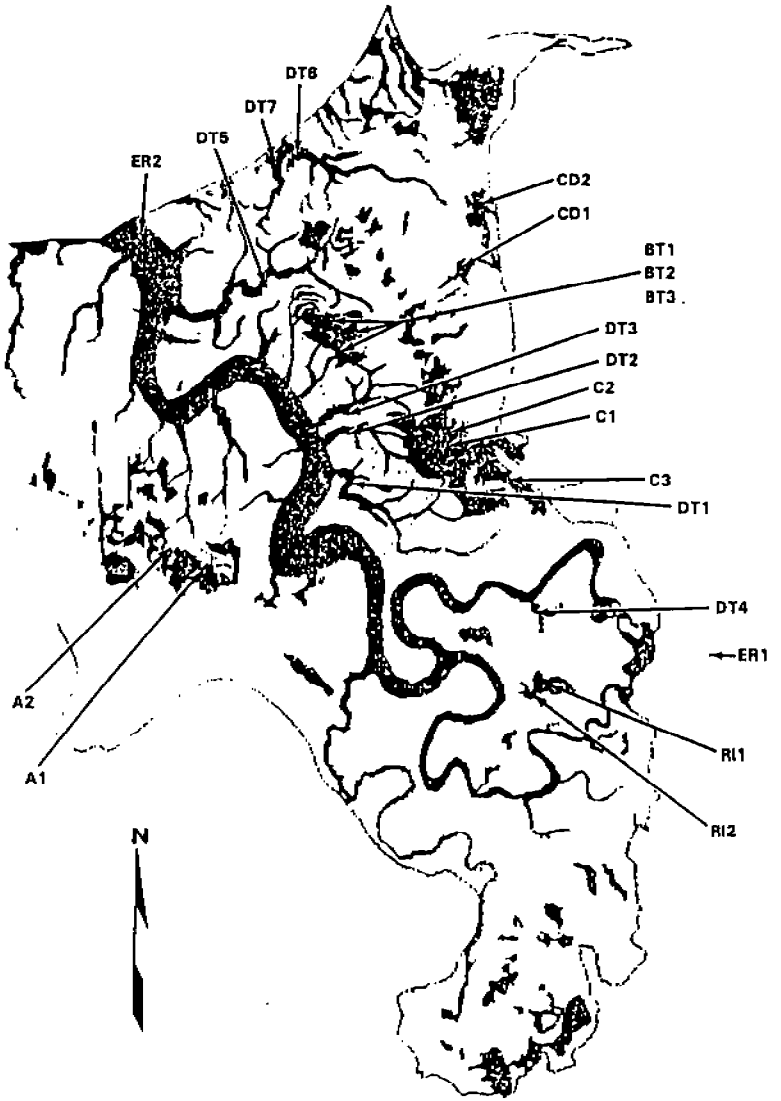


Figure III-1-1. Locations of the Eagle River and Goose Bay sample sites.

Table III-1-1. Coordinates for sample site locations, Eagle River Flats, AK, July 1993.

	UTM coordinates		Date collected	
Sample site	East	West	Sed/Invert.	Water
ER1	353600.00	6802300.00	7/20 NI	7/20
ER2 & DUP2	356195.00	6801203.00	7/21 NI	7/21
DT1	354570.00	6801150.00	7/16	NC
DT2	354525.00	6801325.00	7/16	NC
DT3	354500.00	6801400.00	7/16	NC
DT4	355570.00	6800600.00	7/21 NI	7/21
DT5	354351.00	6802027.00	7/16	7/21
DT6	354465.00	6802508.00	7/16	7/21
DT7	354272.00	6802376.00	7/16	7/21
A1	354000.00	6800700.00	7/19	7/19
A2	353700.00	6800975.00	7/19	7/19
CD1	355200.00	6802350.00	7/18	7/18
CD2	355325.00	6801175.00	7/18	7/18
BT1	354615.00	6801750.00	7/14	7/14
BT2	354620.00	6801675.00	7/14	7/14
BT3	354620.00	6801850.00	7/20	7/20
C1	355100.00	6801300.00	7/14	7/14
C2	355170.00	6801300.00	7/14	7/14
C3	355325.00	6801175.00	7/15	7/15
DUP1 (C3)	355325.00	6801175.00	7/21	7/21
RI1	355474.00	6800291.00	7/19	7/19
RI2	355474.00	6800252.00	7/19	7/19

NI = No invertebrates sample at these locations due to differences in habitat.
NC = Not collected due to lack of runoff.

OUC Remedial Investigation Figure C-12

OUC 0029644

Environmental Science and Engineering (ESE). *Eagle River Flats Expanded Site Investigation*. Fort Richardson, Alaska. Final Technical Report. Data Item A011. Prepared for the U.S. Army Toxic and Hazardous Material Agency. 1990.

Racine, C.H., M.E. Walsh, C.M. Collins, D.J. Calkins, B.D. Roebuck, and L. Reitsma. *Waterfowl Mortality in Eagle River Flats, Alaska–The Role of Munitions Residues*. CRREL Report 92-5. Cold Regions Research and Engineering Laboratory, U.S. Army Corps of Engineers. 1992.

4.0 Figure Sources

Figure Number	Source
C-1	ESE, 1990
C-2	ESE, 1990
C-3	ESE, 1990
C-4	ESE, 1990
C-5	ESE, 1990
C-6	ESE, 1990
C-7	ESE, 1990
C-8	ESE, 1990
C-9	ESE, 1990
C-10	Racine *et al.*, 1992
C-11	Racine *et al.*, 1992
C-12	Bouwkamp, in Racine *et al.*, 1994

Appendix D
Quality Assurance Audits

MEMORANDUM CH2M HILL

TO: U.S. Army Engineer District, Alaska

COPIES: Jacques Gusmano/ANC

FROM: CH2M HILL, Anchorage, Alaska

DATE: December 26, 1995

SUBJECT: Summary Report: 1995 Field Quality Assurance Audits, Eagle River Flats, Fort Richardson, Alaska

PROJECT: 130463.A1.50

The U.S. Army Corps of Engineers (COE) contracted with CH2M HILL to assist with quality assurance (QA) oversight of 1995 Eagle River Flats (ERF) field activities. This work was initiated under a scope of work titled Field QA Audits for 1995 Agency Field Work, Task 14 and 14A of Contract No. DACA85-92-D-0015, Delivery Order 1.

According to the Scope of Work for Task 14 and 14A, CH2M HILL was to provide periodic field quality assurance/quality control (QA/QC) audits in accordance with the 1995 quality assurance program plan (QAPP) document developed by CH2M HILL.

The QA audits were completed by CH2M HILL during site visits to ERF on the following dates during 1995:

- July 11: Physical Systems Dynamics study (U.S. Army Cold Regions Research and Engineering Laboratory [CRREL], Dan Lawson)
- July 25: Dredging Treatability study (CRREL, Mike Walsh)
- August 9: Eagle and Waterfowl Telemetry study and AquaBlok™ Treatability study (Denver Wildlife Research Center, John Cummings and Patty Pochop)
- September 1: Waterfowl Mortality study (New England Institute for Landscape Ecology, Shan Bursen)
- September 16: follow-up audit for Dredging Treatability study (CRREL, Mike Walsh)

The attached technical memorandums describe observations of field research activities conducted during the audits and recommendations that were made for improved QA/QC procedures for future fieldwork at ERF. Immediately following each of the QA audits, CH2M HILL auditors verbally summarized their observations and recommendations to

Ms. Laurie Angell of the 6th Infantry Division, Fort Richardson, and to the field researcher(s) involved in each audit.

Attachments: Field Quality Assurance Audit Memorandums

MEMORANDUM

CH2M HILL

TO: Rich Jackson/ADCOE

COPIES: Jacques Gusmano/ANC

FROM: Mike McCrum/ANC

DATE: December 26, 1995

SUBJECT: Eagle River Flats, Fort Richardson, Alaska–Quality Assurance Field Audit Assistance Visit, July 11, 1995

PROJECT: 130463.A1.50

Introduction

One site visit was made to the Eagle River Flats on Fort Richardson to observe treatability studies and interview researchers performing the studies. This July 11, 1995, site visit focused on the physical system dynamics study conducted by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). The objectives of the site visit were as follows:

- Provide insight into specific objectives and methods being used as part of this study
- Determine what types of data were being collected as part of the study and how they are to be used
- Observe field procedures being employed during the study and how these procedures are documented
- Review with research personnel how samples are being handled and how data are being managed
- Provide rapid feedback to the research team on potential improvements that could be made to the fieldwork to make it more consistent with the typical requirements for such work at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites

The results of this site visit were recorded in the field notebook kept for site visits conducted as part of CH2M HILL's data quality assurance (QA) effort.

Observations

Observations made during the site visit are summarized below. Observations were limited to collection of field data in support of the project objective. The project objective was to determine the hydrology, sedimentology, and hydraulic processes controlling the erosion, transport, deposition, and burial of sediments bearing white phosphorus (WP).

Sampling locations for this study were at Bread Truck Pond and Racine Island. The project approach, materials, and equipment to be used; instrument calibration; documentation procedures; data documentation; and data management were discussed with CRREL field team members. The following specific observations were made during the site visit:

- Data collection is performed at pre-designated stations. Each station contains the following equipment:

  - A Campbell CR-10 data logger (including power source)

  - HydroLab for pH, specific conductivity (SC), temperature, oxidation reduction potential (redox), salinity

  - Marsh-McBirney flowmeter

  - ISCO auto sampler for total suspended solids (TSS) sampling in gullies

  - Surveyed stakes and measuring points along each gully edge for measuring erosion

  - Floating platform to keep equipment dry during flooding tide

- The data logger is used to store water quality parameters, including TSS, DO, redox, temperature, SC, and salinity. Additional data recorded by the data logger include surface-water flow velocity and water level stage (on flats).

- The procedure for downloading data from the data logger to final destination into ARCINFO (geographical information system [GIS] database) is as follows:

  - Data are downloaded from the data logger onto a Northgate portable computer hard disk.

  - Data stored on the Northgate hard disk are downloaded to a Bernouli storage device.

- From the Bernouli storage device, data are transferred onto a desktop PC and into Excel.

- The Excel file is imported into ARCINFO.

- After data are put into ARCINFO, the end time and date are verified.

- Calibration procedures, as specified by the manufacturer, are followed for use of the HydroLab field instrument. The calibration is reported to be performed bimonthly. In 1994, the HydroLab was calibrated at the beginning and end of the year. Only minor drift on the salinity measurement was noted. Calibration is accomplished through TSS measurements.

- The TSS and base-load solids are being measured in gully water adjacent to Bread Truck Pond. The TSS samples are collected at pre-defined times from the gully. Collection is based on the flooding tide. Samples are collected with increasing frequency as the maximum height of the flooding tide approaches and with decreasing frequency as the height of the flooding tide diminishes.

- Each carousel in the ISCO autosampler holds up to 25 TSS sample jars. Once sampling is complete, lids are placed on the jars and the jars are removed. During sampling, the jars are covered inside the autosampler. A new carousel with empty jars is then placed in the sampler and a new sampling frequency is programmed. The full sample jars (still in the carousel) are transported to Building 992 (laboratory) where TSS is measured. TSS is measured as described in notes from the 1994 QA site visit.

- The OBS, used for field measurements of TSS, is calibrated by using results of TSS samples analyzed offsite.

- Discussed, but did not observe, data collection for deposition rate, erosion in gullies, and sample collection by using plankton nets. Erosion and sediment deposition activities are identical to 1994. Plankton nets are set in gullies and the net bottoms are held on the bottom of gully. The fine mesh in the net allows suspended sediment to pass through, but coarser bed load is held. Sediment is trapped in a metal cup at the end of the net and is collected in jars. Nets are allowed to stay in the gully for only a short period of time because flow reversal during incoming tide causes the net to tangle and become ineffective as a sample collection device during the outgoing tide.

Findings

The procedures being used by the field personnel appear to be consistent and understood by the individual members of the field staff. Because the stations are automated, most of the effort expended by the field crew is to clean off the probes, download data from the Campbell CR-10 data logger, and change sample bottles in the autosampler. The most critical of these activities, from a QA perspective, is the data-downloading task. Although this activity minimizes the impact of field activities on data quality, it makes data handling and data management of paramount importance.

Observations made during the field visit were discussed with the field crew. During this discussion, team members reported placing sediment samples from the plankton net in the refrigerator in Building 992. Neither the room containing the refrigerator nor the refrigerator is secured. The field team was informed that this practice is not consistent with chain-of-custody procedures.

Recommendations

On the basis of findings during the site visit, the following recommendations are made to assist the field teams at Eagle River Flats in producing data that will be more likely and better able to meet the requirements for use in the CERCLA process.

- The refrigerator in Building 992 should be secured during those times when no project team members are within direct line of sight with the refrigerator.

- The automated nature of the fieldwork reduces the potential for many of the activities performed by field personnel to significantly affect data quality. Downloading the data is a process that should be documented by the team, however, and procedures for verifying the accuracy of the data should be developed and documented. The procedures should include standard operating procedures for downloading, transferring, and checking the data for accuracy and consistency both before and after the data are input into the GIS system.

- Field calibration of instruments should be documented separately from other field-data-collection activities. These records should be kept in a central notebook that may be reviewed easily so that error in the data attributable to issues such as potential instrument drift may be defined.

MEMORANDUM

CH2M HILL

TO: Rich Jackson/ADCOE

COPIES: Jacques Gusmano/ANC

FROM: Mike McCrum/ANC

DATE: December 26, 1995

SUBJECT: Eagle River Flats, Fort Richardson, Alaska–Quality Assurance Field Audit Assistance Visit, July 11, 1995

PROJECT: 130463.A1.50

Introduction

One site visit was made to Eagle River Flats (ERF) on Fort Richardson to observe a study being conducted as part of the current investigation. Researchers performing the study were also interviewed. This September 1, 1995, site visit focused on the study being conducted by the New England Institute for Landscape Ecology (NEILE). The objectives of the site visit were as follows:

- Observe field personnel as they walk mortality transects
- Observe how carcasses are processed, counted and documented
- Verify that project personnel are performing field-data-collection activities per standard operating procedures included in the 1995 work plan

The results of this site visit were recorded in the field notebook kept for site visits conducted as part of CH2M HILL's data quality assurance (QA) effort.

Observations

Observations made during the site visit are summarized below. Observations were limited to collection of field data in support of the project objective. The project objective was to monitor waterfowl mortality in specific areas of ERF and monitor trends in the waterfowl population during the same period as mortality counts are performed. The field-data-collection activities for this study are documented in the work plan titled "A Proposal for the 1995 Eagle River Flats Field Season."

Population Counts. The field team spends several hours each morning in the tower on Cole Point observing and counting waterfowl on ERF. The purpose of this effort is to estimate the

total population of waterfowl on ERF that day. The results are compared with population estimates made during a weekly flyover made by the U.S. Fish and Wildlife Service.

Mortality Transects. A series of predefined transects are traversed by field personnel once each week during the spring and fall migrations. Carcasses observed along these transects are tagged and counted and species type is recorded. Carcasses that appeared to be relatively fresh (death is estimated to have occurred within the last several hours) were collected, bagged, and shipped to a laboratory for tissue analysis (by Dr. Bill Roebuck's team and Dartmouth College).

Findings

The field team leader has been participating in this study for several years, and is quite familiar with the study objectives and procedures. The members of the field team use consistent observation and tagging techniques. They check each other's field notes periodically for consistency and accuracy. The field team members are also familiar with transect locations and follow consistent paths on each transect. The field team is generally close enough to other members to discuss observations made in the field, enhancing the team's ability to make consistent observations.

Recommendations

The field team discusses their observations with the U.S. Fish and Wildlife service periodically in an effort to compare census results obtained by the two teams. However, it is not clear how often the NEILE team coordinates with the Denver Wildlife Research Center team. Although not critical, it is recommended that these two teams meet to discuss observations periodically.

Carcasses collected for toxicology work (performed at Dartmouth) should be handled according to the same chain-of-custody procedures as for other samples. Standard operating procedures for collecting, preserving and shipping carcasses should be maintained by the field team in a location where they may be conveniently referred to by field team members. Chain-of-custody records and other pertinent sample documentation should be maintained in single notebook that may be made available for review on short notice. As part of the sample handling process, sample storage should comply with standard chain-of-custody procedures, including securing samples when not in direct line of sight by field team members.

The final and most important recommendation involves coordination between mortality estimating activities and hazing. Areas where mortality has been documented in the past have been targeted for hazing through the use of several different methods. The documentation reported in previous years suggesting that hazing is at least partially effective

in reducing waterfowl mortality makes it highly probable that hazing is affecting the accuracy of the data collected as part of the mortality estimating project. This conclusion is consistent with observations made in the field (flagging, carbon dioxide cannons, and periodic visits by hazing personnel). It is recommended that continuation of this effort to estimate waterfowl mortality in ERF be performed under different conditions that would minimize the impacts of hazing on the results of this study.

MEMORANDUM CH2M HILL

TO: Rich Jackson/ADCOE

COPIES: Jacques Gusmano/ANC

FROM: Mike McCrum/ANC

DATE: December 26, 1995

SUBJECT: Eagle River Flats, Fort Richardson, Alaska–Quality Assurance Field Audit Assistance Visit, August 9, 1995

PROJECT: 130463.A1.50

Introduction

One site visit was made to Eagle River Flats (ERF) on Fort Richardson to observe treatability studies and interview researchers performing the studies. This August 9, 1995, site visit focused on the eagle and waterfowl telemetry study and the AquaBlok™ study, both conducted by the Denver Wildlife Research Center (DWRC) APHIS/USDA. The objectives of the site visit were as follows:

- Provide insight into specific objectives and methods being used as part of this study
- Determine what types of data were being collected as part of the studies and how they are to be used
- Observe field procedures being employed during the studies and how these procedures are documented
- Review with research personnel how samples are being handled and how data are being managed
- Provide rapid feedback to the research team on potential improvements that could be made to the fieldwork to make it more consistent with the typical requirements for such work at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites

The results of this site visit were recorded in the field notebook kept for site visits conducted as part of CH2M HILL's data quality assurance (QA) effort.

Observations

Field-data-collection activities for the telemetry and AquaBlok™ studies are documented in the following work plans, respectively: Monitor the Movements, Distribution, and Relative Risk of Waterfowl and Bald Eagles Using Eagle River Flats at Fort Richardson, Alaska, and Evaluation of AquaBlok™ on Contaminated Sediments to Reduce Mortality of Foraging Waterfowl. The observations, made during this site visit and summarized below were limited to collection of field data in support of the project objectives. Three tasks were observed under the two projects: (1) checking the AquaBlok™ site, (2) data collection in support of the telemetry study, and (3) bird tagging (part of the telemetry study).

AquaBlok™ Site. The project approach, materials, and equipment to be used; documentation procedures; data documentation; and data management were discussed with field team members. The following specific observations were made during the site visit:

- Six staff gauges were being used for measurement of water height around the perimeter of the pond. The staff gauges establish the depth of water over the AquaBlok™. A local datum is noted at each measuring point.

- Ducks were counted from the air with the use of a rotor wash to move grass.

Telemetry. The project approach, materials, and equipment to be used; documentation procedures; data documentation; and data management were discussed with field team members. The following specific observations were made during the site visit:

- Ducks that had been recently been captured were being processed. See the section on bird tagging below.

- Receivers were used in towers located at Canoe Point and on Cole Point to record the azimuth for the ducks that had been fitted with transmitters and remained on ERF. Four readings were made in the morning and two readings were made in the evening for each duck fitted with a transmitter.

- Separate radio tracking forms (one for each duck) were used to record the azimuth on individual ducks. The forms were copies of the original form placed in the master notebook. The competed copies were filed in the notebook with the original so that the location of each duck could be calculated by triangulation.

Bird Tagging. The following specific observations were made during the site visit:

- Three widgeons were captured in mist nets. The birds were transported to Building 992 (laboratory). Each bird was identified by sex, banded and tagged,

and weighed. Transmitters were then placed on their backs. The birds were allowed to remain at Building 992 for several hours before being released.

- The serial numbers and descriptions of birds that were equipped with transmitters were logged in the master log book with the data listed above.

Findings

The procedures being used by the field personnel appear to be consistent and understood by the individual members of the field staff. The QA program established and followed by DWRC personnel is extensive and effective. The field teams were knowledgeable and appeared to maintain detailed records of field activities on preprinted forms. Recorded data were carefully maintained. The standard operating procedures listed in the 1995 work plan were followed. No deviations from these procedures were observed. The work plan provided a form to be filled out when such deviations occur so that exceptions to the plan may be recorded.

In general, the QA procedures followed by the DWRC field team were followed consistently. The teams followed the work plan as written and their documentation procedures were excellent.

Recommendations

The QA program established for field data collection by the DWRC was consistently applied and is very effective. No procedures or practices were observed in the field that warranted change. It is recommended that the data collected by DWRC be reviewed by the researchers after it has been entered in the database for completeness and accuracy.

MEMORANDUM

CH2M HILL

TO: Rich Jackson/ADCOE

COPIES: Jacques Gusmano/ANC

FROM: Colleen Burgh/ANC

DATE: December 26, 1995

SUBJECT: Eagle River Flats, Fort Richardson, Alaska–Quality Assurance Field Audit Assistance Visit, July 25, 1995; and Follow-up Quality Assurance Audit, September 16, 1995

PROJECT: 130463.A1.50

Introduction

A quality assurance (QA) audit field visit was conducted at Eagle River Flats (ERF), Fort Richardson, on July 25, 1995. A follow-up audit was completed on September 16, 1995. The field audits focused on the dredging treatability study that was under way at Area C of ERF. This study is being conducted by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). Mike Walsh is the principal investigator and was onsite during the field visits.

The objectives of the audits were as follows:

- Provide insight into specific objectives and methods being used as part of this study
- Determine what types of data were being collected as part of the study and how they are to be used
- Observe field procedures being employed during the study and how these procedures are being managed
- Review with research personnel how samples are being handled and how data are being managed
- Provide rapid feedback to the research team on potential improvements that could be made to the field work to make it more consistent with Comprehensive Environmental Response, Compensation, and Liability Act requirements for National Priorities List sites.

The results of both QA audits were recorded in the field notebook kept for site visits conducted as part of CH2M HILL's assistance task for ERF field studies.

July 25, 1995, Field Visit

Observations

The July 25, 1995, QA audit included observations of the dredge spoils retention basin at the explosive ordnance disposal (EOD) pad and CRREL's sample collection procedures of the dredge spoils at the retention basin.

The dredge was in operation off Clunie Point, within Area C of ERF. When the dredge is in operation, the only personnel at the Area C site are the two operators of the dredge, who stay inside a protective booth while remotely operating the dredge and viewing the subsurface dredging conditions on a monitor. No other personnel are allowed at the dredging site during active dredging, because of safety concerns with unexploded ordnance. Therefore, the QA audit consisted of observations at the EOD pad where samples of the dredged material were obtained.

Mike Walsh, principal investigator and project coordinator for the dredging treatability study, was onsite and was the sampler for CRREL during this QA audit. The dredge spoils exit the discharge line into the retention basin. Mike samples the dredge spoils through a small outlet on the discharge line, before the spoils empty into the retention basin. The outlet is fitted with a valve that can be opened and closed for sampling.

According to the sampling and analysis plan for this study, dredge spoils were to be sampled from the discharge line at 15-minute intervals. Percent solids in the discharge was approximately 4 to 10 percent, less than the target of 20 percent solids. Four samples, taken 15 minutes apart, were collected into a dedicated 5-gallon bucket marked with graduated "fill lines" and were allowed to temporarily settle out before collection of the solids into sample jars. The dredged material was allowed to settle out for a minimum of 2 hours, or overnight if the last sampling episode occurred at the end of the work day. Mike pre-labeled sample jars before filling them with the dredged material.

Throughout the day, the dredge operators, Mike, and the Fort Richardson range control personnel maintained excellent communications with the use of two-way radios and a dedicated channel for ERF activities. Several sets of dredge spoil sample collection were observed during the site visit. Mike used proper sampling techniques to fill the sample containers; however, he did not wear protective gloves during all of the sampling procedures, as specified in the sampling standard operating procedures (SOP) and quality assurance program plan (QAPP). Mike maintained field notes in a bound notebook onsite throughout the day. His field notebook was reviewed during the audit, and it was observed that not all pages were numbered and initialed as specified in the ERF QAPP. The information in the notebooks appeared legible and complete, and it was presented in a logical sequence.

According to Mike, there was no comprehensive sample numbering system established for ERF field sampling this year. He had developed his own sample identification system that he was using for all samples he collected. Sample numbers were correctly entered into his field notebook, on the jar labels, and on the chain-of-custody (COC) forms. At the end of each day of sample collection, Mike filled out a COC form and submitted a copy of the form with the samples to the Chemtrack International, Inc., personnel assigned to receive and analyze samples. Mike was not sure what happened to the samples after he relinquished them to Chemtrack. Mike retained his copy of each COC form.

Sampling of the sediment basin supernatant is done at the weir located across the retention basin from the discharge line area. Mike collected one sample from this location during the audit. He did not wear protective gloves during the sample collection, as specified in the QAPP. Access to the sampling area was done by carefully stepping down into the weir area and onto an overturned 5-gallon bucket. This did not appear to be a safe way to enter the weir area due to high potential of slipping or falling from the bucket, especially if it overturned.

Findings

Mike was very cooperative during this QA audit and genuinely interested in learning more about proper sampling techniques and documentation for this study. This is the pilot test for the dredge, and continuing "glitches" with the equipment need his attention. He devoted his full attention to the sampling routine during the times that dredge spoils were available in the line for sampling, however, and he did a good job of obtaining the samples and documenting the site activities in his field notebook.

The following findings were observed during the audit on July 25, 1995:

1. Gloves should be worn during sampling, as specified in the SOP for collecting soil samples and in the QAPP.

2. Pages in the field notebooks need to be consistently numbered, dated, and signed by the author.

3. Leaving buckets full of the dredged material out overnight for settling of the solids does help in collection of the solids; however, technically this practice does not maintain the samples under COC, and it does not guarantee that appropriate temperature control is maintained for the material, as specified in the SOP and QAPP. Although the EOD pad area itself has restricted access, that does not qualify the samples left onsite as being under COC.

Additional Issues

1. It was apparent during this QA audit that a pre-designated sample identification strategy was not developed for samples collected at ERF this year. Lack of an identification strategy may make data review and data entry more difficult. Mike's sample-numbering scheme matched the information in his field notebook and should assist with re-constructing the origin of the samples collected during the dredging study.

2. Mike was properly filling out and retaining his copies of the COC form; however, there did not appear to be an established and consistent procedure for getting copies of the COCs to the CRREL database team for tracking samples.

3. No information was available regarding the disposition of samples after CRREL hands samples over to Chemtrack. Proper sample custody, shipping, analysis, documentation, and sample tracking by Chemtrack could not be determined during this QA audit. According to Mike, the analyses are performed locally; therefore, packaging the samples for air shipment may not be necessary.

4. Operations at Building 992 were not observed during this audit. A sample storage refrigerator is used in the building for temporarily storing project samples before shipment and analysis. According to Mike Walsh and other personnel who use the building, the refrigerator that temporarily stores project samples is not equipped with a lock to maintain samples under proper COC.

Recommendations

1. Gloves need to be worn during collection of all samples, as specified in the SOP and QAPP.

2. Pages in field notebooks need to be consecutively numbered and signed by the author.

3. Dredge spoils that are collected in the 5-gallon buckets and left onsite for any length of time for settling out of solids need to be secured under COC if the sampler is not onsite. The buckets need to be transported to a place where they can be locked up, or a locking cabinet needs to be situated onsite for use.

4. Copies of the completed COC forms need to be routinely sent to the CRREL database project manager or his representative for sample tracking and data entry.

5. The refrigerator at Building 992 needs to be equipped with a lock if samples are stored in it, to maintain COC.

September 16, 1995, Field Visit

On September 16, 1995, a follow-up QA audit was completed during a site visit with Mike Walsh and the dredging crew. The purpose of this audit was to check on improvements in the QA/QC procedures implemented since the July 25 audit. The dredge was still operating in the Clunie Point area at ERF, and the overall monitoring and sampling operation at the EOD settling pond was the same as described for the July 25 audit. Mike was onsite for this field visit as the team leader for CRREL and Chemtrack International, Inc.

The following observations were documented during the September 16 follow-up audit:

- Mike Walsh was collecting samples from the dredge discharge line correctly and wearing protective gloves, as specified in the QAPP.
- A locking storage cabinet was located onsite for temporary storage of dredge spoils, and COC was properly maintained for samples onsite before transfer to Chemtrack personnel.
- Mike's field notebook was correctly filled out and all site activities appeared to be adequately described.
- Although Building 992 was not inspected during the audit, reportedly a lock had been put on the refrigerator that was used to store samples under COC.

During the site visit, Mike noted that he was running out of COC forms and COC seals for the coolers. On the following Monday, September 18, CH2M HILL sent a replacement supply of forms and custody seals to Fort Richardson for Mike's use.

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QUALITY CONTROL
FIELD AUDIT CHECKLIST

PROJECT NO. GLE74024.NBDD DATE OF AUDIT 5/23/94
PROJECT MANAGER Bill Gossweiler AUDITOR Joe Sandon
FACILITY NAME Eagle River Flats
LOCATION Fort Richardson Alaska

FIELD PERSONNEL Carl Bowskamp, Rick Griffiths

Summary and Recommendations

U.S. Army Environmental Hygiene Agency

Samples were being gathered to assess and evaluate sediment toxicity and transport of WP.

The USAEHA field team had a thorough understanding of the scope, objectives and requirements of their project. They were experienced field professionals who were also familiar with the site.

The observed sampling activities were performed in a consistent manner with no observable deficiencies based on the nature of the sampling, the contaminants, and the intended use of the data.

Though samples were collected in an organized manner, they were not collected at the location identified in the original work plan due to changes in field conditions. The work plan did not include criteria for selecting or modifying sampling locations.

Chain of custody forms were single page forms with two carbon copies. The sole copy was shipped with the samples and no copy was retained by the field team.

There were no written SOPs for instrument calibration, instrument operation, maintaining log books, chain of custody, sample shipment.

Summary and Recommendations (continued)

Recommendations:

1. All deviations from the (work plan, study plan, QAPP and other) project documents need to be documented in the field log book).

2. The (work plan/study plan) should include criteria for selecting, identifying or modifying sampling locations. Any changes to previously identified sampling locations should be identified in the field logbook along with the rationale for the change.

3. Chain of custody forms should have multiple copies and one copy should be retained by the field crew. The chain of custody form is the primary link between the sampler and the final data. It is a record of samples taken and of data expected from the laboratory.

4. SOP's should be developed and implemented for all project activities like calibration, instrument operation, chain of custody, field log books, sample packing and shipment and other regular project activities.

PLANNING AND PREPARATION

Yes or No

1. Was the field audit announced or unannounced?
   Comments: _____

2. Was a QA Project Plan prepared for this activity? — ✓
   Comments: There was a work plan which included elements of a QA plan but there was no separate QA plan.

3. Was a site Health and Safety Plan prepared for this activity? ✓ —
   Comments: There is a site wide HrS plan.

4. Was a briefing held with project field participants? ✓ —
   Comments: _____

5. Were additional instructions given to project field participants (i.e., changes in project plan)? — —
   Comments: N/A due to small size of team

6. Was there a written list of sampling locations and descriptions? ✓ —
   Comments: The work plan included a list of planned sampling locations and a map

7. Was there a map of sampling locations available to to field personnel? ✓ —
   Comments: See comment above

8. Was equipment list given to equipment coordinator with adequate lead time? — —
   Comments: N/A

Yes or No

9. Was laboratory given a list of sample containers with adequate lead time? ___ ___
Comments: N/A

10. Were analyses scheduled with the laboratory in advance? ___ ___
Comments: N/A

SAMPLING

GENERAL PROCEDURES

		Yes or No
1.	Was permission granted to enter and inspect the facility? Comments: ~~Ran~~ Range control entry procedures were followed	✓ —
2.	Was permission to enter the facility documented? Comments: N/A	— —
3.	Were sampling locations properly selected? Comments: See overall comments	— —
4.	Were samples collected starting with the least likely contaminated and proceeding to the most likely contaminated? Comments: N/A	— —
5.	Were new disposable rubber gloves worn during sample collection? Comments: Gloves were generally not worn during sample collection	— ✓
6.	Was sampling equipment wrapped in aluminum foil or otherwise protected from possible contamination prior to sample collection? Comments: N/A - The nature of the contamination does not require this type of effort	— —
7.	If equipment was cleaned in the field, were proper procedures used? Comments: Equipment was thoroughly rinsed between sampling locations with site water, and there was acetone and rinse water available. There was, however, no decon SOP	✓ —

Yes or No

8. What field instruments were used during this investigation? ✓ —
   Comments: ~~Hnu~~ - pH/conductivity/temp meter

9. Were field instruments properly calibrated? — —
   Comments: Not possible to determine Operators said instruments are calibration checked daily prior to going to the field.

10. Were calibration procedures documented in the field notes? — ✓
    Comments: No

11. Were samples chemically field preserved? — —
    Comments: N/A

12. Were samples iced? — —
    Comments: Final packing was not observed but samples were iced at the truck

WELL SAMPLING

1. Was depth of well determined? — —

2. Was depth to water determined? — —

3. Was measuring tape properly decontaminated between wells? — —
   Comments:

4. Were the above depths to water converted to water level elevations common to all wells? — —
   Describe how the depths were determined.

5. How was the volume of water originally present in each well determined?

Yes or No

6. Was the volume determined correctly? ___ ___

7. How was completeness of purging determined?
   Volume
   Measure_____
   Time/Flow rate_____
   Cond./ph/T_____

8. Was a sufficient volume purged? ___ ___

   Was the well over-purged? ___ ___

9. Was the disposal of purge water handled properly? ___ ___
   Comments: _____

10. Was a dedicated (in-place) pump utilized? ___ ___

    If no, describe the method of purging (bailer - include type and construction material. pump - include type)_____

11. How were the samples collected?

    Bailer ____
    Pump ____
    Combination ____

    Construction material of bailer:

    S.S. ____
    Teflon ____
    PVC ____
    Other ____

    Comments: _____

12. If a pump was used, describe how it was cleaned before and/or between wells._____

	Yes or No
13. Were the samples properly transferred from bailer to sample bottles (i.e., was the purgeable sample agitated, etc.)?	— —
14. Was the rope or line allowed to touch the ground?	— —
15. Was wetted rope or line discarded after use at each well?	— —
16. Was cotton or teflon coated rope used?	— —
17. Were generators/gas pumps placed in a down wind position from the well during operation?	— —

SURFACE WATER SAMPLING

		Yes or No
1.	What procedures were used to collect surface water samples? Containers were dipped below the water surface to fill	
2.	Did the samplers wade in the stream during sample collection?	✓ —
	If yes:	
	Did sampler face upstream while collecting sample?	✓ —
	Did the sampler insure that roiled sediments were not collected along with water sample?	✓ —
3.	Note any deficiencies observed during the collection of the surface water samples? None observed	

SEDIMENT SAMPLING

1.	What procedures were used to collect the samples? Samples were collected with a stainless steel scoop. A plastic bucket with the bottom cut out was used to isolate the area to be sampled. A sieve was also used to separate detritus	
2.	Were the samples well mixed prior to placing the sample in the sample container?	✓ —
3.	Note any deficiencies observed during the collection of the samples. None observed. Though samples were taken boat handed. This will not be a contamination problem, but there could be Health and Safety concerns.	

4. Were samples composited?
If so, how were composites collected and mixed? N/A

SOIL SAMPLING

Yes or No

1. What procedures were used to collect samples?

2. Were the samples well mixed prior to placing the sample in the sample container? ___ ___

3. Note any deficiencies observed during the collection of the samples.

4. Were samples composited? ___ ___
If so, how were composites collected and mixed?

OTHER SAMPLING

1. What other types of samples were collected during this investigation?

2. What procedures were used for the collection of these samples?

QUALITY ASSURANCE/QUALITY CONTROL

Yes or No

(While not all of these QA/QC procedures will be necessary during each sampling activity, the following techniques may be employed. If so, please note.)

1. Did sampling personnel utilize any trip blanks? N/A ___ ___

2. Did sampling personnel utilize preservative blanks? N/A ___ ___

If yes, to either of the above questions, list the types and handling of the blanks._____

3. Were any equipment blanks collected? N/A ___ ___

If yes, list:_____

4. Were any duplicate samples collected? N/A ___ ___

If yes, list the types (parameter coverage, etc.) and describe their handling._____

5. Were any spiked samples utilized? N/A

If yes, list the types (parameter coverage, etc.) and describe their handling._____

6. Were QA/QC samples specified in the QA Project Plan? ___ ___

Were the QA/QC samples collected in accordance with the QA Project Plan? ___ ___

7. Check method used to collect split sample N/A

___ Filled one large container and then transferred portions

___ Sequentially filled bottles

FIELD DOCUMENTATION AND CHAIN-OF-CUSTODY

		Yes or No
1.	Were chain-of-custody records completed for all samples?	✓ —
2.	Were all samples identified with Sample I.D. tags or labels? Comments: Labels	✓ —
3.	Were Sample I.D. tags or labels filled-out (e.g., completely station no., location, date, time, analyses, signatures of samplers, type preservatives, etc.)? Comments:	✓ —
4.	Did information on Sample I.D. tags or labels and Chain-of-Custody Records match? Comments: Not checked	— -

5. Check manner of sample delivery to the lab.

— Hand delivered by sampling team member

✓ Shipped by common carrier

If shipped by common carrier:

Did the Chain-of-Custody Records indicate the method of sample shipment? — —
Comments:

If shipped by common carrier:

Was a Chain-of-Custody record included with the samples in the shipping container? ✓ —
Comments:

		Yes or No
6.	Were samples kept under lock and key or kept in a secure place after collection?	✓ / —
7.	Were sample tags, Chain-of-Custody forms, and field notebook signed by sampling personnel?	✓ / —
8.	Does the field notebook contain adequate information about each sample including the sample I.D. number, date, location, and information necessary to reconstruct the sample? Comments: Greater detail in the field notebook would help others in understanding the notes	— / ✓
9.	Were entries to the field notebook made in ink? Comments:	✓ / —
10.	Were corrections properly executed with one line through the error in the field notebook? Comments:	— / —
11.	Was sampling documented with photographs?	— / ✓
	If yes, was a photolog maintained?	— / —
12.	Were amendments to the project plan documented (on the project plan itself, in a project logbook, elsewhere)? Comments:	— / ✓

Attachment D

QUALITY CONTROL
FIELD AUDIT CHECKLIST

PROJECT NO. NTE 7 #024.03/31 DATE OF AUDIT 3/24/94
PROJECT MANAGER Bill Gwozdz AUDITOR Joe Sandrin
FACILITY NAME Eagle River Flats
LOCATION Fort Richardson Alaska

FIELD PERSONNEL Marianne Walsh, Charles Collins
Dave Dillingham

Summary and Recommendations

CRREL

The field team was observed setting up monitoring stations for the natural attenuation study

Some field measurements were made, but no samples were taken.

The work was carried out in an organized and professional manner according to the study plan. No deviations were observed.

The work observed was the setup of a longer term study but there was little to observe in sampling or data gathering.

Recommendations:

1. Develop and implement SOPs for project activities including field sampling and measurement, instrument calibration and operation, field log books and other regular project activities.

PLANNING AND PREPARATION

Yes or No

1. Was the field audit announced or unannounced?
   Comments: _____

2. Was a QA Project Plan prepared for this activity? — ✓
   Comments: no

3. Was a site Health and Safety Plan prepared for this activity? ✓ —
   Comments: Yes

4. Was a briefing held with project field participants? ✓ —
   Comments: Yes

5. Were additional instructions given to project field participants (i.e., changes in project plan)? — —
   Comments: N/A

6. Was there a written list of sampling locations and descriptions? ✓ —
   Comments: Yes

7. Was there a map of sampling locations available to to field personnel? ✓ —
   Comments: Yes

8. Was equipment list given to equipment coordinator with adequate lead time? — —
   Comments: N/A

Summary and Recommendations (continued)

SAMPLING

GENERAL PROCEDURES

		Yes or No
1.	Was permission granted to enter and inspect the facility? Comments: Yes	✓ —
2.	Was permission to enter the facility documented? Comments: no	— ✓
3.	Were sampling locations properly selected? Comments: Yes	✓ —
4.	Were samples collected starting with the least likely contaminated and proceeding to the most likely contaminated? Comments: N/A	— —
5.	Were new disposable rubber gloves worn during sample collection? Comments:	— —
6.	Was sampling equipment wrapped in aluminum foil or otherwise protected from possible contamination prior to sample collection? Comments:	— —
7.	If equipment was cleaned in the field, were proper procedures used? Comments:	— —

Yes or No

9. Was laboratory given a list of sample containers with adequate lead time? N/A — —
Comments: _____

10. Were analyses scheduled with the laboratory in advance? — —
Comments: _____

Yes or No

8. What field instruments were used during this investigation? — —
Comments: N/A

9. Were field instruments properly calibrated? — —
Comments:

10. Were calibration procedures documented in the field notes? — —
Comments:

11. Were samples chemically field preserved? — —
Comments:

12. Were samples iced? — —
Comments:

WELL SAMPLING

1. Was depth of well determined? — —

2. Was depth to water determined? — —

3. Was measuring tape properly decontaminated between wells? — —
Comments:

4. Were the above depths to water converted to water level elevations common to all wells? — —
Describe how the depths were determined.

5. How was the volume of water originally present in each well determined?

Yes or No

6. Was the volume determined correctly? ___ ___

7. How was completeness of purging determined?
   Volume
   Measure_____
   Time/Flow rate_____
   Cond./ph/T_____

8. Was a sufficient volume purged? ___ ___

   Was the well over-purged? ___ ___

9. Was the disposal of purge water handled properly? ___ ___
   Comments: _____

10. Was a dedicated (in-place) pump utilized? ___ ___

    If no, describe the method of purging (bailer - include type and construction material. pump - include type)_____

11. How were the samples collected?

    Bailer ____
    Pump ____
    Combination ____

    Construction material of bailer:

    S.S. ____
    Teflon ____
    PVC ____
    Other ____

    Comments: _____

12. If a pump was used, describe how it was cleaned before and/or between wells._____

Yes or No

13. Were the samples properly transferred from bailer to sample bottles (i.e. was the purgeable sample agitated, etc.)? — —

14. Was the rope or line allowed to touch the ground? — —

15. Was wetted rope or line discarded after use at each well? — —

16. Was cotton or teflon coated rope used? — —

17. Were generators/gas pumps placed in a down wind position from the well during operation? — —

SURFACE WATER SAMPLING

Yes or No

1. What procedures were used to collect surface water samples? _____

2. Did the samplers wade in the stream during sample collection? — —

   If yes:

   Did sampler face upstream while collecting sample? — —

   Did the sampler insure that roiled sediments were not collected along with water sample? — —

3. Note any deficiencies observed during the collection of the surface water samples? _____

SEDIMENT SAMPLING

1. What procedures were used to collect the samples? _____

2. Were the samples well mixed prior to placing the sample in the sample container? — —

3. Note any deficiencies observed during the collection of the samples. _____

4. Were samples composited?
If so, how were composites collected and mixed?

QUALITY ASSURANCE/QUALITY CONTROL

Yes or No

N/A

(While not all of these QA/QC procedures will be necessary during each sampling activity, the following techniques may be employed. If so, please note.)

1. Did sampling personnel utilize any trip blanks? — —

2. Did sampling personnel utilize preservative blanks? — —

   If yes, to either of the above questions, list the types and handling of the blanks._____

3. Were any equipment blanks collected? — —

   If yes, list:_____

4. Were any duplicate samples collected? — —

   If yes, list the types (parameter coverage, etc.) and describe their handling._____

5. Were any spiked samples utilized?

   If yes, list the types (parameter coverage, etc.) and describe their handling._____

6. Were QA/QC samples specified in the QA Project Plan? — —

   Were the QA/QC samples collected in accordance with the QA Project Plan? — —

7. Check method used to collect split sample

SOIL SAMPLING

Yes or No

1. What procedures were used to collect samples?

2. Were the samples well mixed prior to placing the sample in the sample container?

3. Note any deficiencies observed during the collection of the samples.

4. Were samples composited?
If so, how were composites collected and mixed?

OTHER SAMPLING

1. What other types of samples were collected during this investigation?

2. What procedures were used for the collection of these samples?

FIELD DOCUMENTATION AND CHAIN-OF-CUSTODY

Yes or No

1. Were chain-of-custody records completed for all samples? N/A ___ ___

2. Were all samples identified with Sample I.D. tags or labels? ___ ___
   Comments: _____

3. Were Sample I.D. tags or labels filled-out (e.g., completely station no., location, date, time, analyses, signatures of samplers, type preservatives, etc.)? ___ ___
   Comments: _____

4. Did information on Sample I.D. tags or labels and Chain-of-Custody Records match? ___
   Comments: _____

5. Check manner of sample delivery to the lab.

   ___ Hand delivered by sampling team member

   ___ Shipped by common carrier

   If shipped by common carrier:

   Did the Chain-of-Custody Records indicate the method of sample shipment? ___ ___
   Comments: _____

   If shipped by common carrier:

   Was a Chain-of-Custody record included with the samples in the shipping container? ___ ___
   Comments: _____

Yes or No

N/A

6. Were samples kept under lock and key or kept in a secure place after collection? — —

7. Were sample tags, Chain-of-Custody forms, and field notebook signed by sampling personnel? — —

8. Does the field notebook contain adequate information about each sample including the sample I.D. number, date, location, and information necessary to reconstruct the sample? — —
Comments:_____

9. Were entries to the field notebook made in ink? — —
Comments:_____

10. Were corrections properly executed with one line through the error in the field notebook? — —
Comments:_____

11. Was sampling documented with photographs? — —

If yes, was a photolog maintained? — —

12. Were amendments to the project plan documented (on the project plan itself, in a project logbook, elsewhere)? — —
Comments:_____

___ Filled one large container and then transferred portions

___ Sequentially filled bottles

Attachment C

QUALITY CONTROL
FIELD AUDIT CHECKLIST

PROJECT NO. NPE 76024.NQ.30 DATE OF AUDIT 5/24/94
PROJECT MANAGER Bill Goswellen AUDITOR Joe Sandrin
FACILITY NAME Eagle River Flats
LOCATION Fort Richardson Alaska

FIELD PERSONNEL Chuck Racine Mike Brouillette /CRREL

Summary and Recommendations
CRREL

The field team was observed making field observations (vegetation identification), water quality measurements and Global positioning System (GPS) measurements.

Calibration information was not available for the field instruments.

There were no SOPs for instrument calibration or operation, for GPS operation and data logging, field notebooks or other project activities.

The was no Quality Assurance plan or data management plan to cover these activities

GPS measurements were made without a base station reference (according to the field staff) which can significantly affect accuracy of the measurements. This likewise may needs to be recorded and reflected in the log book for a given day as it may affect future measurement needs.

Recommendations:

1. SOPs should be developed and implemented for all project activities like calibration, instrument operation, field log books, field data and measurements (GPS) and other regular project activities.

Summary and Recommendations (continued)

2. A data management plan should be developed and implemented to address handling and management of all site data. The accuracy of the data should be addressed in the plan and issues like use / recording of field data (including GPS) also need to be included.

3. Gathering of GPS data should be covered in a Sampling Plan or some type with the rationale and frequency and recording requirements for the measurements being addressed in the plan.

PLANNING AND PREPARATION

Yes or No

1. Was the field audit announced or unannounced?
   Comments: _____

2. Was a QA Project Plan prepared for this activity? — ✓
   Comments: ND

3. Was a site Health and Safety Plan prepared for this activity? ✓ —
   Comments: Yes

4. Was a briefing held with project field participants? ✓ —
   Comments: Yes. There were in and out briefings for the field teams.

5. Were additional instructions given to project field participants (i.e., changes in project plan)? — —
   Comments: N/A

6. Was there a written list of sampling locations and descriptions? — —
   Comments: N/A

7. Was there a map of sampling locations available to to field personnel? — —
   Comments: N/A

8. Was equipment list given to equipment coordinator with adequate lead time? — —
   Comments: N/A

Yes or No

9. Was laboratory given a list of sample containers with adequate lead time? — —
Comments: N/A

10. Were analyses scheduled with the laboratory in advance? — —
Comments: N/A

SAMPLING

GENERAL PROCEDURES

		Yes or No
1.	Was permission granted to enter and inspect the facility? Comments: Yes	✓ —
2.	Was permission to enter the facility documented? Comments: No	— ✓
3.	Were sampling locations properly selected? Comments: N/A	— —
4.	Were samples collected starting with the least likely contaminated and proceeding to the most likely contaminated? Comments:	— —
5.	Were new disposable rubber gloves worn during sample collection? Comments:	— —
6.	Was sampling equipment wrapped in aluminum foil or otherwise protected from possible contamination prior to sample collection? Comments:	— —
7.	If equipment was cleaned in the field, were proper procedures used? Comments:	— —

Yes or No

8. What field instruments were used during this investigation? — —
Comments: GPS and pH/conductivity

9. Were field instruments properly calibrated? — —
Comments: Unknown

10. Were calibration procedures documented in the field notes? — ✓
Comments: NO

11. Were samples chemically field preserved? — —
Comments: N/A

12. Were samples iced? — —
Comments:

WELL SAMPLING

1. Was depth of well determined? — —

2. Was depth to water determined? — —

3. Was measuring tape properly decontaminated between wells? — —
Comments:

4. Were the above depths to water converted to water level elevations common to all wells? — —
Describe how the depths were determined.

5. How was the volume of water originally present in each well determined?

Yes or No

6. Was the volume determined correctly? ___ ___

7. How was completeness of purging determined?
   Volume
   Measure_____
   Time/Flow rate_____
   Cond./ph/T_____

8. Was a sufficient volume purged? ___ ___

   Was the well over-purged? ___ ___

9. Was the disposal of purge water handled properly? ___ ___
   Comments: _____

10. Was a dedicated (in-place) pump utilized? ___ ___

    If no, describe the method of purging (bailer - include type and construction material. pump - include type)_____

11. How were the samples collected?

    Bailer ____
    Pump ____
    Combination ____

    Construction material of bailer:

    S.S. ____
    Teflon ____
    PVC ____
    Other ____

    Comments: _____

12. If a pump was used, describe how it was cleaned before and/or between wells._____

Yes or No

13. Were the samples properly transferred from bailer to sample bottles (i.e. was the purgeable sample agitated, etc.)? — —

14. Was the rope or line allowed to touch the ground? — —

15. Was wetted rope or line discarded after use at each well? — —

16. Was cotton or teflon coated rope used? — —

17. Were generators/gas pumps placed in a down wind position from the well during operation? — —

SURFACE WATER SAMPLING

Yes or No

1. What procedures were used to collect surface water samples? _____

2. Did the samplers wade in the stream during sample collection? — —

   If yes:

   Did sampler face upstream while collecting sample? — —

   Did the sampler insure that roiled sediments were not collected along with water sample? — —

3. Note any deficiencies observed during the collection of the surface water samples? _____

SEDIMENT SAMPLING

1. What procedures were used to collect the samples? _____

2. Were the samples well mixed prior to placing the sample in the sample container? — —

3. Note any deficiencies observed during the collection of the samples. _____

4. Were samples composited?
If so, how were composites collected and mixed?

QUALITY ASSURANCE/QUALITY CONTROL

Yes or No

(While not all of these QA/QC procedures will be necessary during each sampling activity, the following techniques may be employed. If so, please note.)

1. Did sampling personnel utilize any trip blanks? N/A ___ ___

2. Did sampling personnel utilize preservative blanks? ___ ___

   If yes, to either of the above questions, list the types and handling of the blanks._____

   _____

   _____

   _____

3. Were any equipment blanks collected? ___ ___

   If yes, list:_____

   _____

   _____

   _____

4. Were any duplicate samples collected? ___ ___

   If yes, list the types (parameter coverage, etc.) and describe their handling._____

   _____

   _____

   _____

5. Were any spiked samples utilized?

   If yes, list the types (parameter coverage, etc.) and describe their handling._____

   _____

   _____

   _____

6. Were QA/QC samples specified in the QA Project Plan? ___ ___

   Were the QA/QC samples collected in accordance with the QA Project Plan? ___ ___

7. Check method used to collect split sample

SOIL SAMPLING

Yes or No

1. What procedures were used to collect samples?

2. Were the samples well mixed prior to placing the sample in the sample container? ___ ___

3. Note any deficiencies observed during the collection of the samples.

4. Were samples composited? ___ ___
If so, how were composites collected and mixed?

OTHER SAMPLING

1. What other types of samples were collected during this investigation?

2. What procedures were used for the collection of these samples?

FIELD DOCUMENTATION AND CHAIN-OF-CUSTODY

Yes or No

1. Were chain-of-custody records completed for all samples? N/A ___ ___

2. Were all samples identified with Sample I.D. tags or labels? ___ ___
   Comments: _____

3. Were Sample I.D. tags or labels filled-out (e.g., completely station no., location, date, time, analyses, signatures of samplers, type preservatives, etc.)? ___ ___
   Comments: _____

4. Did information on Sample I.D. tags or labels and Chain-of-Custody Records match? ___
   Comments: _____

5. Check manner of sample delivery to the lab.

   ___ Hand delivered by sampling team member

   ___ Shipped by common carrier

   If shipped by common carrier:

   Did the Chain-of-Custody Records indicate the method of sample shipment? ___ ___
   Comments: _____

   If shipped by common carrier:

   Was a Chain-of-Custody record included with the samples in the shipping container? ___ ___
   Comments: _____

Yes or No

6. Were samples kept under lock and key or kept in a secure place after collection? N/A

7. Were sample tags, Chain-of-Custody forms, and field notebook signed by sampling personnel?

8. Does the field notebook contain adequate information about each sample including the sample I.D. number, date, location, and information necessary to reconstruct the sample?
Comments:

9. Were entries to the field notebook made in ink?
Comments:

10. Were corrections properly executed with one line through the error in the field notebook?
Comments:

11. Was sampling documented with photographs?

If yes, was a photolog maintained?

12. Were amendments to the project plan documented (on the project plan itself, in a project logbook, elsewhere)?
Comments:

___ Filled one large container and then transferred portions

___ Sequentially filled bottles

MOBILE LABORATORY EVALUATION
AUDIT CHECKLIST

Laboratory: BUILDING 992 LAB
Date: 8/25/94 Evaluation Type: FIELD AUDIT
Project: EAGLE RIVER FLATS Project No.: GLE 7ØØ24.NØ.3Ø

Personnel Contacted	Title
PAT WEYRICH	CRREL, CHEMIST/ANALYST

Evaluation Team	Title
JOSEPH SANDRIN	CH2M HILL/QA AUDITOR

m Directions: Mark answer and comment as appropriate.

I. Organization and Management

A. Person responsible for overall technical effort
   1. Name: DAN LAWSON, CRREL
   2. Education: –
   3. Experience: –

B. Laboratory Supervisor
   1. Name:
   2. Education:
   3. Experience:

C. Lead Analyst
   1. Name PAT WEYRICH, CRREL
   2. Education: APPROPRIATE
   3. Experience: APPROPRIATE

D. Sample Preparation Analyst
   1. Name:
   2. Education:
   3. Experience:

E. Do persons have appropriate education to accomplish objectives of lab?

(Yes)/No/Comments:

F. Do persons have appropriate level and type of experience to accomplish objectives of the lab?

(Yes)/No/Comments: LEAD ANALYST FULLY QUALIFIED FOR THE WORK.

G. Is there adequate staff to meet commitments in a timely manner?

(Yes)/No/Comments:

H. Does the lab have an independent quality assurance officer?

Yes/(No)/Comments: THERE SHOULD BE A DESIGNATED ONSITE QA PERSON FOR THE PROJECT

I. Does the quality assurance officer report to senior management levels?

Yes/No/Comments:

J. Was the quality assurance officer available during the evaluation?

Yes/No/Comments:

K. Additional Comments:

1. _____

2. _____

II. Sample Receipt and Storage

A. Is there a sample custodian?
1. Name:

(Yes)/No/Comments: THE ANALYST IS THE SAMPLE CUSTODIAN

B. Are standard operating procedures (SOPs) available for receipt and storage of samples in that area?

Yes/No/Comments: N/A. SAMPLES ARRIVE FROM THE FIELD AND ARE ANALYZED TYPICALLY THE SAME DAY THEY ARE RECEIVED

C. Does each sample have a unique identifying number, date and time of collection, full sample identification, and identification of sampler?

Yes/(No)/Comments:

D. Are chain-of-custody forms and seals employed where required?

(Yes)/No/Comments: NOT TYPICALLY REQUIRED FOR THIS PROJECT

E. Are the specified proper sample containers used?

Yes/No/Comments: N/A

F. Are sample and transportation containers opened in a contamination-free area?

(Yes)/No/Comments: LAB WORK AREA IS CLEAN

G. Are proper sample preservation protocols present or absent?

Yes/No/Comments: N/A

H. Are samples requiring preservation stored in such a way as to maintain their preservation?

Yes/No/Comments:

I. Are there adequate facilities for storage of samples, including cold storage?

(Yes)/No/Comments: COLD STORAGE NOT REQUIRED

J. Are there separate storage areas for each type of sample analysis (organic, inorganic, or conventional)?

Yes/No/Comments: N/A

K. Is the temperature of the cold storage recorded daily in a log book?

Yes/No/Comments:

L. Are the sample receipt/storage and temperature logbooks maintained in a manner consistent with "good laboratory practices"?

Yes/No/Comments:

M. Are proper sample holding time and sample retention time protocols present or absent?

(Yes)/No/Comments: SAMPLES ARE ANALYZED THE SAMEDAY OR NEXT DAY

N. Additional Comments:

1. THE ONLY ANALYSIS CURRENTLY BEING DONE IS - TSS (TOTAL SUSPENDED SOLIDS)

2. _____

II. Sample Preparation and Conventional Analysis

A. Is the lab maintained in a clean and organized manner?
Yes/No/Comments: YES, WITHIN THE SPECIFIC AREAS USED FOR THE ANALYSIS

B. Does the lab have adequate work space for each analyst?
Yes/No/Comments: MARGINAL, THE AREA IS CROWDED BUT WORKABLE

C. Is the laboratory secure? Is there controlled access?
Yes/No/Comments: PARTIAL

D. Are toxic chemical handling areas either a stainless steel bench or an impervious material covered with absorbent material?
Yes/No/Comments: N/A
NO TOXIC CHEMICALS USED

E. Are contamination-free work areas provided for trace level analytical work?
Yes/No/Comments: N/A
NO TRACE LEVEL WORK BEING DONE.

F. Are contamination-free work areas provided for handling of toxic materials (i.e. hood, glovebox)?
Yes/No/Comments: N/A
NO TOXIC MATERIALS USED

G. Is the air flow of the hood periodically checked and recorded?
Yes/No/Comments: N/A
NO HOOD USED

H. Are chemical waste disposal policies/procedures adequate?
Yes/No/Comments: N/A
NO CHEMICAL DISPOSAL

I. Is there a source of reagent water (i.e. distilled or demineralized)?
Yes/No/Comments: YES. PURCHASED DISTILLED WATER IS BEING USED

J. Is the conductivity or resistivity of the reagent water routinely checked?
Yes/No/Comments: N/A
NOT NECESSARY FOR THE ANALYSES BEING PERFORMED

K. Can the lab document that trace-free reagent water is available for preparation of standards and blanks?

Yes/No/Comments: NO BLANKS WERE BEING RUN

L. Is the analytical balance in an area free from interference (i.e. vibration, temperature variation?

Yes/No/Comments: NO, THE LAB IS IN A WAREHOUSE/STORAGE AREA

M. Has the balance been calibrated within one year by a certified technician?

Yes/No/Comments: YES, THE BALANCE IS NEW, AND THE BALANCE IS CHECKED REGULARLY

N. Are voltage control devices used on major instrumentation?

Yes/No/Comments: N/A

O. Is chemical storage vented properly so as to prevent lab contamination?

Yes/No/Comments: N/A

P. Is the appropriate portion of the SOP available in the sample preparation area?

Yes/No/Comments: YES, THE SOP WAS AVAILABLE FOR IMMEDIATE REFERENCE

Q. Are reagent or higher purity chemicals used to prepare standards?

Yes/No/Comments: N/A

R. Are analytical reagents dated on receipt?

Yes/No/Comments: N/A

S. Are reagent inventories maintained on a first-in, first-out basis?

Yes/No/Comments: N/A

T. Are fresh analytical standards prepared at a frequency consistent with good QA?

Yes/No/Comments: N/A

U. Are reference materials properly labeled with concentration, date of preparation, and the identity of the person preparing them?

Yes/No/Comments: N/A

V. Is a spiking/calibration standards preparation and tracking logbook(s) maintained?

Yes/No/Comments: N/A

W. Are primary standards traceable to EPA or NIST standards?

Yes/No/Comments: N/A

X. Do the analysts record bench data in a neat and accurate manner?

Yes/No/Comments: YES, BENCH DATA WAS NEATLY AND ACCURATELY RECORDED

Y. Are standards stored separately from samples or prepared samples (i.e. extracts)?

Yes/No/Comments: N/A

Z. Is the SOP for cleaning available in the area?

Yes/No/Comments: NO. THE CLEANING PROCEDURE FOR GLASSWARE SHOULD BE WRITTEN DOWN.

AA. Is the temperature of the cold storage recorded daily?

Yes/No/Comments: N/A NO COLD STORAGE

AB. Are temperature excursions noted and appropriate actions taken?

Yes/No/Comments: N/A

AC. Additional Comments:

1. _____

2. _____

IV. Sample Analysis/Instrumentation Area (Repeat for each one.) N/A

A. _____ Instrument Area

1. Instrument information:

a. Manufacturer: _____

b. Model/Revision: _____

c. Installation date: _____

d. Accessories: _____

(1) Autosampler:

(2) Microcomputer: _____

(3) Software: _____

(4) Concentrator: _____

(5) Other: _____

2. Are manufacturer's operating manuals readily available to the operator? Yes/No/Comments: _____

3. Are SOPs for subsampling methods written and available? Yes/No/Comments: _____

4. Is there a calibration protocol available to the operator? Yes/No/Comments: _____

5. Are the calibration results kept in a permanent record? Yes/No/Comments: _____

6. Is a permanent service record maintained in a logbook? Yes/No/Comments: _____

7. Has the instrument been modified in any way? Yes/No/Comments: _____

8. Is the instrument properly serviced and vented? Yes/No/Comments: _____

9. Is service maintenance in-house or by contractor? Yes/No/Comments: _____

B. Is preventive maintenance applied and documented? Yes/No/Comments: _____

1. Are in-house replacement parts available? Yes/No/Comments: _____

2. Is raw data being archived and documented properly? Yes/No/Comments: _____

3.Additional Comments:

a. _____

b. _____

V. Data Handling and Review

A. Is data properly recorded? (Yes)/No/Comments: YES

1. Laboratory notebooks with consecutively numbered pages? (Yes)/No/Comments: YES

2. Type of work clearly noted? (Yes)/No/Comments: YES

3. Maintained in a legible manner? (Yes)/No/Comments: YES

4. Entries noting anomalies routinely recorded? (Yes)/No/Comments: YES

5. Avoided obliterated entries or use of pencil? (Yes)/No/Comments: YES

6. Errors lined out, dated, and initialed? (Yes)/No/Comments: YES

B. Are data calculations reviewed by the analyst? (Yes)/No/Comments: YES

C. Are data calculations reviewed by a second person? Yes/(No)/Comments: NO

D. Are in-house QC records maintained and accessible for analysis (i.e. QC charts, QC summaries)? Yes/(No)/Comments: NO, PARTIAL. ALL APPLICABLE DATA IS IN THE LAB NOTEBOOK BUT THERE IS NO SEPARATE QC RECORD

E. Do QC records show corrective action when results fail to meet QC criteria? Yes/No/Comments: N/A

F. Are computer programs validated before use? Yes/No/Comments: N/A

G. Do supervisory personnel review the data and QC results?

Yes/No/Comments: NOT FOR QC PURPOSES THOUGH THE DATA IS REVIEWED FOR USE.

H. Has the supervisor of the individuals maintaining logbooks/data books/bench sheets personally examined and reviewed them periodically, and signed them with date and comments as to their appropriate maintenance?

Yes/No/Comments: NO. DATA IS NOT REVIEWED BY SOMEONE OTHER THAN THE ANALYST

I. Are records maintained and properly archived?

Yes/No/Comments: YES

J. Additional Comments:

1. _____

2. _____

VI. Quality Control Manual and SOPs

A. Does the lab maintain a QC manual? SOPs manual?

Yes/No/Comments: THERE IS NO QC PROGRAM MANUAL

B. Do the manuals address important elements of a QC program, including the following:

Yes/No/Comments: N/A

1. Personnel?

Yes/No/Comments: _____

2. Facilities and equipment?

Yes/No/Comments: _____

3. Operations of instruments?

Yes/No/Comments: _____

4. Documentation of procedures?

Yes/No/Comments: _____

5. Chain-of-custody and document control?

Yes/No/Comments: _____

6. Preventive maintenance?

Yes/No/Comments: _____

7. Reliability of data?

Yes/No/Comments: _____

8. Data validation?

Yes/No/Comments: _____

9. Feedback and corrective action? Yes/No/Comments: N/A

10. Instrument calibration? Yes/No/Comments: _____

C. Additional Comments:

1. _____

2. _____

VII. Summary Checksheet

A. Do responses to the evaluation indicate that project and supervisory personnel are aware of QA/QC and its application to the project? (Yes)/No/Comments: PROJECT STAFF ARE VERY AWARE OF QC ISSUES AND WANT TO DO THE BEST POSSIBLE JOB FOR THE PROJECT.

B. Do project and supervisory personnel place positive emphasis on QA/QC? (Yes)/No/Comments: STRONG DESIRE TO "DO IT RIGHT"

C. Have responses with respect to QA/QC aspects of the project been open and direct? (Yes)/No/Comments: STAFF WERE VERY OPEN AND DIRECT. ALL QUESTIONS WERE ANSWERED WITHOUT HESITATION.

D. Has a cooperative attitude been displayed by all project and supervisory personnel? (Yes)/No/Comments: EXTREMELY COOPERATIVE

E. Does the organization place the proper emphasis on QA? (Yes)/No/Comments: THE INTEREST IN QC IS STRONG AND GROWING

F. Have any QA/QC deficiencies been discussed before ending the audit? (Yes)/No/Comments: _____

G. Is the overall QA adequate to accomplish the objectives of the project? (Yes)/No/Comments: (See next page)

H. Have corrective actions recommended during previous evaluations been implemented? If not, provide details. Yes/No/Comments: N/A

I. Additional Comments:

1. _____

2. _____

3. _____

OVERALL COMMENTS:

1. THE ONSITE LABORATORY WAS SET UP AND OPERATED IN A PROFESSIONAL MANNER. THE LAB HAD A WRITTEN SOP FOR THE WORK BEING PERFORMED (TSS ANALYSIS). THOUGH THERE WAS NO QA MANUAL AND NO QA OFFICER ON THE PROJECT, EXCEPT AS AN AUDITOR, THE LABORATORY WAS FOLLOWING THE METHOD AND MEETING QA REQUIREMENTS. THE LABORATORY HAD A SITE-SPECIFIC WRITTEN SOP FOR THE METHOD AND IT WAS AVAILABLE TO THE ANALYST AND WAS BEING USED.
2. CONTROLLING ACCESS TO THE LABORATORY WAS DIFFICULT BECAUSE IT WAS IN A WAREHOUSE AREA. ADDITIONALLY, THE AREA IS CROWDED AND DIFFICULT TO MAINTAIN BECAUSE OF ALL OF THE GROUPS USING THE SPACE. DESPITE THE LIMITATIONS OF THE SPACE AND WORKING CONDITIONS THE LABORATORY IS DOING QUALITY WORK FOR THE REQUIRED DATA NEEDS.
3. THE LABORATORY IS ANALYZING SAMPLES FOR TSS AND THE LEVELS BEING FOUND ARE RELATIVELY HIGH (UP TO SEVERAL HUNDRED Mg/L). BASED ON THE HIGH TSS LEVELS MEASURED AND THE INTENDED USE OF THE DATA (TO ASSESS TRANSPORT OF WP) THE LAB SETUP, SOP AND QA PRACTICED ARE SUFFICIENT TO PRODUCE DATA OF THE QUALITY NEEDED FOR THIS PROJECT

Attachment E

QUALITY CONTROL
FIELD AUDIT CHECKLIST

PROJECT NO. [redacted] NPE 7ØØ2A.NØ.3Ø DATE OF AUDIT 8/26/94
PROJECT MANAGER Bill Gossweiler AUDITOR Joe Sandrin
FACILITY NAME Eagle River Flats
LOCATION Fort Richardson, Alaska

FIELD PERSONNEL Ben Steele, Len Kiefsmo
Dan Dearborn Heather Hossie

Summary and Recommendations
NEILE

The field team was observed counting birds within the flats and walking transects away from the flats to monitor bird mortality. The bird counts were conducted in a regular and systematic manner. Maps of ERF were available at the observation points to assist in the counting process.

Transects were walked and dead birds and feather piles were recorded. Significant efforts were made to retrace the same transects as in previous visits to maintain consistency.

There were no written SOPs for conducting the bird counts, walking the transects and maintaining field notebooks.

Recommendations.

1. Develop and implement SOPs for regular project activities such as: bird counts, transect walks and field log books.

2. It was observed that many abbreviations were used in the field log books. It was suggested that a summary table explaining the abbreviations used be included in the notebook to assist others in understanding the notebook contents.

Summary and Recommendations (continued)

PLANNING AND PREPARATION

		Yes or No
1.	Was the field audit announced or unannounced? Comments:	
2.	Was a QA Project Plan prepared for this activity? Comments:	— ✓
3.	Was a site Health and Safety Plan prepared for this activity? Comments:	✓ —
4.	Was a briefing held with project field participants? Comments:	✓ —
5.	Were additional instructions given to project field participants (i.e., changes in project plan)? Comments:	— —
6.	Was there a written list of sampling locations and descriptions? Comments:	— —
7.	Was there a map of sampling locations available to to field personnel? Comments:	— —
8.	Was equipment list given to equipment coordinator with adequate lead time? Comments: N/A	— —

Yes or No

9. Was laboratory given a list of sample containers with adequate lead time? N/A — —

Comments: _____

_____

_____

10. Were analyses scheduled with the laboratory in advance? — —

Comments: _____

_____

_____

SAMPLING

GENERAL PROCEDURES

		Yes or No
1.	Was permission granted to enter and inspect the facility? Comments: Yes	✓ —
2.	Was permission to enter the facility documented? Comments:	— ✓
3.	Were sampling locations properly selected? Comments:	— —
4.	Were samples collected starting with the least likely contaminated and proceeding to the most likely contaminated? Comments: N/A	— —
5.	Were new disposable rubber gloves worn during sample collection? Comments:	— —
6.	Was sampling equipment wrapped in aluminum foil or otherwise protected from possible contamination prior to sample collection? Comments:	— —
7.	If equipment was cleaned in the field, were proper procedures used? Comments:	— —

Yes or No

8. What field instruments were used during this investigation? Yes, GPS — —
   Comments: _____

9. Were field instruments properly calibrated? — —
   Comments: _____

10. Were calibration procedures documented in the field notes? — —
    Comments: _____

11. Were samples chemically field preserved? N/A — —
    Comments: _____

12. Were samples iced? — —
    Comments: _____

WELL SAMPLING

1. Was depth of well determined? — —

2. Was depth to water determined? — —

3. Was measuring tape properly decontaminated between wells? — —
   Comments: _____

4. Were the above depths to water converted to water level elevations common to all wells? — —
   Describe how the depths were determined. ___

5. How was the volume of water originally present in each well determined? _____

Yes or No

6. Was the volume determined correctly? ___ ___

7. How was completeness of purging determined?
   Volume
   Measure _____
   Time/Flow rate _____
   Cond./ph/T _____

8. Was a sufficient volume purged? ___ ___

   Was the well over-purged? ___ ___

9. Was the disposal of purge water handled properly? ___ ___
   Comments: _____

10. Was a dedicated (in-place) pump utilized? ___ ___

    If no, describe the method of purging (bailer - include type and construction material. pump - include type) _____

11. How were the samples collected?

    Bailer ____
    Pump ____
    Combination ____

    Construction material of bailer:

    S.S. ____
    Teflon ____
    PVC ____
    Other ____

    Comments: _____

12. If a pump was used, describe how it was cleaned before and/or between wells. _____

Yes or No

13. Were the samples properly transferred from bailer to sample bottles (i.e. was the purgeable sample agitated, etc.)? — —

14. Was the rope or line allowed to touch the ground? — —

15. Was wetted rope or line discarded after use at each well? — —

16. Was cotton or teflon coated rope used? — —

17. Were generators/gas pumps placed in a down wind position from the well during operation? — —

SURFACE WATER SAMPLING

Yes or No

1. What procedures were used to collect surface water samples? _____

2. Did the samplers wade in the stream during sample collection? — —

   If yes:

   Did sampler face upstream while collecting sample? — —

   Did the sampler insure that roiled sediments were not collected along with water sample? — —

3. Note any deficiencies observed during the collection of the surface water samples? _____

SEDIMENT SAMPLING

1. What procedures were used to collect the samples? _____

2. Were the samples well mixed prior to placing the sample in the sample container? — —

3. Note any deficiencies observed during the collection of the samples. _____

4. Were samples composited?
If so, how were composites collected and mixed?

SOIL SAMPLING

Yes or No

1. What procedures were used to collect samples?

2. Were the samples well mixed prior to placing the sample in the sample container? — —

3. Note any deficiencies observed during the collection of the samples.

4. Were samples composited? — —
If so, how were composites collected and mixed?

OTHER SAMPLING

1. What other types of samples were collected during this investigation?

2. What procedures were used for the collection of these samples?

QUALITY ASSURANCE/QUALITY CONTROL

Yes or No

(While not all of these QA/QC procedures will be necessary during each sampling activity, the following techniques may be employed. If so, please note.)

1. Did sampling personnel utilize any trip blanks? ___ ___

2. Did sampling personnel utilize preservative blanks? ___ ___

   If yes, to either of the above questions, list the types and handling of the blanks._____

3. Were any equipment blanks collected? ___ ___

   If yes, list:_____

4. Were any duplicate samples collected? ___ ___

   If yes, list the types (parameter coverage, etc.) and describe their handling._____

5. Were any spiked samples utilized?

   If yes, list the types (parameter coverage, etc.) and describe their handling._____

6. Were QA/QC samples specified in the QA Project Plan? ___ ___

   Were the QA/QC samples collected in accordance with the QA Project Plan? ___ ___

7. Check method used to collect split sample

___ Filled one large container and then transferred portions

___ Sequentially filled bottles

FIELD DOCUMENTATION AND CHAIN-OF-CUSTODY

Yes or No

1. Were chain-of-custody records completed for all samples? ___ ___

2. Were all samples identified with Sample I.D. tags or labels? ___ ___
   Comments: _____

3. Were Sample I.D. tags or labels filled-out (e.g. completely station no., location, date, time, analyses, signatures of samplers, type preservatives, etc.)? ___ ___
   Comments: _____

4. Did information on Sample I.D. tags or labels and Chain-of-Custody Records match? ___
   Comments: _____

5. Check manner of sample delivery to the lab.

   ___ Hand delivered by sampling team member

   ___ Shipped by common carrier

   If shipped by common carrier:

   Did the Chain-of-Custody Records indicate the method of sample shipment? ___ ___
   Comments: _____

   If shipped by common carrier:

   Was a Chain-of-Custody record included with the samples in the shipping container? ___ ___
   Comments: _____

Yes or No

6. Were samples kept under lock and key or kept in a secure place after collection? ___ ___

7. Were sample tags, Chain-of-Custody forms, and field notebook signed by sampling personnel? ___ ___

8. Does the field notebook contain adequate information about each sample including the sample I.D. number, date, location, and information necessary to reconstruct the sample? ___ ✓
Comments: See cover sheet comments and recommendations.

9. Were entries to the field notebook made in ink? ✓ ___
Comments:

10. Were corrections properly executed with one line through the error in the field notebook? ✓ ___
Comments:

11. Was sampling documented with photographs? ✓ ___

If yes, was a photolog maintained? ___ ___

12. Were amendments to the project plan documented (on the project plan itself, in a project logbook, elsewhere)? ___ ___
Comments:

OUC 0029735

Atti

GUIDELINES FOR THE PREPARATION OF STANDARD OPERATING PROCEDURES (SOPS)

FOR

FIELD AND LABORATORY MEASUREMENTS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION V

MONITORING AND QUALITY ASSURANCE BRANCH

QUALITY ASSURANCE SECTION

536 S. CLARK STREET

CHICAGO, ILLINOIS 60605

MARCH 16, 1989

GUIDELINES FOR THE PREPARATION OF STANDARD OPERATING PROCEDURES (SOPS) OF FIELD AND LABORATORY MEASUREMENTS

Field and laboratory protocol for qualitative and quantitative measurements, that are selected for a specific project shall be submitted to the Region V Quality Assurance Section (QAS) as an attachment to the sit-specific Quality Assurance Project Plan (QAPjP) for review/approval prior to the start of the measurement activity.

The field and laboratory measurement protocol should be documented in a standard operating procedure (SOP) format. This SOP shall describe in "cookbook" details the exact instructions to follow and the equipment and materials required to make the measurement.

This document outlines the elements that are to be considered for inclusion in all SOPs.

1. Parameter(s) to be measured.

2. Range of Measurement (Working Linear Range).

3. Limit of Detection. (Where appropriate procedure used for determination of method detection limit shall be specified).

4. Sample Matrix.

5. Principle, Scope and Application.

6. Interferences and Corrective Actions. (Specify method/steps to be taken to eliminate the interferences. Method shall be matrix-specific).

7. Safety Precautions.

8. Sample Size, Collection, Preservation, and Handling (Describing for each matrix which measurement procedure is applicable).

9. Apparatus (including instrument and instrumental parameters) and Materials.

10. Routine Preventative Maintenance, including procedures and frequency.

11. Reagents and Calibration Standards (including preparation procedures, storage and shelf life).

12. Calibration Procedures (including instrument tuning and routine performance checks, etc. If appropriate, specify whether internal standard or external standard techniques are to be used).

13. Sample Preparation (i.e., Extraction, Digestion, etc.)

14. Analytical Measurement (Describing in cookbook detail. Include separate details for each sample matrix if the procedure is applicable to more than one sample matrix).

15. Flow Chart or Table that describes the method step by step.

16. Data Treatment (Details of calculation, including equations).

17. Data Deliverables (define the content of data packages), as a minimum, the following shall be provided:

    a) Case narrative, briefly describe the sample preparation and analysis, problems encountered and corrective action taken during the process of sample preparation and analysis.

    b) Summary of initial calibration and continuing calibration check results.

    c) Summary of Sample Analysis, arranging in increasing order of sample number.

    d) Summary of QC sample analyses.

    e) Raw data including instruments printout, mass spectra, Chromatograms, etc.

    f) Instrument logbook (including serial number, date of purchase, date brought on line, maintenance and repair history over the period of service provided for this specific project. Daily entries should include name of analyst, parameter measured, instrument setting, comments on the sample analysis and any other information that may be deemed of interest.

18. Quality Control Requirements (Specify internal requirements for blanks, spikes, duplicates, and external requirements for reference and QC samples).

19. References.

20. Method Validation Data (if available) should be included to support the validity, limitation and the applicability of the measurement method. If the method is a "Standard Method", i.e., EPA APHA, ASTM or AOAC, this element need not be addressed. If the method has not been validated, then the description of the SOP should include the process for method validation to be conducted for approval prior to the use of the method for sample measurements. If the parameter(s) being measured is for health and safety requirement for field screening to select sampling locations, then method validation data is not required.

ER.

TECHNICAL MEMORANDUM NO. 2

CH2MHILL

PREPARED FOR: U.S. Army Engineer District, Alaska

PREPARED BY: CH2M HILL, INC., Anchorage, Alaska

DATE: September 13, 1994

SUBJECT: Summary Report: Field Quality Assurance Audit #2 (August 22-26, 1994), Eagle River Flats, Fort Richardson, Alaska

PROJECT: NPE70024.N0.30

The U.S. Army Corps of Engineers (COE) contracted with CH2M HILL to assist with quality assurance (QA) oversight of 1994 Eagle River Flats (ERF) field activities. This work was initiated under a scope of work titled *Evaluation and Recommendations for Data Quality Objectives and Quality Assurance/Quality Control*, Contract No. DACA85-92-D-0007, Delivery Order 14, Modification No. 2. Task 4 of Modification No. 2 for Delivery Order 14 consisted of a CH2M HILL senior level technical employee to provide periodic Field Quality Assurance/Quality Control (QA/QC) audits in accordance with the Quality Assurance Program Plan (QAPP) document developed by CH2M HILL as part of Delivery Order 14. Requirements for the field visit portion of the QA/QC audits included the following:

> *Field visits will include visiting with site investigation teams, viewing sampling work and chain of custody procedures and practices and provide a report to the 6th Infantry Division. The field auditor should advise field sampling teams of apparent deviations from sampling plan and QAPP requirements while on site, and immediately advise these teams and the 6th Infantry of substantial field quality assurance problems which could invalidate sample results. The field auditor will not have the authority to stop sampling work but shall be required to advise sampling teams and the 6th Infantry immediately of substantial QA/QC problems which could be alleviated via field decisions.*

During the week of August 22-26, 1994, Mr. Joseph Sandrin, a CH2M HILL senior QA auditor, conducted the second of two field QA audits of research teams performing fieldwork at the ERF. The first field QA audit was completed by Mr. Sandrin during the week of May 23-27, 1994. A summary of the May audit was previously submitted to the COE. (Please note that the dates in that summary report were incorrectly listed as May 22-26; the correct dates should be Monday, May 23 through Friday, May 27, 1994)

The following summary report describes Mr. Sandrin's observations of field research activities conducted during the August audit and recommendations for improved QA/QC procedures for future fieldwork at the ERF. The observations and recommendations

summarized in this report were verbally presented to Mr. Bill Gossweiler of the 6th Infantry Division, Fort Richardson, during an audit outbriefing on August 26, 1994.

Attachments: Field Quality Assurance Audit #2 Summary Report with Attachments A-F

Field Quality Assurance Audit #2
Summary Report

Eagle River Flats
Fort Richardson, Alaska
August 22-26, 1994

Introduction

During the week of August 22-26, 1994, Mr. Joseph Sandrin, CH2M HILL senior quality assurance (QA) officer, visited Fort Richardson and observed fieldwork being performed by the various researchers at the ERF. The observations were completed as part of a QA/QC audit of 1994 ERF field research operations. The purpose of the August audit was to review field operations of the research groups conducting ongoing studies at the ERF and to provide rapid feedback to the research groups and Fort Richardson staff on potential improvements that could be made to the ERF investigation to make it more consistent with the typical requirements for such work at CERCLA sites.

In a typical audit, the performance of fieldwork is measured against the approved project Standard Operating Procedures (SOP) documents and an approved Quality Assurance Program Plan (QAPP). The QAPP for the 1994 ERF investigation had been completed just prior to the August audit. The SOPs for the ongoing work were still under development as a result of recommendations made in the initial May 1994 QA audit. The audit conducted during August was therefore conducted based on the researchers' original scopes of work that were prepared prior to the start of 1994 fieldwork. The August audit was performed to monitor changes and improvements after the initial audit, and to identify additional QA/QC issues that may need to be addressed.

An initial inbriefing was held with Mr. Bill Gossweiler, other representatives of Fort Richardson Public Works, and representatives of various field teams on the afternoon of Monday, August 22. At that meeting, the general purpose of the audit was explained and a tentative schedule was established for the audits of each team conducting field work that week.

• Monday, August 22 (a.m.)	Patuxent Wildlife Research Center (PWRC)
• Tuesday, August 23	Denver Wildlife Research Center (DWRC)
• Wednesday, August 24	Cold Regions Research and Engineering Laboratory (CRREL)–Chuck Collins and Marianne Walsh

•	Thursday, August 25 (a.m.)	Northeastern Institute for Landscape Ecology (NEILE)
•	Thursday, August 25 (p.m.)	U.S. Army Environmental Hygiene Agency (AEHA)
•	Friday, August 26 (a.m.)	CRREL–Chuck Racine
•	Friday, August 26 (p.m.)	Outbriefing–Bill Gossweiler

The outbriefing with Bill Gossweiler was conducted by Mr. Sandrin on the afternoon of August 26. A brief summary of the audit findings and recommendations was presented and discussed.

Copies of the QA audit checklist for each research group that was observed during the August audit visit are attached (Attachments A through F). The following discussions summarize the findings for each group and provide specific and general recommendations for modifications or improvements to the overall QA/QC for the ERF investigation.

Observations

Patuxent Wildlife Research Center (PWRC)–The field team was observed collecting a shorebird from its mist nets, banding the bird and drawing a blood sample.

Their efforts are directed towards evaluating potential biomarkers as monitoring mechanisms for WP effects as opposed to the current methods which require sacrificing the birds.

Denver Wildlife Research Center (DWRC)–The field team was observed collecting telemetry data from birds fitted with radio transmitters and attempting to track transmitter fitted eagles which had moved off of Eagle River Flats.

Cold Regions Research and Engineering Laboratory (CRREL)–The field team was observed retrieving sediment plugs containing planted WP particles and downloading data-loggers of data to evaluate the natural attenuation of WP in the sediment as it dries.

Northeastern Institute for Landscape Ecology (NEILE)–The field team was observed conducting a morning census of birds within the Eagle River Flats. The team was also observed conducting a mortality transect to monitor waterfowl carcasses on Racine Island.

U.S. Army Environmental Hygiene Agency (AEHA)–The field team was observed collecting sediment, surface water, fish and invertebrate samples from one location to conduct sediment bioassays for WP toxicity and monitor for potential uptake and bioaccumulation of WP in the food chain.

CRREL–The field team was observed conducting vegetation surveys along a transect in Area A and conducting Global Positioning System (GPS) measurements.

Findings

Specific audit comments and recommendations for each field team are included in the attached audit reports (Attachments A-F). The following findings and recommendations are applicable to all teams or have implications to more than just one team.

1. The field teams were cooperative in the audit and totally forthcoming with information and answers to all questions asked. During the audit, researchers offered their field notebooks for review and suggestions on how to improve their records.

2. The overall attention to QA/QC issues was more consistent than in the initial visit.

3. Though generally under development, SOPs were not completed for the ongoing field efforts. The operations observed were generally conducted in a consistent manner due, in part, to the consistent composition of the field teams and the highly repetitive nature of much of the work like bird census counts and mortality transects.

   The research teams are also developing data for publication in peer-reviewed literature. This use of the research requires that the data be gathered and evaluated in a repeatable and technically acceptable manner. The procedures used to generate the data for publication may also satisfy CERCLA requirements; however, that final determination can only be made after all the data has been entered and evaluated.

4. Data was being gathered by each of the field teams for incorporation into the sitewide database under development by CRREL. However, standard input forms and data structures have not yet been developed, according to information obtained during the QA audit.

5. Field notebooks were being kept in a consistent manner by the field teams. Most field teams were using waterproof or permanent ink and the notebooks were legible and readable. One individual was observed using a pencil for taking field notes. Some of the notebooks included summaries of abbreviations to assist other readers.

6. During the audit, field teams discussed with Mr. Sandrin some concerns and recommendations for routine communication among the researchers in the field. With several different studies being conducted over relatively short

periods of time, and field schedules subject to changes due to unforeseen logistical or environmental factors, it is difficult for researchers to always know what work is being done by each other onsite, the areas being worked in, schedule updates, and potential impacts of one field team's work on another's. Teams sometimes need to change sample locations and activities after initial plans are made, and it is difficult to communicate changes to researchers in timely manner. This creates the potential for one research team to unknowingly impact research done by others.

7. Each team is gathering information and making observations in the field. Because of the large amounts of data being gathered independently by different researchers, it is possible that data gathered by one team for their study or incidental to their study may prove to be of some use to another team. However, procedures are not established that enables information gathered by one team to get communicated to other teams throughout the field season.

Recommendations

1. SOPs for each team need to be completed for all routine operations. Specific SOPs which should be considered are recommended in the audit reports. These include, at a minimum: sample collection procedures, chain of custody procedures, sample preparation and shipping procedures, field notebook procedures, use and calibration of field equipment such as the GPS and Hydrolabs, and other regularly conducted systematic activities. Regularly conducted systematic activities such as bird census, bird netting and blood sampling, and mortality transects should also have SOPs prepared. The above list is not all inclusive but provides a starting point to identify the types of SOPs that should be in place.

2. Immediate efforts must be made to establish and standardize data management activities. A data management plan should be developed which covers all aspects of data management such as how the data will be collected and recorded, input in to the database, and data validation. Data structures for input from each group, and the format and abbreviations to be used for input to the database need to be standardized as part of the plan.

   A professional database programmer is often brought into this type of process at an early point to assist in establishing a database that will be complete, accurate, and useable to meet project requirements. The ERF project may want to consider this approach. If the database is not complete, accurate, and useable by current and future project personnel, the data gathered and contained in the database will not support the CERCLA project.

3. All field notebooks should be written in waterproof or permanent ink. A summary of abbreviations used in the notebook should be included in the notebook to assist those reading the notebook in interpreting the data recorded there. Notebooks should be maintained as described in the QAPP (Section 5.3).

4. It is suggested that a mechanism be developed to promote the exchange of information between groups while fieldwork is ongoing. The information exchange could take the form of weekly meetings or exchange of notebook information. Weekly meetings would allow for regular updating of ongoing work and observations, and help each group to understand the ongoing work and their own potential contributions to the overall project. Some exchange of notebook data, taking into account the proper handling of draft data, during the field season could provide potentially useful information to other teams. Although the potential amount of data available may be large and cumbersome, the potential synergy from information and data exchange should be considered.

TECHNICAL MEMORANDUM

CH2M HILL

PREPARED FOR: U.S. Army Engineer District, Alaska

PREPARED BY: CH2M HILL, Inc.; Anchorage, Alaska

DATE: January 10, 1995

SUBJECT: Summary Report: Field QA Audit Assistance Visit (October 7, 1994), Eagle River Flats, Fort Richardson, Alaska
Contract DACA85-92-D-0007
Delivery Order 14, Modification No. 2

PROJECT: NPE70024.N0.30

On October 7. 1994, Mr. Mike McCrum of CH2M HILL's Anchorage office conducted a field Quality Assurance (QA) Audit Assistance visit of a research team conducting work at the Eagle River Flats (ERF). The following summary report and completed *Quality Control Field Audit Checklist* describe Mr. McCrum's observations of field work conducted during that visit and recommendations for improved Quality Assurance/Quality Control (QA/QC) procedures for similar work conducted in the future at the site. The observations and recommendations summarized in the attached report were also verbally discussed with the onsite researchers during the audit assistance visit.

The QA Audit Assistance visit completed on October 7 was conducted under the scope of work entitled "Evaluation and Recommendations for Data Quality Objectives and Quality Assurance/Quality Control", Contract DACA85-92-D-0007, Delivery Order 14, Modification No. 2.

The October 7 visit was the final field audit activity performed by CH2M HILL during the 1994 field season at the ERF.

Attachments: Field Quality Assurance Audit Assistance Site Visit
(October 7, 1994):
Summary Report
Quality Control Field Audit Checklist

FIELD QUALITY ASSURANCE AUDIT ASSISTANCE SITE VISIT

SUMMARY REPORT

EAGLE RIVER FLATS
FORT RICHARDSON, ALASKA

October 7, 1994

INTRODUCTION

Mr. Mike McCrum of CH2M HILL conducted an onsite Quality Assurance (QA) audit assistance visit to the Eagle River Flats (ERF) on Fort Richardson on October 7, 1994 to observe data collection and interview researchers studying the surface water hydrology of the area. Mr. McCrum accompanied Mr. Dan Lawson, Cold Regions Research and Engineering Laboratory (CRREL), and his research team during this QA visit at the ERF. This group was the only research team working at the sites during the audit assistance visit. The objectives of this site visit were as follows:

- Discuss what type of data were being collected as part of the studies and how it is to be used.
- Discuss field procedures being employed during the study and how these procedures are documented.
- Review with researchers how samples are being handled and how data is being managed.
- Provide rapid feedback to the research teams on potential improvements that could be made to the field work to make it more consistent with the typical requirements for such work at CERCLA sites.

The results of these visits are recorded on a field audit checklist designed for this type of activity and in the field notebook kept for site visits conducted as part of CH2M HILL's data quality assurance effort. A summary of observations, findings, and recommendations resulting from the two site visits follows. A completed *Quality Control Field Audit Checklist* is attached.

OBSERVATIONS

The CRREL research team collected field data at five different sampling stations during the October 7 audit visit at the ERF. The sampling stations are specific areas that have been located and given the following identification names by ERF researchers: Otter,

Bread Truck Pond, Mortar, Parachute, and Spring. The observed field data collection procedures for the CRREL study were conducted primarily at fixed stations using autosamplers and data loggers to record in situ water quality data. This approach promotes consistency in sample collection and simplifies logistics that make it difficult to maintain consistently high data quality.

Observations made during the site visit are summarized below.

FINDINGS

The procedures used by the CRREL field team appeared to be consistent and understood by those doing the data collection and recording. Detailed written procedures for routine field tasks were not observed and are assumed to not exist as part of project documentation. Examples of such procedures include collecting depth to water data, downloading data loggers and collecting pond sediment samples. The team members appear to be benefiting from the presence of well trained staff and from the fact that much of the work has been performed and/or led by the same staff for an extended period of time.

A data quality issue that may require additional attention is variations to the sampling plans described in the scopes of work for each activity. Because the scopes of work were prepared during the investigation planning process and prior to the start of the onsite work, it is not surprising that some field procedures observed did not follow the original plan. However, these changes were not always recorded in detail in the field notebooks. The proper documentation of all field activities and measurements is a key to the future useability of the data.

RECOMMENDATIONS

Based on the observations during the October 7 site visit, the following recommendations are made to assist the field team at Eagle River Flats in producing data which will be better suited to meet the requirements for use in the CERCLA process.

The majority of the recommendations are the same as those recommendations included in previous summary reports completed during the May and August QA audits and QA audit assistant visits at the ERF. The recommendations regarding development of documents for field procedures may be most applicable to future 1995 field studies.

1. Develop written, standardized Standard Operating Procedures (SOPs) for each routine or repeated activity performed by the team.

2. Develop a Standard Operating Procedure for preparation and maintenance of field notebooks.

3. Develop a Standard Operating Procedure for sample tracking and chain of custody for each group taking environmental related samples at the site.

4. It is recommended that, given the tight schedules for the treatability studies, to include sections in the final reports on how actual data collection varied from the proposed scope of work and the rationale for the changes made.

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Revision Number 0
Date November 1991

QUALITY CONTROL
FIELD AUDIT CHECKLIST

PROJECT NO. NPE 70424.NQ.30 DATE OF AUDIT Oct 7, 1994
PROJECT MANAGER C. Burgh AUDITOR M. McCrum
FACILITY NAME Ft. Richardson Eagle River Flats
LOCATION Anchorage Alaska

FIELD PERSONNEL Dan Lawson / CRREL, Kurt Knuth / CRREL, John Balette, CRREL
Mike McCrum / CH2M Hill

Summary and Recommendations

① Reviewed types of data being collected
② Discussed field documentation
③ Reviewed field data collection methods

Types of Data Collection -

- TSS collected by Isco autosampler using pre-programmed schedule with increased frequency near high tide
- Datalogger used for pH, salinity, temperature and water depth
- Sedimentation rate measured by painting ground & collecting sample from painted spot periodically. Thickness of sediment on top of paint relative to elapsed time yields estimate of sedimentation rate
- Flow rate in gully measured using Marsh-McBirney meter & recorded on Data Logger
- Grain size distribution is measured for samples collected from painted area

Sites visited: Otter, Bread Truck, Mortar, Parachute, Spring

Automated datalog collection stations were established at each site.

Summary and Recommendations (continued)

Field documentation

- Each team member maintains their own notebook. Pages are numbered in sequential order so that each book is unique. Page numbers do not overlap between books.
- Because a number of people are involved in this project and different personnel are onsite at different times, information is recorded in numerous books. A trip summary sheet is printed for each trip to summarize field activities.
- Most routine sampling is automated, reducing the probability that changes in planned sampling procedures occur.
- Problems with dataloggers & autosampler are recorded in field books and summarized on trip summary sheet.

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PLANNING AND PREPARATION

		Yes or No
1.	Was the field audit announced or unannounced? Comments:	✓ —
2.	Was a QA Project Plan prepared for this activity? Comments: A program plan was prepared, but ~~proj~~ documentation of project-specific QC measures has yet to be completed	✓ —
3.	Was a site Health and Safety Plan prepared for this activity? Comments: The BNF general H&S plan is being used	✓ —
4.	Was a briefing held with project field participants? Comments: Discussion was ongoing throughout the site visit	✓ —
5.	Were additional instructions given to project field participants (i.e., changes in project plan)? Comments: Simply identified what was being done & documented (in general) procedures for those activities	— ✓
6.	Was there a written list of sampling locations and descriptions? Comments: The sampling stations are fixed and instrumented with data loggers. Locations were originally chosen based on field observation	— ✓
7.	Was there a map of sampling locations available to to field personnel? Comments: See above	— ✓
8.	Was equipment list given to equipment coordinator with adequate lead time? Comments: Sampling eqpt is ~~per~~ installed at each station for entire season & is dedicated to the project	— ✓

	Yes or No
9. Was laboratory given a list of sample containers with adequate lead time?	✓
Comments: All analyses performed by field sampling team in field lab	
10. Were analyses scheduled with the laboratory in advance?	✓
Comments: See Comment 10	

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Date November 1991

SAMPLING

GENERAL PROCEDURES

		Yes or No
1.	Was permission granted to enter and inspect the facility? Comments:	✓
2.	Was permission to enter the facility documented? Comments: Record of personnel onsite kept by Range Control.	✓
3.	Were sampling locations properly selected? Comments:	✓
4.	Were samples collected starting with the least likely contaminated and proceeding to the most likely contaminated? Comments: Not applicable	
5.	Were new disposable rubber gloves worn during sample collection? Comments: Not applicable	
6.	Was sampling equipment wrapped in aluminum foil or otherwise protected from possible contamination prior to sample collection? Comments: Not applicable	
7.	If equipment was cleaned in the field, were proper procedures used? Comments: Not applicable	

Yes or No

8. What field instruments were used during this investigation?
   Comments: Data logger with probes for pH, SC, temp & current velocity. ISCO auto sampler programmed to collect water samples for TSS analysis

9. Were field instruments properly calibrated?
   Comments: Initial calibrations were performed (beginning of field season) But not reported. Calibration procedures probably OK (based on discussion of those procedures) but should be performed more frequently

10. Were calibration procedures documented in the field notes?
    Comments: _____

11. Were samples chemically field preserved?
    Comments: Not applicable

12. Were samples iced?
    Comments: Not applicable

WELL SAMPLING Not applicable

1. Was depth of well determined?

2. Was depth to water determined?

3. Was measuring tape properly decontaminated between wells?
   Comments: _____

4. Were the above depths to water converted to water level elevations common to all wells?
   Describe how the depths were determined. ___

5. How was the volume of water originally present in each well determined?_____

Yes or No

_____
_____

6. Was the volume determined correctly? ___ ___

7. How was completeness of purging determined?
   Volume
   Measure_____
   Time/Flow rate_____
   Cond./ph/T_____

8. Was a sufficient volume purged? ___ ___

   Was the well over-purged? ___ ___

9. Was the disposal of purge water handled properly? ___ ___
   Comments: _____
   _____
   _____

10. Was a dedicated (in-place) pump utilized? ___ ___

    If no, describe the method of purging (bailer - include type and construction material, pump - include type)_____
    _____
    _____

11. How were the samples collected?

    Bailer _____
    Pump _____
    Combination _____

    Construction material of bailer:

    S.S. _____
    Teflon _____
    PVC _____
    Other _____

    Comments: _____
    _____
    _____

12. If a pump was used, describe how it was cleaned before and/or between wells._____

		Yes or No
13.	Were the samples properly transferred from bailer to sample bottles (i.e., was the purgeable sample agitated, etc.)?	___ ___
14.	Was the rope or line allowed to touch the ground?	___ ___
15.	Was wetted rope or line discarded after use at each well?	___ ___
16.	Was cotton or teflon coated rope used?	___ ___
17.	Were generators/gas pumps placed in a down wind position from the well during operation?	___ ___

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SURFACE WATER SAMPLING

		Yes or No
1.	What procedures were used to collect surface water samples? ISCO autosampler	
2.	Did the samplers wade in the stream during sample collection?	— ✓
	If yes:	
	Did sampler face upstream while collecting sample?	— —
	Did the sampler insure that roiled sediments were not collected along with water sample? Not applicable	— —
3.	Note any deficiencies observed during the collection of the surface water samples?	

SEDIMENT SAMPLING

1.	What procedures were used to collect the samples? Repeated sediment sampling on painted surface	
2.	Were the samples well mixed prior to placing the sample in the sample container? Grain size analysis & total	— —
3.	Note any deficiencies observed during the collection of the samples.	

4. Were samples composited?
If so, how were composites collected and mixed?

_____
_____
_____
_____

SOIL SAMPLING Not applicable

Yes or No

1. What procedures were used to collect samples?

2. Were the samples well mixed prior to placing the sample in the sample container? ___ ___

3. Note any deficiencies observed during the collection of the samples.

4. Were samples composited? ___ ___
If so, how were composites collected and mixed?

OTHER SAMPLING

1. What other types of samples were collected during this investigation?

2. What procedures were used for the collection of these samples?

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QUALITY ASSURANCE/QUALITY CONTROL

		Yes or No
	(While not all of these QA/QC procedures will be necessary during each sampling activity, the following techniques may be employed. If so, please note.)	
1.	Did sampling personnel utilize any trip blanks?	— —
2.	Did sampling personnel utilize preservative blanks?	— —
	If yes, to either of the above questions, list the types and handling of the blanks._____	
3.	Were any equipment blanks collected?	— —
	If yes, list:_____	
4.	Were any duplicate samples collected?	✓ —
	If yes, list the types (parameter coverage, etc.) and describe their handling._____	
5.	Were any spiked samples utilized?	
	If yes, list the types (parameter coverage, etc.) and describe their handling._____	
6.	Were QA/QC samples specified in the QA Project Plan?	✓ —
	Were the QA/QC samples collected in accordance with the QA Project Plan? None needed for TSS except duplicates which were collected	— —
7.	Check method used to collect split sample	

___ Filled one large container and then transferred portions

_✓_ Sequentially filled bottles

FIELD DOCUMENTATION AND CHAIN-OF-CUSTODY

		Yes or No
1.	Were chain-of-custody records completed for all samples?	✓
2.	Were all samples identified with Sample I.D. tags or labels? Comments:_____	✓
3.	Were Sample I.D. tags or labels filled-out (e.g., completely station no., location, date, time, analyses, signatures of samplers, type preservatives, etc.)? Comments:_____	✓
4.	Did information on Sample I.D. tags or labels and Chain-of-Custody Records match? Comments:_____	✓

5. Check manner of sample delivery to the lab.

✓ Hand delivered by sampling team member

___ Shipped by common carrier

If shipped by common carrier:

Did the Chain-of-Custody Records indicate the method of sample shipment? ___
Comments:_____

If shipped by common carrier:

Was a Chain-of-Custody record included with the samples in the shipping container? ___
Comments:_____

		Yes or No
6.	Were samples kept under lock and key or kept in a secure place after collection?	___ ✓
7.	Were ~~sample tags, Chain-of-Custody forms, and~~ field notebook signed by sampling personnel?	✓ ___
8.	Does the field notebook contain adequate information about each sample including the sample I.D. number, date, location, and information necessary to reconstruct the sample? field Comments: Sample logs in lab contain this info	✓ ___
9.	Were entries to the field notebook made in ink? Comments:	✓ ___
10.	Were corrections properly executed with one line through the error in the field notebook? 2 6 Comments:	___ ___
11.	Was sampling documented with photographs?	✓ ___
	If yes, was a photolog maintained?	___ ✓
12.	Were amendments to the project plan documented (on the project plan itself, in a project logbook, elsewhere)? Comments: No detailed SAP available - documentation lacking	___ ✓

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DEBRIEFING FOLLOWING FIELD AUDIT

	Yes or No
1. Was a debriefing held with project participants after the audit was completed?	✓
Comments: time was short	
2. Were any recommendations made to project participants during the debriefing?	—
If yes, briefly describe what recommendations were made.	

APPENDIX C

QUALITY CONTROL
FIELD AUDIT CHECKLIST

PROJECT NO. NPE70024.SO.30 DATE OF AUDIT AUGUST 24, 1994
PROJECT MANAGER BILL GOSWELLER AUDITOR JOE SANDLIN
FACILITY NAME EAGLE RIVER FLATS
LOCATION FORT RICHARDSON ALASKA

FIELD PERSONNEL CHARLIE COLLINS, MARIANNE WALSH.

Summary and Recommendations

THIS CRREL GROUP WAS OBSERVED DOWNLOADING DATA LOGGERS AND RETRIEVING TEST SAMPLE SEDIMENT PLUGS FROM TWO SAMPLING LOCATIONS IN BRENDA TRUCK POND.

FIELD NOTEBOOKS USED WERE NEAT AND LEGIBLE. ENTRIES WERE MADE IN WATERPROOF INK. ACCORDING TO C. COLLINS GROUP MEMBERS COPY AND EXCHANGE NOTEBOOK PAGES TO TRANSFER REQUIRED INFORMATION THAT ONE TEAM MEMBER MAY NOT HAVE BEEN ABLE TO RECORD.

LATEX GLOVES WERE WORN DURING SAMPLING FOR BULK DENSITY THOUGH THEY WERE NOT LONG ENOUGH TO PROTECT THE SAMPLERS FOREARMS WHEN SAMPLING AT A DEPTH OF 30 CM.

WRITTEN SOPs are UNDER DEVELOPMENT BUT WERE NOT AVAILABLE FOR THIS AUDIT. SOP1 SHOULD BE DEVELOPED FOR BULK DENSITY SAMPLING AND FOR DATA LOGGER DOWN LOADS. SET UP AND OPERATION OF THE MONITORING STATIONS, EQUIPMENT MAINTENANCE SHOULD ALL BE INCLUDED IN SOPs.

SAMPLES FROM THIS LOCATION WERE NOT INTENDED FOR OFFSITE ANALYSIS SO CHAIN OF CUSTODY PAPERWORK WAS NOT PREPARED. ONSITE ANALYSIS FOR BULK DENSITY AND PHYSICAL EXAMINATION FOR THE WP PARTICLES WAS NOT OBSERVED. SAMPLES ARE ANALYZED BY THE FIELD CREW AND ARE MAINTAINED UNDER THEIR CONTROL THROUGH ANALYSIS. WHEN CHAIN OF CUSTODY PAPERWORK IS REQUIRED, MULTIPLE COPIES ARE USED AND A COPY IS RETAINED BY THE ORIGINATOR.

(OVER)

PLANNING AND PREPARATION

		Yes or No
1.	Was the field audit announced or unannounced? Comments:	
2.	Was a QA Project Plan prepared for this activity? Comments: Yes, however the teams only received the plan 1-2 weeks before the audit	✓ —
3.	Was a site Health and Safety Plan prepared for this activity? Comments: There is a HASP for the whole project	✓ —
4.	Was a briefing held with project field participants? Comments: The project field team was informed of the audit purpose and described their planned work.	✓ —
5.	Were additional instructions given to project field participants (i.e., changes in project plan)? Comments: N A	— —
6.	Was there a written list of sampling locations and descriptions? Comments:	— —
7.	Was there a map of sampling locations available to to field personnel? Comments:	
8.	Was equipment list given to equipment coordinator with adequate lead time? Comments: N A	

The locations from which samples were taken were established in the spring and this effort was to collect data and recover sediment plugs. —

Yes or No

9. Was laboratory given a list of sample containers with adequate lead time? — —
Comments: N/A

10. Were analyses scheduled with the laboratory in advance? — —
Comments: N/A

SAMPLING

GENERAL PROCEDURES

		Yes or No
1.	Was permission granted to enter and inspect the facility? Comments: Permission from range control is required to enter the facility	✓ —
2.	Was permission to enter the facility documented? Comments: NA	— —
3.	Were sampling locations properly selected? Comments: NA - locations were pre-existing having been established in the spring	✓ —
4.	Were samples collected starting with the least likely contaminated and proceeding to the most likely contaminated? Comments: NA	— —
5.	Were new disposable rubber gloves worn during sample collection? Comments: Yes latex gloves were worn however longer gloves would have better protected the sampler	✓ —
6.	Was sampling equipment wrapped in aluminum foil or otherwise protected from possible contamination prior to sample collection? Comments: Sample containers for bulk density were stored in plastic bags prior to use	✓ —
7.	If equipment was cleaned in the field, were proper procedures used? Comments: NA	— —

Yes or No

8. What field instruments were used during this investigation?
   Comments: NA
9. Were field instruments properly calibrated?
   Comments: NA
10. Were calibration procedures documented in the field notes?
    Comments: NA

Each sampling location was a data station with data logger and multiple data collection devices (temp, resistance, water level . . .)

11. Were samples chemically field preserved?
    Comments: NA
12. Were samples iced?
    Comments: NA

WELL SAMPLING

1. Was depth of well determined?
2. Was depth to water determined?
3. Was measuring tape properly decontaminated between wells?
   Comments:
4. Were the above depths to water converted to water level elevations common to all wells?
   Describe how the depths were determined.
5. How was the volume of water originally present in each well determined?

Yes or No

6. Was the volume determined correctly? ___ ___

7. How was completeness of purging determined?
   Volume
   Measure _____
   Time/Flow rate _____
   Cond./ph/T _____

8. Was a sufficient volume purged? ___ ___

   Was the well over-purged? ___ ___

9. Was the disposal of purge water handled properly? ___ ___
   Comments: _____

10. Was a dedicated (in-place) pump utilized? ___

    If no, describe the method of purging (bailer - include type and construction material. pump - include type) _____

11. How were the samples collected?

    Bailer ____
    Pump ____
    Combination ____

    Construction material of bailer:

    S.S. ____
    Teflon ____
    PVC ____
    Other ____

    Comments: _____

12. If a pump was used, describe how it was cleaned before and/or between wells. _____

Yes or No

13. Were the samples properly transferred from bailer to sample bottles (i.e., was the purgeable sample agitated, etc.)? — —

14. Was the rope or line allowed to touch the ground? — —

15. Was wetted rope or line discarded after use at each well? — —

16. Was cotton or teflon coated rope used? — —

17. Were generators/gas pumps placed in a down wind position from the well during operation? — —

SURFACE WATER SAMPLING

Yes or No

1. What procedures were used to collect surface water samples? _____

2. Did the samplers wade in the stream during sample collection? ___ ___

   If yes:

   Did sampler face upstream while collecting sample? ___ ___

   Did the sampler insure that roiled sediments were not collected along with water sample? ___ ___

3. Note any deficiencies observed during the collection of the surface water samples? _____

SEDIMENT SAMPLING

1. What procedures were used to collect the samples?

2. Were the samples well mixed prior to placing the sample in the sample container? ___ ___

3. Note any deficiencies observed during the collection of the samples. _____

4. Were samples composited?
If so, how were composites collected and mixed?

SOIL SAMPLING

Yes or No

1. What procedures were used to collect samples?
Soil/Sediment samples were collected in brass sleeves for bulk density analysis. Procedures used were the same for all samples taken.

2. Were the samples well mixed prior to placing the sample in the sample container? ~A

3. Note any deficiencies observed during the collection of the samples. The gloves worn were not long enough to protect the sampler for deep samples.

4. Were samples composited?
If so, how were composites collected and mixed?
~A

OTHER SAMPLING

1. What other types of samples were collected during this investigation?

2. What procedures were used for the collection of these samples?

QUALITY ASSURANCE/QUALITY CONTROL

Yes or No

(While not all of these QA/QC procedures will be necessary during each sampling activity, the following techniques may be employed. If so, please note.)

1. Did sampling personnel utilize any trip blanks? N/A ___ ___

2. Did sampling personnel utilize preservative blanks? N/A ___ ___

If yes, to either of the above questions, list the types and handling of the blanks._____

_____

_____

_____

3. Were any equipment blanks collected? N/A ___ ___

If yes, list:_____

_____

_____

_____

4. Were any duplicate samples collected? ___ ___

If yes, list the types (parameter coverage, etc.) and describe their handling._____

_____

_____

_____

5. Were any spiked samples utilized? N/A

If yes, list the types (parameter coverage, etc.) and describe their handling._____

_____

_____

_____

6. Were QA/QC samples specified in the QA Project Plan? ___ ___

Were the QA/QC samples collected in accordance with the QA Project Plan? ___ ___

7. Check method used to collect split sample

___ Filled one large container and then transferred portions

___ Sequentially filled bottles

FIELD DOCUMENTATION AND CHAIN-OF-CUSTODY

		Yes or No
1.	Were chain-of-custody records completed for all samples? N/A not reviewed as part of this audit	— —
2.	Were all samples identified with Sample I.D. tags or labels?	— —
	Comments: _____	
3.	Were Sample I.D. tags or labels filled-out (e.g., completely station no., location, date, time, analyses, signatures of samplers, type preservatives, etc.)?	— —
	Comments: _____	
4.	Did information on Sample I.D. tags or labels and Chain-of-Custody Records match?	— —
	Comments: _____	
5.	Check manner of sample delivery to the lab.	
	___ Hand delivered by sampling team member	
	___ Shipped by common carrier	
	If shipped by common carrier:	
	Did the Chain-of-Custody Records indicate the method of sample shipment?	— —
	Comments: _____	
	If shipped by common carrier:	
	Was a Chain-of-Custody record included with the samples in the shipping container?	— —
	Comments: _____	

Yes or No

6. Were samples kept under lock and key or kept in a secure place after collection? — —

7. Were sample tags, Chain-of-Custody forms, and field notebook signed by sampling personnel? — —

8. Does the field notebook contain adequate information about each sample including the sample I.D. number, date, location, and information necessary to reconstruct the sample? ✓ —
Comments: Yes, field notebooks kept with waterproof pen and

9. Were entries to the field notebook made in ink? ✓ —
Comments: Yes, waterproof ink on water resistant paper

10. Were corrections properly executed with one line through the error in the field notebook? — —
Comments: N/A - no changes were noted in field notes

11. Was sampling documented with photographs? This effort was not photographed — ✓

If yes, was a photolog maintained? — —

12. Were amendments to the project plan documented (on the project plan itself, in a project logbook, elsewhere)? — —
Comments:

DEBRIEFING FOLLOWING FIELD AUDIT

		Yes or No
1.	Was a debriefing held with project participants after the audit was completed? Comments: Yes, but there was not sufficient time to discuss findings. They were told a report would follow.	✓ —
2.	Were any recommendations made to project participants during the debriefing? If yes, briefly describe what recommendations were made. See cover pag	— —

Appendix F
Responses to Comments

RESPONSES TO COMMENTS ON DRAFT FINAL REMEDIAL INVESTIGATION REPORT, OPERABLE UNIT C, FORT RICHARDSON, ALASKA

Reviewer: Howard Orlean, U.S. EPA, Region 10

Item No.	Page	Comment	CH2M HILL Response
1	ES-2, Second Full Paragraph	*The second sentence of this paragraph appears to...*	The text has been clarified to state that "... in some ponds where high mortality has been observed, WP has not been extensively detected in the sediment. This finding suggests that some birds may ingest WP in a contaminated area but fly away..."
2	ES-3, First Full Paragraph	*This paragraph states that the findings of the...*	The statement was added and Method 7580 in SW846 Update III was referenced.
3	ES-4, Number 11 & 5-6, Section 5.4.1.2	*The last part of the second sentence in Number II...*	The change was made per the comment
4	ES-5, Top of Page, First Sentence	*EPA agrees that evaluation of remedial success...*	The sentence has been corrected.
5	3-5, Figure 3-1	*This figure should be updated in include the work...*	1996 field activities have been added to the figure.
6	4-8 & 4-10, Figures 4-2 &4-4	*From these (black and white) figures it appears as...*	The text is correct. The appearance of elevated detects in Areas A and B are the result of overlapping symbols. The legend to these figures were prepared to clarify misinterpretation.

OUC 0029782

Reviewer: Howard Orlean, U.S. EPA, Region 10			
Item No.	**Page**	**Comment**	**CH2M HILL Response**
7	4-23, Section 4.4, Fourth Paragraph	*The statement is made in this paragraph that...*	Goose Bay concentrations are not considered to be background. A background soils and groundwater data report was prepared by Ecology and Environment, Inc. in January 1996. This report included background information for both Fort Richardson and Elmendorf AFB. This information was incorporated into the Final RI. However, no sediment background data was included in this 1996 publication. Sediment concentrations from three areas were available for this RI: Goose Bay, Alaska Stream and Lake and Eagle River Bridge and Cottonwood. Goose Bay sediment concentrations were generally the lowest of the three areas and were cited in the RI because overall they were the most conservative. The text has been clarified to state that sediment concentrations from ERF were generally lower than the three available reference areas. The text will also refer the reader to Section 6 for additional reference area information.
8	6-4, Middle of Page, Scope of Work, First Bullet	*This bullet is confusing. How many wells were...*	The bullet has been rephrased to be less confusing.
9	6-4, Middle of Page, Scope of Work, Second Bullet, First Sentence	*Three soil samples were collected from each of...*	The bullet has been corrected per the comment.
10	6-6, Section 6.5.1 & 6-10, Figure 6-2	*Were ground-water elevation measurements...*	The existing piezometers had not been sampled because they were dry. They were installed approximately 6 meters below ground surface (bgs). The water table is generally 8 to 10 meters bgs. This was clarified in the text and on Figure 6.2.

OUC 0029783

Reviewer: Howard Orlean, U.S. EPA, Region 10			
Item No.	**Page**	**Comment**	**CH2M HILL Response**
11	6-15, Table 6-4	*Mercury concentrations for the OB/OD area...*	Maximum metals concentrations measured at the OB/OD pad are compared to average background concentrations in Table 6-4. 26 soil samples were analyzed for mercury during the November 1996 investigation. Of those, only 2 had concentrations greater than nondetect. The average OB/OD pad mercury concentration would likely be within range of the references areas if these nondetect sample results were included in the calculation. Thus because mercury detects were only 8%, and because even the maximum concentrations are below action levels, mercury is not of concern. The variability in metals concentrations is likely attributed to geologic variability, soil origin (windblown dust or runoff), plant uptake or sampling methodology (E&E, 1996). No change to the text was made per this comment. However the reader has been directed to Appendix E for specific metals concentrations.
12	7-3 through 7-6, Section 7.2.1	*According to Section 6 concentrations of...*	This section has been revised with additional text to clarify the chemical-specific ARARs are not needed for OB/OD Pad groundwater.
13	7-9, Last Full Paragraph	*A draft Natural Resource Damage Assessment...*	Paragraph was deleted.
14	7-18, Table 7-6	*EPA's Draft Munitions Rule should be listed as...*	The munitions rule was finalized and has been included as a location-specific and action-specific ARAR.
15	10-1 through 10-5, Section 10.1	*This section discusses preliminary remediation...*	Section 10 has been revised to focus on the two PRGs of reduction in waterfowl mortality and reduction in WP hot zones agreed upon by the RPMs and BTAG. Additional detail regarding PRGs, treatment options, and measurements of success will be included in the OUC feasibility study.
16	10-16, Section 10.3, Last Paragraph	*The discussion on confirmatory monitoring as...*	The reference to confirmation monitoring has been revised to "baseline monitoring." The text has been modified to reflect the comment.

OUC 0029784

Reviewer: Matt McAtee, U.S. Army Center for Health Promotion and Preventive Medicine			
Item No.	**Page**	**Comment**	**CH2M HILL Response**
Major Comments			
1	10-4 and Figure 10-1	*Current PRGs Based Upon Unsupported Premise...*	Comment noted. The long-term biological and physical PRGs were established by OUC RPMs and BTAG. As additional information is gathered and evaluated during implementation of remedial technologies and during future monitoring at ERF, PRGs may be revised. This is one of the reasons for the 5-year review. Discussion of future monitoring of remedial technology implementation and baseline monitoring of the natural systems, including waterfowl use and mortality, and the relationships between remedial technology evaluation and PRGs will also be included in the feasibility study. Section 10 have been revised to clarify this in response to RPM (EPA) comments.
2	8-22, Section 8.2.5	*Quantitating Uncertainty. It is stated that estimated...*	Comment noted; no text revision. The PRGs were developed by the OUC RPMs and BTAG. Quantitative uncertainty estimates have not been developed from past ERF data. The commentor is correct in noting that natural variability in mortality and other population dynamics, in addition to uncertainties associated with available methods for measuring WP hot spots, will indeed influence the ability to monitor for PRG success. This has been a central theme during the development of PRGs to date. Periodic review of remedial action at ERF and monitoring of natural systems at ERF will seek to verify that PRGs are being achieved, or that modifications to PRGs and/or remedial action are necessary.

OUC 0029785

Reviewer: Matt McAtee, U.S. Army Center for Health Promotion and Preventive Medicine			
Item No.	**Page**	**Comment**	**CH2M HILL Response**
3	8-16, Section 8.2.4.1 and 10-2, Table 10-1	*Effects Other Than Mortality Are Ignored in the Long...*	Monitoring adverse reproductive effects from WP may be possible but not without substantial risk to personnel who would need to locate and study nests on ERF. The long-term monitoring plan seeks to generate data necessary to assess the effectiveness of remediation efforts while recognizing the need to accomplish this goal with minimal risk to investigators. While we agree with the commentor that the effect of WP on waterfowl reproduction rates may be important, it should be noted that the laboratory toxicity studies specifically designed to address this issue did not generate a reliable LOEL dose value for chronic (non-acute) effect (Sparling et al., in Racine et al., 1995). To measure the subchronic effects in field studies would present an even greater challenge. The human health risks would probably outweigh the benefit of conducting these studies. However, as Section 10 notes, monitoring of the ERF natural systems and remedial technologies will be conducted and PRGs may be revised in the future.
Minor Comments			
4	5-24, Section 5.10.2	*It is stated that "occasional shorebirds are found...*	Finding any number of shorebird carcasses is probably more than the "usual" rates; a paragraph was added to Section 2.2.3 of Appendix A and in Section 8.2.1.2 to provide similar supporting information as given on page 5-24.
5	6-4, Section 6-3	*The comment in the left margin of this page...*	The date has been corrected.

OUC 0029786

Reviewer: Matt McAtee, U.S. Army Center for Health Promotion and Preventive Medicine			
Item No.	**Page**	**Comment**	**CH2M HILL Response**
6	8-6, Section 8.2.1.2	*The rationale for risk to plants only from the...*	The rationale for discounting the risk to plants from the organic compounds (other than di-n-butylpthalate) was based on the fact that plants would not be likely to take up significant quantities of the explosive residues and SVOCs detected on the OB/OD Pad. There are three reasons for this judgment: 1) These compounds could only be significantly translocated into plant roots by diffusion if there was a high concentration gradient (i.e., high concentrations in the soil). The low detected concentrations in soil were considered not high enough for significant diffusion into the roots to take place; 2) The compounds could be actively translocated across the root cell membranes if the plant expended energy. Because these compounds are not normally linked to plant metabolism, active transport by the plant is not likely; and 3) Nitroamines in general can be taken up by plants from nutrient solution and soil but the concentration in plants is rapidly decreased by either chemical vaporization or metabolic breakdown (Bell, 1992). The text has been modified to indicate these reasons.
7	8-8, Section 8.2.2.2	*Results are not provided for the kestrel study...*	Brief description of the kestrel study results is provided on page 8-14. Text has been modified on page 8-8 to summarize the kestrel studies.
8	8-8, Section 8.2.2.2	*The significance of results from a single tissue...*	Comment noted; no text revision.
9	8-10, Section 8.3.2.1	*A reference is made to "low exposure rates" ...*	There is no contradiction. The apparent confusion stems from the discussion of spring and fall season exposure rates. The text has been modified to make this distinction more clear. Low exposure rate refers to the relative number of birds using the particular portions of ERF where ground-level bird counts were performed.
10	8-20, Section 8.2.4.1	*The percentage use of hot areas listed in the box to...*	The border captions have been corrected.
11	B-9, Section 2.2	*The oral RfD for WP is stated once as $2x10^{-5}$ mg/kg-...*	The discrepancy has been corrected.
12	B-12, Section 4.0	*Please provide the date the information was extracted...*	The date has been added.
13	Appendix A	*The section on field and laboratory studies does not...*	The reproductive studies are discussed on page A-66.

OUC 0029787

Reviewer: CRREL, Marianne Walsh, Charles Collins, and Michael Walsh			
Item	**Page**	**Comment**	**CH2M HILL Response**
1	X	*P_4 is the molecular formula specifically for the white allotrope of...*	The glossary has been corrected per the comment.
2	X	*P_4O_6 is not "phosphoric" oxide. Rather it is phosphorus oxide...*	The glossary has been corrected per the comment.
3	XI	*RDX is "...-1,3,5-triazine" not ..." ...-1,3,5-triamine"*	The glossary has been corrected per the comment.
4	ES-3	*Not all white phosphorus munitions contain "plasticized" white...*	The word "plasticized" has been deleted.
5	Table 2-4	*Comp B is 60% RDX and 40% TNT with 1% was added.*	The table has been corrected.
6	2-11, third paragraph, last sentence	*Western channel of eagle River has much reduced flow but is not...*	The sentence has been revised to read "...the flow in the western channel of Eagle River was reduced when..."
7	2-23, third paragraph, second sentence	*Change to "High Explosive (or HE) projectiles...made the craters,...*	The sentence has been revised per the comment.
8	2-24, first paragraph	*Somewhere should add a sentence to clarify that WP smoke...*	The following sentence has been added to the paragraph discussing WP and HC smokes as the most common agents "WP smoke projectiles contain a very small HE bursting charge and do not form craters upon impact."
9	3-5, Figure 3-1	*1990 Activities. Change "Sampling augmented to include...*	The modifications have been made per the comment.
10	3-11	*ESE work was not conclusive, as pointed out in para. 3-5 on...*	The phrase "statistically significant" has been deleted.
11	3-12, third paragraph	*WP (P_4) is not a "compound" since it is not made up of two or...*	The word "compounds" has been replaced with the word "chemicals."
12	3-12, 3.1.4.1, third paragraph, last sentence	*Change "...was augmented to include testing for WP in sediment...*	The sentence has been revised per the comment.
13	3-12, last sentence in 3.1.4.1	*Add the word "Aqueous soluble" before phosphate...*	The suggested phrase has been added.
14	3-12, first sentence 3.1.4.2	*Field observations were actually made from an observation tower...*	The sentence has been modified to read "Field observations... were conducted...from an observation tower..."
15	3-13, first word.	*Dartmouth Medical School conducted the toxicity studies...*	The text has been revised to reference Dartmouth Medical School as the organization that conducted the toxicity studies.

OUC 0029788

Reviewer: CRREL, Marianne Walsh, Charles Collins, and Michael Walsh			
Item	**Page**	**Comment**	**CH2M HILL Response**
16	3-13, first paragraph under 3.1.5.1	*Method 7580 is in SW846 Update III (January 1995). (MEW)...*	Update III has been added to the reference of SW846.
17	3-13 to 3-14	*Somewhere in this discussion you should mention that...*	The suggested discussion has been added as the last paragraph to the section discussing sediment in Section 3.1.5.1.
18	3-15, first paragraph under 3.1.5.3	*Replace (CRREL, undated) with (Nam et al. 1994). (MEW)...*	The correction has been made. The Nam reference was already in the bibliography.
19	3-18, second paragraph	*We feel that this overstates the effects of the erosion and...*	The text has been revised in the following manner "...it was concluded that the processes of erosion and sedimentation may reduce WP concentration in surface sediment over a portion of ERF. Gully erosion and headwall recession may drain larger areas..."
20	Section 3.1.5.3	*In this discussion USFWS has been substituted for PWRC...*	The references to organizations that conducted toxicological studies has been revised per Bill Eldridge's review.
21	Section 3.1.6.1.	*1994 Studies. Add paragraph. CRREL study of the persistence ...*	The discussion has been added as the third paragraph of Section 3.1.6.1.
22	3-17	*1994 Studies. NEILE conducted mortality studies, not...*	The text has been reflected to state that NEILE conducted the mortality studies, not USFWS.
23	4-3, first paragraph	*Core samples were only taken in 1991 and 1992 before the...*	A sentence has been added to clarify that core samples were taken only in the period between 1991 and 1992.
24	4-4, first paragraph under 4.2	*Particle masses ranged from 0.1 to 3.4 milligrams...*	The units have been corrected and a brief discussion regarding the 150-mg particle found at Racine Island has been added to the text.
25	4-7	*Area A. You may want to consider the years when large...*	This discussion has been added as the third paragraph of Section 4.2.1.
26	4-13, Section 4.2.3, last paragraph	*Some post-dredging sampling occurred in Area C in 1996...*	Reference to the post-dredging sampling has been added to the last paragraph in Section 4.2.3.
27	4-23, Section 4.3.2	*Change first sentence to "...WP concentrations (typically less...*	The changes recommended in the comment have been made.
28	4-26, second paragraph of 4.5, last sentence	*Because the length of time that the sediments are unsaturated...*	This discussion has been added to the second paragraph in Section 4.5.

OUC 0029789

Reviewer: CRREL, Marianne Walsh, Charles Collins, and Michael Walsh			
Item	**Page**	**Comment**	**CH2M HILL Response**
29	5-1-p. 5.2. first paragraph of Section 5.2	*Incorrect information on crater formation...*	The text has been revised to state that craters are produced by high explosive projectiles.
30	Section 5.4	*We have evidence that suspension of contaminated sediments...*	Figures 5-2 and 5-4 have been deleted and the title of Figure 5-3 has been revised. The term "particles" has been quantified by distinguishing between "microgram" and "milligram" quantities. Distinctions were made in the text between microgram-sized particles in suspension and milligram-sized particles that settle.
31	5-11, Section 5.4.2, last sentence	*size of "small" particles should be quantified...*	The size "small" has been quantified to mean "microgram sized." Bouwkamp, 1993 has been cited. In addition, the following sentences have been added to the end of Section 5.4.2. However, there is no evidence that milligram-sized particles can be resuspended or transported. It is these larger particles that are of concern with regard to dabbling ducks and lethal WP doses.
32	5-6, Section 5.4.1.2	*I have seen no evidence that "signification erosion, transport,...*	The text in Section 5.4.1.2 describing erosion, transport, and deposit has been abated to reflect the comment. Words like "significant," active, and dynamic have been deleted. In addition, the following two sentences have been added per the comment. (1) "Field observations suggest that more than 20 cm of deposition must occur before significant consolidation would occur in permanent ponds." and (2) "Dabbling ducks easily disturb fine sediments that have settled to pond bottoms."
33	5-12, Section 5.4.2.2	*Size of WP that could be suspended should be quantified...*	The size of WP particles has been quantified by distinguishing between microgram and milligram sized particles. Microgram sized particles can be resuspended and transported in water. Milligram-sized particles settle to pond bottom sediment.
34	Figure 5-5	*P_4 is not "reduced"; P_4 has an oxidation state of zero. pH_3...*	The scale at the bottom of Figure 5-3 (formerly Figure 5-5) has been deleted.
35	Table 5-1	*The value and units for Henry's Law Constant should be...*	The units for the Henry's Law Constant have been revised. The footnote superscripts have also been corrected.
36	5-15	*P_4O_6 forms phosphorous acid, not phosphoric...*	The first reference to "phosphorous acid" has been revised to read "phosphorous/phosphonic acid". The incorrect reference to "phosphoric acid" has been revised to read "phosphonic acid".
37	5-19, Section 5.6.3	*First two paragraphs should be eliminated...*	The first two paragraphs in Section 5.6.3 of the Draft Final RI have been revised.

OUC 0029790

Reviewer: CRREL, Marianne Walsh, Charles Collins, and Michael Walsh			
Item	**Page**	**Comment**	**CH2M HILL Response**
38	6-3, second full paragraph.	*That's the Route Bravo bridge, not Point Bravo...*	The name of the Bridge has been corrected.
39	Table 6-2	*Underline and use bold for the word "Explosives"...*	The stylistic correction has been made.
40	Table 8-2	*Should read 4-amino-2,6-DNT. Superscript "c" seems to be...*	The correction to the name of the chemical has been made.
41	8-5, first full sentence	*Change to "...WP could be found in some of the small ponds...*	The sentence has been revised per the comment.
42	8-14	*Contradiction with pg. 7-16 on LD50 and LOE rates...*	There is no contradiction. On page 7-16 the reported LD_{50} (between 3 and 4 mg/kg) is for pelletized WP and the reported LOEL (approximately 1 to 2 mg/kg) is for single WP doses in waterfowl. On page 8-14, the estimated LD_{50} (1 to 2 mg/kg bw) is for eagles or other predatory birds. The text has been revised on both pages to make this more clear.
43	8-15	*More confusion over microgram vs milligram...*	The text has been corrected per the comment and details provided in Bouwkamp, 1995.
44	8-20, second sentence.	*The detected WP levels in bird tissues have been higher...*	The cited statement was based only on comparisons of absolute values for reported concentrations and the text has been revised to clarify the specific comparisons. We agree with the commentor that the quantities of WP found in gizzards also lend support to the conclusion that waterfowl were ingesting sufficient quantities to cause mortality. However, since gizzards were not analyzed in toxicity tests (Attachment 1, Appendix A), there could be no direct comparison of field-collected tissues to those taken from WP-dosed waterfowl. The statement was intended to link WP tissue concentrations for in-field collected waterfowl and WP toxicity test subjects to show that the data indicate that lethal doses of WP have been ingested on ERF.
45	8-20, second full paragraph.	*There have been many more disruptions to waterfowl...*	The fifth paragraph of Section 8.2.4.2 has been revised to read "Activities at ERF that cause disruptions to waterfowl also make it difficult... Bird hazing, walking transects, the heavy use of helicopters, the dredging activities, and the duck pen studies have all altered behavior of the ducks and swans. These activities appear to have a lesser effect...Thus at a minimum, bird hazing should be stopped..."
46	8-21	*Another uncertainty is the actual cause of death of...*	This additional uncertainty has been added to the discussion in Section 8.2.5.
47	8-23, second full paragraph.	*"No trespassers have been observed." There have been...*	The text has been revised to read "Very few trespassers have been observed."

OUC 0029791

Reviewer: CRREL, Marianne Walsh, Charles Collins, and Michael Walsh			
Item	**Page**	**Comment**	**CH2M HILL Response**
48	9-3, Conclusion 4	*Remove the word "plasticized"...*	The word has been removed.
49	9-3, Conclusion 6	*WP particles will not readily oxidize at cold temperatures...*	The revision has been made per the comment.
50	10-3	*How did ERF being closed to access for part of the summer...*	The waterfowl mortality rate referred to on page 10-3 was determined by the 1996 field season telemetry studies and this has been clarified in the text. For this reason, there was presumably no effect due to lack of access to ERF during 1996; or at least none was mentioned by the authors of the study (Cummings et al., 1996). As discussed on page 3 in the previous Draft Final Remedial Investigation response to comments (Sec.3. P.3-46, Last Par.), mortality estimates from the telemetry and transect data were not integrated because they were not directly comparable. These studies measured different parameters at different time scales. The telemetry studies measured the mortality rate for a known number of ducks over specified time intervals with WP exposure occurring from any location on ERF. The ground surveys estimated the mortality from carcass and feather counts along the transects corrected for predation losses. The different measures and uncertainties associated with the tow studies preclude the validity of the comparison.
51	10-5, Section 10.2.1, third paragraph	*Remove the words "from WP exposure" unless cause of death...*	The phrase has been deleted per the comment.
52	10-9 to 10-11	*Based on your decision to include some of the C/D ponds as hot..*	The words "from WP exposure" have been removed from the text. We agree with the commentor about limitations concerning mortality estimates from the telemetry studies. In fact, the same recommendations (and others) for improving the estimates are discussed in Appendix G on pages G-3 and G-4 in the Draft Feasibility Study Report (CH2M HILL, 1997). For the reasons discussed in response #50 and the risk to research personnel conducting ground-level mortality surveys on ERF, the continuation of the mortality transect studies has not been recommended.
53	10-15	*A map would be useful showing the locations of the intermittent...*	The intermittent pond names have been added to Figure 10-3.
54	11-1 to 11-6, Section 11	*Some inconsistency between citations here and citations...*	Citations have been thoroughly reviewed and corrected by a senior editor and are believed to be correct.

OUC 0029792

Reviewer: CRREL, Marianne Walsh, Charles Collins, and Michael Walsh			
Item	**Page**	**Comment**	**CH2M HILL Response**
55	A-10 Table 2-2. Same Table 8-2	*Correct per comment for Table 8-2...*	The correction to the name of the chemical has been made.
56	A-13, second paragraph	*"The exposure route for shorebirds...have not been well...*	The text has been revised to read "The exposure routes for shorebirds and fish-eating birds are not completely understood. Based on the mass of WP found in the gizzard contents of some shorebirds, direct ingestion of WP particles from the sediment is one exposure route. However, it is unclear whether these birds are being exposed secondarily..."
57	A-40, Table 3-5	*The units for concentration should be µg/kg not mg/kg...*	The units have been corrected.
58	B-6 to B-7 and Table 2-1	*The data used in this section to estimate exposure to humans...*	The recommended data has been included in the human health risk assessment to replace the original incomplete data set. The direction provided in the comment is appreciated.
59	B-7, Table 2-1	*What is the difference between pectoral and breast muscle?...*	There is no difference. Reference to the "pectoral" muscle has been deleted. The term was originally used to preserve the classification scheme of the researchers.
60	B-9	*There is an inconsistency in the reported reference dose...*	The inconsistency has been corrected.
Note: Chuck Racine's changes and additions in Section 2 were addressed, except that "eulachon" on p. 2-19 was not underlined or italicized because it is the common name of the fish (the scientific name follows in parentheses).			

OUC 0029793

Reviewer: Ferrell, EN-G-MI			
Item No.	**Page**	**Comment**	**CH2M HILL Response**
1	ES-5	*"Hot pond" needs to be defined. The partial...*	The definition of "hot ponds" has been highlighted in the executive summary. The reference to monitoring activities has been revised.
2	df 1-3, paragraph 1.2.1	*Paragraph 1.2.1 seemingly fixes the cause of any...*	The margin text has been revised.
3	df 2-1, p2.1.2.	*The extreme cold temperature of -18 C seems...*	The text has been revised to refer to -18 degrees C as the average minimum temperature.
4	df 3-14	*The physiologic mechanism of white phosphorus...*	The physiologic mechanism for WP toxicity was evaluated by Roebuck. Those interested in these studies may refer to his work. Detailed discussion on this topic is beyond the scope of this RI.
5	df 3-18	*This section, 3-18, points out that WP concentrations...*	The spatial variations of WP concentrations at ERF are a function of the extreme heterogeneity of the distribution, not a decrease in WP concentration with time. Comparing WP concentrations spatially with time had been performed as part of the nature and extent evaluation of the RI but no trends were discernible. No changes to the text or figures have been made for this comment.
6	df 4-14	*Consistency in the use of symbols would help...*	Only four sampling locations are depicted on Figure 4-14. Due to production complications, no changes were made to symbols used in the figure.
7	df 5-1	*Not necessarily contrary to the statement in para 5.2...*	Discussion of particle settlement has been revised per CRREL's comments.
8	df 5-2	*Some where in the discussion of WP particles,...*	Discussion of particle size and kinetic energy have been revised per CRREL's comments.
9	df 5-5	*The resistance to photolysis is fact as stated and WP...*	Discussion of WP persistence has been revised per CRREL's comments.
10	df 5-6	*Additional emphasis is needed on the fact that the...*	Discussion of particle size has been revised per CRREL's comments.
11	df 5-14, Table 5	*The footnotes to this table contain typos.*	The footnotes have been revised to include superscripts.
12	df 5-15	*The paragraph on phosphates raises the problem...*	The discussion has been revised to read "Phosphoric acids have the potential to lower pH in systems with low water hardness..."
13	df 5-16, Page 5.6.1	*Probability is normally used as a ratio. It needs...*	It is stated in the text that the term "hazard probability" is a qualitative term. An example is provided to demonstrate relative risk. This expanded discussion addresses a BTAG comment on Draft RI. No changes have been made to the text.
14	df 5-19, Page 5.6.2	*The next to final sentence in the first paragraph...*	The typos have been corrected.

OUC 00029794

Reviewer: Ferrell, EN-G-MI			
Item No.	**Page**	**Comment**	**CH2M HILL Response**
15	df 5-23, Page 5.10.2	*Perhaps the reason, for ingestion of particles is not...*	Chuck Racine had explored this topic. He concluded that birds are feeding on invertebrates and seeds, not grit. The means of ingestion of WP particles is relevant to waterfowl toxicity because they will ingest the particles while feeding unless the particle-to-bird pathway is removed. A supply of gizzard grit would not likely affect waterfowl exposure at ERF. No change has been made to the text.
16	df 5-24, Page 5.11	*Is there any data relevant to the continued toxicity...*	There are no data concerning continued WP toxicity after digestion; it is not relevant to this assessment. No change has been made to the text.
17	df 8-15	*Reference to the laboratory exposure and death of...*	Life expectancy is not relevant in these fixed-period tests conducted to assess toxicity; no text revision.
18	df 9-5, paragraph 9-2	*The recommendations listed need to include specific...*	Remedial actions will be evaluated in the Feasibility Study. Reference to this document will be highlighted in the text.
19	df 10-1, paragraph 10.1	*The third bullet has a "Preliminary Remediation Goal...*	Discussion of PRGs has been revised per EPA comments.
20	df 10-10, Table 10-5	*Where WP has been demonstrated the date of the...*	Date of sample collection can be determined from CRREL annual reports. This table was intended to be a quick summary of the rationale for selecting hot ponds, not summary of the WP database. Therefore, the sampling dates have not been added.
21	A-43, Table 3-6	*This table needs to include controls and blanks.*	The table presents the data that are relevant to the assessment. No changes have been made to this table per RPM (Fort Richardson).
22	A-76, 3.3.2	*Much of the discussion in not clear. Specimens...*	The text has been revised to discuss identification of "specimen."

OUC 0029795

Reviewer: Marlowe Dawag, U.S. Corps of Engineers			
Item No.	**Page**	**Comment**	**CH2M HILL Response**
1	General	*Liked the use of the margins for "key points: of ...*	Comment appreciated.
2	Figure 3.1	*Liked the format of the timeline, however print of ...*	Comment appreciated. The text of the milestones has been darkened.
3	Table 3-2	*Under Bird Behavior/Characteristics-"...and behavior...*	Correction has been made per the comment.
4	Figure 4-1	*A bit difficult to differentiate the solid shapes ...*	Areas of high overlapping symbols represent areas of high sampling and/or detections. The count of symbols in the legend was intended to prevent misinterpretation.
5	Section 4.2,paragraph 4	*Text in this paragraph states area B shows no ...*	The text is correct. The appearance of elevated detects are the result of overlapping symbols. The legends to these figures were prepared to clarify misinterpretation.
6	Section 4.2.4 paragraph 2	*"Sampling was conducted area C/D...". Please insert...*	Correction has been made per the comment.
7	Section 5.4.3, page 5-14; first line	*Delete 2nd "oxide" in "...Phosphorus pentoxide oxide...*	Correction has been made per the comment.
8	Page 6-4, margin text	*"...the field work in 1969 were..." Should the year be...*	Correction has been made per the comment.
9	Section 6.6	*This CSM section is not as clear as the CSM for the...*	The CSM for the OB/OD pad is not as extensive as the CSM for ERF because the OB/OD pad is much less in areal extent, is less conceptually complicated, and poses a lesser risk to human health or the environment.
10	Page 8-18, third paragraph	*"These studies were not conducted..." What health...*	Correction has been made per the comment.
11	Page 8-32, second paragraph	*"...and ingests 200 and 100 mg sediment,...*	Correction has been made per the comment.
12	Page 9-2, second paragraph	*Change "Opening burning" to "open burning".*	Correction has been made per the comment.
13	Page A-52	*What new health and safety requirements? Suggest...*	Correction has been made per the comment.
14	Page A-66, second paragraph	*This statement doesn't make sense; "...only four ...*	The phrase about 'eggs no longer connected to the circulatory system' has been deleted.
15	Section 10-1, 1st bullet	*2nd sentence. Suggest editing into shorter sentences.*	Correction has been made per the comment.
16	Page A-23, second paragraph	*Check percentages stated; particularly the 29...*	The percentage of mallards, pintails and green-winged teal has been revised.
17	Page A-59	*The percentages stated in the first paragraph do not...*	Correction has been made per the comment.
18	Page A-77, second paragraph	*"The reasons for the failure..." Suggest examples...*	The phrase "...and could have been due to a variety of factors" has been deleted. It is currently not prudent to speculate on the cause of failures.
19	Table 4-1, Appendix A	*The values in listed for mortality ratio columns...*	Correction has been made per the comment.
20	Page B-8, margin text	*If one just reads this text alone, it would seem...*	Correction has been made per the comment.

OUC 0029796

Reviewer: Frye, CERMO-HX-T			
Item No.	**Page**	**Comment**	**CH2M HILL Response**
1	Page 7-5, Section 7.2.1	*Federal CWA Ambient Water Criteria are not ARARs...*	This section will remain unchanged at the direction of RPMs.
2	Page 7-5, Section 7.2.1	*The ADEC Hazardous Waste Management Regulation...*	This section will remain unchanged at the direction of RPMs.
3	Page 7-5, Section 7.2.1	*As of July 1996, ADEC no longer manages its...*	The promulgated hazardous waste management regulations are still considered ARARs, as the ADEC still retains authority to administer and enforces the regulations.

OUC 0029797

Reviewer: Jennifer Roberts, Alaska Department of Environmental Conservation (verbal comments received at April 30, 1997 Draft Final RI comment review meeting)			
Item No.	**Page**	**Comment**	**CH2M HILL Response**
1	Page 7-9, fifth paragraph	*This paragraph is confusing; no NRDA has been completed. Please delete paragraph.*	Paragraph deleted.
2	Page 7-11, Table 7-3	*Add Clean Water Act Section 401 to Wetlands ARARs.*	Citation added.
3	Page 7-12	*Correct citation for Alaska Coastal Management Law is AS 46.40.*	Citation corrected.

OUC 0029798

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue
Seattle, Washington 98101

April 4, 1997

Reply to
Attn of; ECL-113

W. A. Gossweiler
Department of the Army
Directorate of Public Works
600 Richardson Drive #6500
Attn: APVR-RPW-EV
Fort Richardson, Alaska 99505-6500

Re: Operable Unit C/Eagle River Flats
Draft Final Remedial Investigation Report

Dear Bill;

The U.S. Environmental Protection Agency (EPA) has completed our review of the document entitled *Operable Unit C Draft Final Remedial Investigation Report* (Draft Final RI). EPA received this document on March 7, 1997.

For the most part, the Draft Final RI has adequately addressed EPA's previous comments. EPA agrees with the Department of the Army that an integrated process of evaluating remedial success for Eagle River Flats (ERF) must be implemented once remedial/removal action is initiated. EPA still has some concerns with the way the preliminary remediation goals for ERF have been outlined in this document. Specific comments on the Draft Final RI are attached.

If you have any questions, please call me at 206-553-6903.

Sincerely,

Howard Orlean

Howard Orlean
Superfund Project Manager

cc: Bruce Duncan, ES-098
Jennifer Roberts, ADEC
Joann Walls, Army Engineer District, Alaska

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EPA Comments on ERF Draft Final RI/BRA
April 4, 1997

Specific Comments

1. **Page ES-2, Second Full Paragraph --**

The second sentence of this paragraph appears to state that even though high levels of white phosphorus (WP) are found in areas of high waterfowl mortality the *extent* (emphasis added) of WP contamination in these areas is not great. Does this mean that the areal extent of hot spots within a particular pond is limited? How does this suggest that birds fly away after being exposed? Please clarify.

2. **Page ES-3, First Full Paragraph --**

This paragraph states that the findings of the RI Report are based largely on data collected before the CERCLA process was implemented. Recommend adding a sentence which also states that the analytical process for the identification of WP concentrations was first developed during this phase and has since been adopted by EPA.

3. **Page ES-4, Number 11 & Page 5-6, Section 5.4.1.2—**

The last part of the second sentence of Number 11 on Page ES-4 is confusing. Since sediment and water samples have not been taken from Knik Arm, but two samples have been collected from the mouth of Eagle River (as per Section 5.4.1.2) this sentence should read *"...there is no evidence to suggest that WP would be detected in Knik Arm."*

4. **Page ES-5, Top of Page, First Sentence --**

EPA agrees that evaluation of remedial success at ERF is extremely important. However, "future monitoring activities" (with respect to evaluation of remedial success) are not actually described in this section. Please correct this sentence or include a discussion of future monitoring activities.

5. **Page 3-5, Figure 3-1 --**

This figure should be updated in include the work that was done during 1996. (e.g. Blowing up of Bread Truck Pond, additional telemetry studies, OB/OD investigation).

6. **Pages 4-8 & 4-10, Figures 4-2 & 4-4 --**

From these (black and white) figures, it appears as if there are several sample locations in Areas A & B at which the WP concentrations are from 10-100 μg/g and >100 μg/g even though the text and the legend in the figures state that there are zero samples at these concentrations.

7. **Page 4-23, Section 4.4, Fourth Paragraph --**

The statement is made in this paragraph that elevated concentrations of metals were found in ERF, but they "all were within the upper 95th percentile of sediments from Goose Bay". Please clarify. Is Goose Bay considered to be a background reference area?

8. **Page 6-4, Middle of Page, Scope of Work, First Bullet --**

This bullet is confusing. How many wells were installed (two, seven or nine)? Were the seven piezometers installed by CRREL developed as monitoring wells? How many cluster wells? Were two clusters installed at two different locations.

9. **Page 6-4, Middle of Page, Scope of Work, Second Bullet, First Sentence --**

Three soil samples were collected from each of the seven *monitoring well* locations. (Not *soil* locations as written.)

10. **Page 6-6, Section 6.5.1 & Page 6-10, Figure 6-2 --**

Were ground-water elevation measurements taken in the piezometers for the OB/OD study? If not, why not? If the piezometers were drilled in 1995, some ground-water elevations should exist and should therefore be incorporated into the RI document.

11. **Page 6-15, Table 6-4 --**

Mercury concentrations for the OB/OD area appear to be higher than the two Reference Areas listed. Please provide an explanation for the higher mercury concentrations.

12. **Pages 7-3 through 7-6, Section 7.2.1 --**

According to Section 6 concentrations of contaminants from the OB/OD Pad do not pose a risk to ground water. As such, ground-water ARARs (e.g. Safe Drinking Water Act) need not be evaluated for the OB/OD Pad.

13. **Page 7-9, Last Full Paragraph --**

A draft Natural Resource Damage Assessment (NRDA) has already been completed by the U.S. Army. Preliminary results from the draft NRDS should be included in this section of the RI.

14. **Pages 7-18, Table 7-6 --**

EPA's Draft Munitions Rule should be listed as TBC. It should be noted that the Draft Munitions Rule was first published in the Federal Register in February 1997. The rule could be therefore be finalized in August 1997.

15. **Pages 10-1 through 10-5, Section 10.1 –**

This section discusses preliminary remediation goals (PRGs) and suggested approaches to achieving those goals. The discussion on the five types of PRGs considered seems appropriate (i.e. reduction in WP concentrations, hot spots, waterfowl acute effects, waterfowl chronic effects and effects in other species). However, the following section which appears to discuss the "approaches" to achieving the five PRGs is confusing. The four items highlighted here (dabbling duck mortality, hot zone, treatment verification and other impacts) are **not** PRGs. For instance; A PRG of elimination of WP exposure pathway might be chosen. Then a treatment option such as Aquablok™ might be selected to meet the PRG of elimination of the exposure pathway. The measurement of the success of that treatment option would be a measure of the success of meeting the PRG. In other words, what is the treatment designed to *accomplish?*. (i.e. Is the treatment designed to reduce hot spots? Is the treatment designed to eliminate an exposure pathway?)

16. **Page 10-16, Section 10.3, Last Paragraph --**

The discussion on confirmatory monitoring as presented is confusing. The way this paragraph reads is that the confirmatory monitoring will help eliminate uncertainty with respect to site conditions. While elimination of uncertainty might be desirable, the primary purpose of confirmatory monitoring should be to confirm that the chosen remedial measures are successful in achieving the final remedial goals.

DEPARTMENT OF THE ARMY
U.S. ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE
5158 BLACKHAWK ROAD
ABERDEEN PROVING GROUND, MARYLAND 21010-5422

REPLY TO
ATTENTION OF

MCHB-DC-EHR (40)

16 APR 1997

MEMORANDUM FOR Commander, U.S. Army Engineer District, Alaska,
ATTN: CENPA-EN-EE-AI/Ms. Joann Walls, P.O. Box 898,
Anchorage, AK 99506-0898

SUBJECT: Draft Final Remedial Investigation Report Operable Unit C, Fort Richardson, Alaska, February 1997

1. The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) reviewed the subject document on behalf of the Office of The Surgeon General. Comments and recommendations are enclosed for your consideration. Due to the significant changes to the sections dealing with preliminary remediation goals, we have reserved our concurrence until we can review your responses to our comments. Please provide one copy of responses to comments and the revised document.

2. The following scientists reviewed the subject document: Dr. Coleen Weese, M.D., Occupational and Environmental Medicine Program; Dr. Janet Whaley, Health Effects Research Program; and Mr. Matthew McAtee, Environmental Health Risk Assessment and Risk Communication Program. Our point of contact is Mr. McAtee who can be reached at DSN 584-2953 or commercial (410) 671-2953 and via the internet at Matthew_McAtee@chppm-ccmail.apgea.army.mil.

FOR THE COMMANDER:

Dennis E. Druck

Encl

DENNIS E. DRUCK
Acting Program Manager, Environmental Health
Risk Assessment and Risk Communication

CF:
HQDA(DASG-HS-PE) (wo/encl)
CDR, USAMEDCOM, ATTN: MCHO-CL-W (w/encl)
CDR, USARAK, ATTN: APVR-RPW-EV/W. Gossweiler (w/encl)
CDR, USAMC, ATTN: AMCEN-A/Mr. Pete Cunanan (w/encl)
CDR, USAEC, ATTN: SFIM-AEC-RPO (w/encl)
CDR, CEMRD, ATTN: CEMRD-ET-EH (w/encl)

Readiness thru Health

COMMENTS AND RECOMMENDATIONS
U.S. Army Center for Health Promotion and Preventive Medicine
Draft Final Remedial Investigation Report OU-C, Fort Richardson, Alaska, February 1997

1. Current PRGs Based Upon Unsupported Premise
Refer to page 10-4 and Figure 10-1, M. McAtee and C. Weese
Comment: The long-term biological and hot zone preliminary remediation goals (PRGs) are based upon an unsupported premise. The current risk assessment does not support the assumption that a 99% reduction in hot zone acreage is needed to achieve a reduction in dabbling duck mortality of 1% above natural mortality rates for the area. The information needed to make a connection between these two PRGs — the natural mortality rate, a quantitative relationship between hot spot area and Eagle River Flats (ERF) mortality rates, and estimates of measurement uncertainty and natural variability — is not yet available. This information is needed to justify the long-term hot zone remediation goal stated in the report (i.e., 99% reduction in hot spot area). The possibility that a more appropriate long term goal may be between 50 and 99% reduction in hot spot area must be acknowledged. For a 75% reduction in hot spot area may very well lead to a more significant reduction in mortality rate than the current investigation seems to suggest.
Recommendation: Provide better justification for the long-term PRGs.

2. Quantitating Uncertainty
Refer to page 8-22, Section 8.2.5, M. McAtee and C. Weese
Comment: It is stated that estimates of uncertainties (or confidence intervals) were not provided in the two reports, and that such an estimation would require that data be collected in such a way as to permit estimation of confidence intervals. It is not clear why such a value could not be calculated. The calculation of confidence intervals is a statistical procedure which is based on the variability of data points when compared with the mean. Quantitative uncertainty estimates should be calculated and considered in the development of the biological and physical remediation goals. This issue is important because important ERF data (especially mortality rates) are either inherently variable or highly uncertain. In fact, the long-term biological remediation goal (a mortality rate 1% greater than background) seems to ignore the natural variability in mortality (and other population dynamics) and the uncertainty in our ability to accurately measure hot spots and mortality rates. It is very possible that the overall uncertainty associated with the site may not warrant such an aggressive remediation goal, especially in light of two considerations: (1) the fact that we are not likely to be able to accurately measure a 1% difference in the mortality rate of these wild and dynamic populations, and (2) the current understanding that the uncertainty in the mortality rate measurement is approximately ±8% (page 10-5 of the report).
Recommendation: Quantitative uncertainty estimates should be calculated and considered in the development of the biological and physical remediation goals.

Encl

3. Effects Other Than Mortality Are Ignored in the Long Term Remediation Goals
Refer to page 8-16, Section 8.2.4.1 and page 10-2, and Table 10-1; C. Weese and M. McAtee

Comment: While it is agreed that few waterfowl chronic effects are specific for white phosphorus (WP) toxicity, the adverse reproductive effects may be possible to monitor. It is appreciated that this is more difficult than counting carcasses, and that the mortality is the most immediate concern. However, focusing on this single endpoint may be unnecessarily short sighted, in light of the 20 years expected for monitoring remedial success. It is stated that "mortality is considered to be the only significant effect of WP on ecological resources." Earlier in the document, it is stated that reproductive toxicology studies demonstrated decreased offspring production and teratogenesis with a multitude of adverse reproductive outcomes. Are these not significant effects? Doses for such effects are undoubtedly lower. Although it is understandable that the primary focus is on bird mortality, this clearly may not be the only outcome of significance in the long run.

Recommendation: It is recommended that other endpoints be considered in the development of the long term remediation goals.

4. Page 5-24, Section 5.10.2, C. Weese
Sediment

Comment: It is stated that "occasional shorebirds are found dead in ERF, and this receptor has been ranked as having a moderate hazard probability." Is there any baseline data available or attempt to quantify whether such deaths are above "usual" or "expected" rates?

Recommendation: Please clarify.

5. Page 6-4, Section 6-3, C. Weese
Site Investigation Plan

Comment: The comment in the left margin of this page incorrectly states that fieldwork was conducted in 1969.

Recommendation: Please correct.

6. Page 8-6, Section 8.2.1.2, C. Weese
Selection of Exposure Pathways, Exposure Routes, and Ecological Receptors

Comment: The rationale for risk to plants only from the singular compound di-n-butylphthalate is not clear. It is assumed that this is due to the lack of CTVs for other organic compounds.

Recommendation: Please clarify.

7. Page 8-8, Section 8.2.2.2, C. Weese
White Phosphorous Tissue Analysis

Comment: Results are not provided for the kestrel study to evaluate the effects of WP poisoning in secondary receptors. Were these of significance?

Recommendation: Please clarify.

8. Page 8-8, Section 8.2.2.2, C. Weese
White Phosphorous Tissue Analysis
Comment: The significance of results from a single tissue sample is not clear.
Recommendation: Although it is useful to provide all results of studies performed, no conclusions can be drawn from this data.

9. Page 8-10, Section 8.3.2.1, C. Weese
Field Studies
Comment: A reference is made to "low exposure rates" precluding strong conclusions about the mortality rate in 1995. However, following this, it is discussed that in 1995 there was higher duck use of the flats. Is this contradictory? What is meant by "low exposure rates?" Does this refer to low opportunity for exposure based on use of the flats, or low exposure concentrations?
Recommendation: Please clarify.

10. Page 8-20, Section 8.2.4.1, C. Weese
Risk Description
Comment: The percentage use of hot areas listed in the box to the left margin do not correspond with the values in the text, page 8-21, paragraph 4.
Recommendation: Please correct.

11. Page B-9, Section 2.2, C. Weese
WP Toxicity Assessment
Comment: The oral RfD for WP is stated once as $2x10^{-5}$ mg/kg-bw/day, and once as $2x10^{-6}$.
Recommendation: Please correct the discrepancy.

12. Page B-12, Section 4.0, C. Weese
OB/OD Pad
Comment: Please provide the date the information was extracted from IRIS, or the "version" utilized.

13. Appendix A, C. Weese
Comment: The section on field and laboratory studies does not discuss the findings of the reproductive studies.
Recommendation: Please include these.

DEPARTMENT OF THE ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY, CORPS OF ENGINEERS
HANOVER, NEW HAMPSHIRE 03755-1290

CECRL-GL

25 March 1997

MEMORANDUM FOR: District Engineer, U.S. Army Engr. Dist. Alaska, ATTN: CENPA-EN-EE-AI/ JoAnn T. Walls, P.O. Box 898, Anchorage, AK 99506-0898

SUBJECT: Comments on Draft Final Remedial Investigation Report, Operable Unit C, Fort Richardson, Alaska

1. Please consider the following comments and corrections. These are the consolidated comments from Marianne Walsh (MEW), Charles Collins (CMC), and Michael Walsh (MRW). Chuck Racine will be sending his comments on the environmental setting section separately.

p. X. P_4 is the molecular formula specifically for the white allotrope of elemental phosphorus. There are other allotropes of elemental phosphorus including red, black, and violet. (MEW)

p. X. P_4O_6 is not "phosphoric" oxide. Rather it is phosphorus oxide. Phosphoric implies oxidation state +5. You might consider using phosphorus(V) oxide for P_4O_{10} and phosphorus(III) oxide for P_4O_6. (MEW)

p. XI. RDX is "...-1,3,5-triazine" not ..." ...-1,3,5-triamine" (MEW)

p. ES-3. Not all white phosphorus munitions contain "plasticized" white phosphorus. In your discussion of plasticized white phosphorus on page 2-24 you reference Yon et al. 1983. Please note on page 20 of the Yon et al. report the list of white phosphorus munitions. Only the 4.2 inch mortar and 5-inch navy rocket contain plasticized white phosphorus. The most commonly used WP projectiles fired into ERF were 60- and 81-mm mortars and 105-mm howitzers, which do not contain the plasticized formulation. (MEW)

Table 2-4. Comp B is 60% RDX and 40% TNT with 1% wax added. (MEW)

p. 2-11, third paragraph, last sentence. Western channel of Eagle River has much reduced flow but is not completely abandoned. (CMC)

p. 2-23, third paragraph, second sentence. Change to "High Explosive (or HE) projectiles....made the craters, ... " (CMC)

p. 2-24-, first paragraph. Somewhere should add a sentence to clarify that WP smoke projectiles contain only a very small HE bursting charge and do not form craters upon impact. (CMC)

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p. 3-5, Figure 3-1. 1990 Activities. Change "Sampling augmented to include phosphate analysis" to "Sampling augmented to included white phosphorus (WP) analysis." Add "Analytical method for detection of WP in sediment modified and refined" and "Analytical method for detection of WP in tissue developed" (CMC)

p. 3-11. ESE work was not conclusive, as pointed out in para. 3-5 on this page. How can a "statistically significant relationship" exist without any corroborating evidence? ADEC data indicated otherwise as well. ESE did, however, rule out white phosphorus as a causative agent. (MRW)

p. 3-12, third paragraph. WP (P_4) is not a "compound" since it is not made up of two or more elements. Replace "compounds" with "chemicals" or other suitable term. (MEW)

p. 3-12., 3.1.4.1. Third paragraph, last sentence. Change "... was augmented to included testing for WP in sediment using a newly modified and refined analytical method."

p. 3-12. Last sentence in 3.1.4.1. Add the words "Aqueous soluble" before phosphate. Total phosphate was not determined, but would be expected to be quite high in all samples. (MEW)

p. 3-12. First sentence in 3.1.4.2. Field observations were actually made from an observation tower. While we referred to these towers as a "blinds" in some our early reports, the waterfowl would really need to be blind not to see a 10 m tall tower in the middle of the flats. (MEW)

p. 3-13, first word. Dartmouth Medical School conducted the toxicity studies, not CRREL. (MEW)

p. 3-13. First paragraph under 3.1.5.1. Method 7580 is in SW846 Update III (January 1995). (MEW)

pp. 3-13 to 3-14. Somewhere is this discussion you should mention that examination of aerial photographs for targets, craters and permanent ponds led to the sampling of Racine Island in August 1993. On our first visit, numerous waterfowl carcasses were found, and subsequent searches between August and October revealed 112 duck and one swan carcasses. WP was detected in several samples, and the concentration found in one sediment sample was over 3000 µg/g, the highest ever detected in by sampling along transects in ERF. (MEW)

p. 3-15 First paragraph under 3.1.5.3. Replace (CRREL, undated) with (Nam et al. 1994). (MEW)

Nam, S.I., B.D. Roebuck and M.E. Walsh (1994) Uptake and loss of white phosphorus in American kestrels. *Environmental Toxicology and Chemistry.* 13(4):637-641.

p. 3-18. Second paragraph. We feel that this overstates the effects of the erosion and deposition in the worst contaminated areas of ERF, the permanently ponded areas. Based on the projected rates of erosion of gullies into most of the worst contaminated ponds , it will take many years before ponds are significantly affected. Measured rates vary significantly from place to place and from year to year. (MRW)

Section 3.1.5.3 In this discussion USFWS has been substituted for PWRC. This substitution confuses the work done by USFWS (W. Eldridge), with that done by PWRC (Sparling et al.). Because institutional names change, you may want to use the actual name of the principal investigator. (MEW)

Section 3.1.6.1 1994 Studies. Add paragraph. CRREL study of the persistence of white phosphorus particles was conducted in 1994. Results of this study showed that planted WP particles were persistent in saturated sediments, but there was loss of WP in unsaturated sediments in ERF. Therefore natural attenuation is a viable remedial option for mudflats and intermittent ponds. (MEW)

p. 3-17. 1994 Studies. NEILE conducted mortality studies, not USFWS. (MEW)

p. 4-3, 1st Paragraph. Core samples were only taken in 1991 and 1992 before the practice was halted by EOD. Therefore the core data is limited and should not be extrapolated beyond its scope. (MRW)

p 4-4 First paragraph under 4.2. Particle masses ranged from 0.1 to 3.4 milligrams (mg), not micrograms (µg). You may want to update this information with 1996 data where a 150 mg particle was found in Racine Island sediment.

p. 4-7. Area A. You may want to consider the years when large numbers of carcasses were found in Area A. Were they found prior to cessation of firing of WP munitions? The maximum crater density in Area A is in the intermittent ponds. Prior to 1990, active firing of WP into these ponds would provide an abundance of WP particles to dabbling waterfowl. These intermittent ponds probably dried somewhat in 1990 and 1992, and most certainly during the summer of 1993 when there was an extended period between flooding tides and fairly warm, dry weather. While we have no direct evidence, significant loss of WP probably occurred in the summer of 1993 in the intermittent ponds of Area A. (MEW)

p. 4-13. Sec. 4.2.3, last para. Some post-dredging sampling occurred in Area C in 1996. (MRW)

p. 4-23. section 4.3.2. Change first sentence to "... WP concentrations (typically less than 0.01 µg/g ..."
Change next to last sentence to "These results indicate that WP-contaminated sediment is being transported through the gullies..." (CMC)

p. 4-26. Second paragraph of 4.5. Last sentence. Because the length of time that the sediments are unsaturated increases with increasing elevation, we may extrapolate the results from these two localized sites in Area C to conclude that natural attenuation is occurring at elevations equal to or higher than these two sites in Area C. These areas would include the mudflats and much of the intermittent ponds of Area C. (MEW)

p. 5-1-p.5.2. 1st para. of Sec. 5.2. Incorrect information on crater formation. WP smoke projectiles contain only a small HE bursting charge. They do not produce a crater when the projectile explodes. All of the 1 to 2 m diameter craters visible in ERF are produced by HE projectiles. (CMC)

Section 5.4 We have evidence that suspension of contaminated sediments with microgram quantities of WP may occur in ERF, but we have no evidence that milligram-size particles are suspended or transported. Figures 5-2 and 5-4 are misleading and should be eliminated. The title of Figure 5-3 should be "Transport of Contaminated Sediment." In the text, any mention of "particles" should be made quantitative by adding concentrations found. This includes discussions in 5.4.2, 5.4.2.1, & 5.4.2.2. See discussion below (CMC, MEW)

p. 5-11 Sec 5.4.2, last sentence, size of "small" particles should be quantified. Reference as given (USAEHA 1993) should be cited as (Bouwkamp 1993) as given in Section 11. However, Bouwkamp's stirring experiments were actually reported in USAEHA 1994 (or Bouwkamp 1994). The mean WP concentration of his stirring experiments was 0.13 µg/g for a 40 g sample. This concentration would be equivalent to the mass of a 0.1 mm dia. or smaller WP particle. This is significant smaller than 0.5 mm dia or larger particles that are of most concern. (CMC)

p. 5-6 Section 5.4.1.2: I have seen no evidence that "significant erosion, transport, and deposition" is occurring in areas where ducks are dying. All these mechanisms take place in and around gully heads, whereas the ponded areas see very little change. Deposition rates are very low in ponds, and consolidation of sediments is a long, slow process. My field experience indicates that over 20 cm of deposition must occur before significant consolidation begins to occur in the permanently ponded areas. The fine sediments that settle out are easily disturbed and penetrated by dabbling ducks, and are a rather poor barrier to access. If it was a significant mechanism, why are ducks continuing to die in ponded areas 8 years after the cessation of firing of WP?

In discussing gully sediment contamination, the report states that "Less than half the sample analyses were positive for WP...". Does that mean 40%, or 0.4%, and at what concentration. The concentrations data area all in the 0.1 µg/g or less range .

There is no mention as to how many sediment samples from ice blocks contained WP, and in what concentrations, so the significance of this information is unknown and overstated as presented. This whole topic of transport and deposition is quite misleading. (MRW)

p. 5-12, Sec.5.4.2.2 Size of WP that could be suspended should be quantified. Again, based on data available, sizes would be much less than 0.1 millimeters in diameter. Using the settlement equations employed in the settlement rate calculations for the dredge retention basin, settling time for a 0.1 mm ø particle in 11 cm of brackish water is less than a second. For finer particles, say 0.01 mmø, the settlement time is much greater, approaching 40 seconds. Therefore, the particles of concern, the WP particles greater than 0.1mm ø, will tend to sort towards the bottom of the sedimentation profile. (MRW)

Figure 5-5. P_4 is not "reduced"; P_4 has an oxidation state of zero. PH_3 is the reduced form. (MEW)

Table 5-1. The value and units for Henry's Law Constant should be 2.1×10^{-3} $(atm \cdot m^3)/mole$. Also, in the footnote, sub- and superscripts need correction: $H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}. (MEW)

Page 5-15. P_4O_6 forms phosphorous acid, not phosphoric. While phosphorous acid is the common name for H_3PO_3, the preferred name is phosphonic acid. (MEW)

p. 5-19. Section 5.6.3. First two paragraphs should be eliminated. (MEW)

p. 6-3, 2nd full para. That's the Route Bravo bridge, not Point Bravo.
Last para., some water level is available from these piezometers in the '95 and '96 ERF Contract Reports. (MRW)

Table 6-2. Underline and use bold for the word "Explosives". (MEW)

Table 8-2. Should read 4-amino-2,6-DNT. Superscript "c" seems to be misplaced. (MEW)

p. 8-5. 1st full sentence. Change to "...WP could be found in some <u>of the small ponds within</u> the Area C/D sedge marsh..." This is were the waterfowl are likely to feed and pick up WP. (CMC)

p. 8-14. Contradiction with pg. 7-16 on LD50 and LOEL rates. (MRW)

p. 8-15. More confusion over microgram vs milligram.
1 μL of WP X (1.82 mg/μL) = 1.82 mg or 1820 μg
To yield a concentration of 5 μg/kg would require:
1820 μg/(5 μg/kg) = 364 kg of sediment.
That's a lot of sediment. Something wrong here. (MEW)

p. 8-20. Second sentence. "The detected WP levels in bird tissues have been higher than corresponding WP levels in tissues from lethally dosed mallards in toxicity studies." How was this comparison made? Statistical test? You may want to give ranges of concentrations found to support this statement. You make this statement to draw the conclusion that "This information suggests that waterfowl can ingest sufficient quantities of WP in ERF to result in mortality." Direct support for this conclusion comes from the milligram quantities of WP found in the gizzards of some waterfowl. (MEW)

p. 8-20. 2nd full para. There have been many more disruptions to waterfowl at ERF in addition to the hazing and transects. The heavy use of helicopters by the physical dynamics group, the dredging activities, and the duck pens studies have all altered behavior of the ducks and swans. This appears to have a lesser effect on resident waterfowl than transient. (MRW)

p. 8-21. Another uncertainty is the actual cause of death of telemetry birds, especially during hunting season. (MEW)

p. 8-23. 2nd full para. "No trespassers have been observed." There have been several observations of boaters entering Eagle River on several occasions, even a few people leaving the boats for a short period of time and walking along the banks. Several rafters have missed the pullout above the Route Bravo bridge and have pulled out along the river below the bridge. In 1995 a small plane crash landed in ERF near the coast. Also, some ATV tracks were discovered in the coastal zone to the west of the mouth of the river. (CMC, MRW)

p. 9-3 Conclusion 4. Remove the word "plasticized". (MEW)

p. 9-3 Conclusion 6. WP particles will not readily oxidize at cold temperatures, even when exposed to air. The WP vapor pressure is not high enough to initiate oxidation. Revise as follows: "WP particles are readily oxidized when exposed to air at temperatures exceeding 20°C. Because they dissolve so slowly, particles have an ....." . (MEW)

p. 10-3 How did ERF being closed to access for part of the summer affect the accuracy of '96 mortality data? Could the '95 data, both transects and telemetry, be used to better refine mortality? (MRW)

p. 10-5. Section 10.2.1 Third paragraph. Remove the words "from WP exposure" unless cause of death is confirmed. Data for telemetry-measured mortality is

limited and incomplete. The dead birds were not autopsied to confirm the cause of death was WP-poisoning. Capturing these birds for tagging by pursuit with a helicopter must be quite stressful, and may be influencing the mortality rates as well. If telemetry is to be used as a measurement of mortality, it should be backed up confirming cause of death and by supplemental data from walking transects. (MRW)

p. 10-9 to 10-11. Based on your decision to include some of the C/D ponds as hot ponds, I suggest you add water depth as a criterion. Some of the C/D ponds are over 1 m deep, beyond the dabbling depth for ducks. The following quote from a paper on lead shot may prove useful:

> "Low *et al.* (1970) found that the maximum depth to which mallards *Anas platyrhynchos* can feed (water plus mud) is 40cm. They therefore suggested that to restrict them to the top 5 cm of sediment, 35 cm of water should be maintained."
>
> Quoted from: Pain, D.J. (1991) Lead shot densities and settlement rates in Carmargue Marshes, France. *Biological Conservation* 57 (1991) 273-286.
>
> Referencing: Low, J.B., G. Lind and R. Spry (1970) Lead shot. Its settlement, oxidation and general availability to waterfowl. Utah Cooperative Wildlife Research Unit, Utah State University, Logan, Utah, Special Report 23-A.
>
> I do not have the original reference, but it may have some information on feeding depths used by swans. (MEW)

p. 10-15. A map would be useful showing the locations of the intermittent ponds listed in Table 10-6. (MEW)

p. 11-1 to 11-6, Sec. 11. Some inconsistency between citations here and citations within the body of the report. (MRW, CMC)

p. A-10 Table 2-2. Same Table 8-2. Correct per comment for Table 8-2. (MEW)

p. A-13. Second paragraph. "The exposure route for shorebirds... have not been well documented..." Based on the mass of WP found in the gizzard contents of some shorebirds (15,500 µg or 15.5 mg in one phalarope), direct ingestion of WP particles from the sediments is certainly one exposure route. (MEW)

p. A-40. Table 3-5. The units for concentration should be µg/kg not mg/kg. (MEW)

p. B-6 to B-7 and Table 2-1. The data used in this section to estimate exposure to humans comes from a variety of sources, and the discussion apologizes for the uncertainties associated with the data. Recall that in 1991 we made similar exposure estimates based on data from five ducks we collected after they exhibited symptoms

of WP poisoning and subsequently died in ERF. This data was reported on page 57 of Racine et al. (1993) CRREL Report 93-17 and the corresponding contract report to USATHAMA in 1992. I do not think your conclusions will change if you use our data, but there is less uncertainty in our data. Also we specifically analyzed edible tissues. You state that "Only one or two measurements were available for muscle tissue..." Our data provide five measurements each for breast and thigh muscle. (MEW)

p. B-7, Table 2-1. What is the difference between pectoral and breast muscle? (MEW)

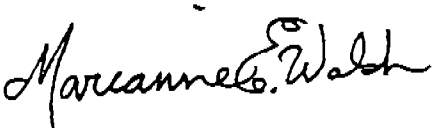
p. B-9. There is an inconsistency in the reported reference dose. The border caption reads $2X10^{-5}$, while the text reads $2X10^{-6}$. (MEW)

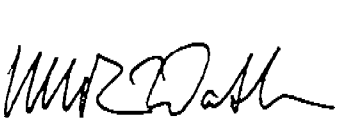
2. Thank you for the opportunity to comment. For questions regarding these comments, please contact any of us at the following:

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TABLE 2-1 Landcover
Hierarchical Classification of ~~Vegetation and Landforms in~~ ERF

I. Mud flat/distributary zone
   1. ~~Unvegetated~~ Sparsely vegetated mud flat (*Puccinellia ~~fultonii~~ nutkaensis, Salicornia europaea, Atriplex ~~gmelini~~ patula*)
   2. Vegetated mud flat
      a. Arrowgrass (*Triglochin maritima*)
      b. Plantain (*Plantago maritima*)
      c. Beach rye (*Elymus arenarius, Potentilla egedii*)
   3. ~~Gully~~ Tidal Creek banks/natural levees (*Elymus arenarius*)
   ~~4. Shallow ponds~~

II. Sedge meadow zone (old levees, pond borders)
   1. Ramenski's sedge (*Carex ramenskii, Triglochin mantima*)

III. Pond/marsh zone
   1. ~~Deep~~ Permanent ponds (>10 cm deep)
      a. Submerged aquatics (*Zannichellia palustris, Potamogeton sp., Ruppia spiralis*)
      b. ~~Swamp~~ *Hippuris tetragona* (*Hippuris tetragona*)
   2. Shallow ponds (~~<10 cm~~ Intermittent)
      a. (No aquatic vegetation)
      ~~b.~~ *Salicornia europaea, Triglochin maritima* (during drying cycle)
   3. ~~Bulrush~~ Sedge marsh
      a. Tall bulrush (*Scirpus validus*)
      b. Low bulrush (*Scirpus paludosus*)
      ~~c. Sedge marsh~~ (*Carex lyngbyei*) Lyngbyes sedge

IV. ~~Inner sedge meadow zone (*Carex lyngbyei; C. ramenskii*)~~ Interior Lowla
   2. Deep ponds 1. Sedge Meadow
   3. Bulrush marsh *Carex lyngbyeae*
V. Bordering shrub/spruce zone *C. ramenskii*
   1. Shrub-grass (*Myrica gale, Calamagrostis spp., Carex spp.*)
   2. Black spruce-sedge
   3. Floating sedge mat (*Carex pluriflora, C. mackenziei, C. lyngbyei*)

Source: Racine, in Racine *et al.*, 1994.

Add VI Coastal Zone
Marine algae (*Ulva sp*)
VII Riverine Zone

Tidal creek channels ~~Distributary channels~~ compose an important drainage system for ERF and connect ERF ponds to the main channel of Eagle River. These distributaries are probably formed by the movement of tidal water and runoff. While the distributaries near Eagle River have eroded deeply into the sediments to form gullies, farther away they form shallow, vegetated depressions that frequently reach back into ponds.

Natural levees occur along the edge of Eagle River and the larger distributary streams near Eagle River. Tall stands of beach rye grow on levees that are higher than 4 m above msl.

2.2.3.2 Sedge Meadow Zone

Old levees, set back from Eagle River, support dense stands of sedge lawn in a narrow band between the mud flat/distributary and pond/marsh zones.

2.2.3.3 Pond/Marsh Zone

Ponds and marshes receive upland freshwater and salt water from tidal flooding.

Behind the sedge meadow zone, there is a complex pattern of brackish ponds and marshes fed partly by fresh water from the uplands and partly by salt water from occasional tidal flooding. Shallow mud-flat ponds (3 to 15 cm deep) frequently become dry during certain times of the summer; deeper, permanent ponds vary in depth from 20 cm to more than 50 cm. Salinity in the permanent ponds varies from as much as 20 parts per thousand (ppt) on the shallow outer edge to less than 5 ppt near freshwater streams or springs. The permanent ponds support a variety of submerged aquatic vegetation as well as emergent vegetation. Dense stands of grasses, sedges, and shrubs grow on pond banks.

Marsh vegetation generally borders the ponds on the inland edge. Two types of marsh dominate ERF: the tall, coarse sedge marsh and the bulrush marsh.

2.2.3.4 Inner Sedge Meadow Zone

The upriver end of ERF, where Eagle River and Otter Creek enter ERF, is covered in a nearly continuous sedge meadow. The vegetation forms an almost impenetrable root/rhizome mat and the surface is only flooded during the spring tides.

Isolated ponds occur at a few locations in this zone and are always surrounded by a broad border of bulrush marsh inside the sedge marsh. Salinities in these ponds are only 2 to 4 ppt.

2.2.3.5 Bordering Shrub/Spruce Zone

Fresh water enters ERF around the edge from streams and springs, supporting vegetation radically different from the more salt-tolerant systems. The vegetation of this zone is diverse, ranging from floating sedge mats to low shrub vegetation and open spruce woodland.

TABLE 2-2
Bird Species Observed During Field Studies in May and August 1991-1992

Common Name	Species Name
Waterfowl	
Common loon	*Gavia immer*
Red-necked grebe	*Podiceps grisegena*
Horned grebe	*Podiceps auritus*
Tundra swan	*Cygnus columbianus*
Trumpeter swan	*Cygnus buccinator*
Greater white-fronted goose	*Anser albifrons*
Snow goose	*Chen caerulescens*
Canada goose	*Branta canadensis*
Mallard	*Anas platyrhynchos*
Green-winged teal	*Anas crecca*
American wigeon	*Anas americana*
Eurasian wigeon	*Anas penelope*
Northern pintail	*Anas acuta*
Northern shoveler	*Anas clypeata*
Blue-winged teal	*Anas discors*
Cinnamon teal	*Anas cyanoptera*
Canvasback	*Aythya valisineria*
Ring-necked duck	*Aythya collaris*
Greater scaup	*Aythya marila*
Lesser scaup	*Aythya affinis*
Barrow's goldeneye	*Bucephala islandica*
Common goldeneye	*Bucephala clangula*
Bufflehead	*Bucephala albeola*
Common merganser	*Mergus merganser*
Gulls and Terns	
Herring gull	*Larus argentatus*
Mew gull	*Larus canus*
Glaucous-winged gull	*Larus glaucescens*
Bonaparte's gull	*Larus philadelphia*
Arctic tern	*Sterna paradisaea*
Raptors	
Bald eagle	*Haliaeetus leucocephalus*
Northern harrier	*Circus cyaneus*
Merlin	*Falco columbarius*
Peregrine falcon	*Falco peregrinus*
Red-tailed hawk	*Buteo jamaicensis*
Rough-legged hawk	*Buteo lagopus*
Sharp-shinned hawk	*Accipiter striatus*
Northern goshawk	*Accipiter gentilis*
American kestrel	*Falco sparverius*
Short-eared owl	*Asio flammeus*

TABLE 2-2
Bird Species Observed During Field Studies in May and August 1991-1992

Common Name	Species Name
Shorebirds	
Sandhill crane	*Grus canadensis*
Semipalmated plover	*Charadrius semipalmatus*
Killdeer	*Charadruis vociferus*
Black-bellied plover	*Pluvialus squatarola*
Lesser golden-plover	*Pluvialis dominica*
Hudsonian godwit	*Limosa haemastica*
Whimbrel	*Numenius phaeopus*
Greater yellowlegs	*Tringa melanoleuca*
Lesser yellowlegs	*Tringa flavipes*
Solitary sandpiper	*Tringa solitaria*
Spotted sandpiper	*Actitis macularia*
Wilson's phalarope	*Phalaropus tricolor*
Red-necked phalarope	*Phalaropus lobatus*
Short-billed dowitcher	*Limnodromus griseus*
Long-billed dowitcher	*Limnodromus scolopaceus*
Common snipe	*Gallinago gallinago*
Ruddy turnstone	*Arenaria interpres*
Surfbird	*Aphriza virgata*
Semipalmated sandpiper	*Calidris pusilla*
Western sandpiper	*Calidris mauri*
Least sandpiper	*Calidris minutilla*
Baird's sandpiper	*Calidris bairdii*
Pectoral sandpiper	*Calidris melanotos*
Dunlin	*Calidris alpina*
Other Birds	
Belted kingfisher	*Ceryle alcyon*
Tree swallow	*Tachycineta bicolor*
Violet-green swallow	*Tachycineta thalassina*
Bank swallow	*Riparia riparia*
Rough-winged swallow	*Stelgidopteryx serripennis*
Cliff swallow	*Hirundo pyrrhonota*
Common northern raven	*Corvus corax*
Northern shrike	*Lanius excubitor*
Savannah sparrow	*Passerculus sandwichensis*
Lincoln's sparrow	*Melospiza lincolnii*
Lapland longspur	*Calcarius lapponicus*
Rusty blackbird	*Euphagus carolinus*

Source: Racine *et al.*, 1993.

Fox Sparrow
Song Sparrow
Robin
Bohemian Waxwing
Magpie

15 of

2.2.7.5 Other Birds

Other bird species that use ERF are listed in Table 2-2. Racine *et al.* (1993) notes that several species of swallows were observed in ERF during 1991 and 1992 field observations. Such species include violet-green, rough-winged, tree, bank, and cliff swallows, in abundance. Observers saw belted kingfishers fishing in the pools on the margins of ERF and rusty blackbirds in the bulrushes in May and August. According to Racine *et al.* (1993), the blackbirds may also breed in ERF. During the studies, savannah sparrows were common throughout the summer, and flocks of Lapland longspurs were common in August.

Common northern ravens also occur in abundance (Racine *et al.*, 1993). Six to eight ravens use ERF regularly. Ravens use dead ducks as their primary food resource, although they are subordinate to the eagles and are often chased away from carcasses.

The Eagle River is an anadromous stream used by king and red salmon.

2.2.7.6 Fish and Aquatic Invertebrates

About 300 to 500 naturally occurring king and red salmon pass through ERF annually on their way to spawn in small clear tributaries of the north and south forks of Eagle River. In 1990, the Alaska Department of Fish and Game (ADFG) released 100,000 king salmon fingerlings into the upper stretches of Eagle River in the hopes of establishing a king salmon sport fishery in Eagle River. This release is likely to produce about 3,000 returning salmon each year, which will also travel through ERF to return to Eagle River spawning grounds. The new sport fishery is currently restricted to sections of Eagle River east of the Glenn Highway (Quirk, 1991).

Dolly Varden trout also occur in Eagle River. Although the lower portion of Eagle River that passes through ERF supports limited rearing activity for salmon and Dolly Varden, it serves primarily as a migration corridor for adult salmon moving upstream (June to September) and juvenile salmon running to the ocean (mid-April to June) (Quirk, 1991).

Fish were sampled for WP analysis during 1993, but species were not identified in the report by Sparling (in Racine *et al.*, 1994). However, sticklebacks and sculpins were shown as potential food-chain components for fish-eating birds such as terns and kingfishers that feed in ERF. Overall, information on the distribution and abundance of fish in ERF is limited.

Benthic macroinvertebrates (bottom-dwelling aquatic insects, crustaceans, and other invertebrates) were collected during 1993 at several pond locations in ERF and at two reference locations in Goose Bay (Sparling, in Racine *et al.*, 1994). Macroinvertebrates also were collected from ERF distributaries where ponding occurred at low tide. The organisms were sorted, identified to species when possible, and

Bowerkamp mentions both types of sticklebacks

20-30 pond + tidal creek

1993 + 94

July 93 20 sites 23 May 94

Bowerkamp

counted to determine diversity (H), species richness, percent contribution of dominant species, and similarity between samples. The benthic macroinvertebrate populations included six or fewer species at each sample site. Typical benthic macroinvertebrates found at the various sampling locations included annelid worms (Oligochaeta), amphipods, and insects, including mainly dipterans (Chironomidae, Ceratopogonidae, Ephydridae, and Muscidae). Other sampling for macroinvertebrates to be analyzed for WP during 1993 included collection of dragonflies and damselflies (Odonata), midges, and brineflies (Diptera), beetles (Coleoptera), snails (Gastropoda), and amphipods (Amphipoda) that were sufficiently abundant for analysis. Odonates were more frequently caught, followed by midge larvae and snails.

Beluga whales feed on salmon in Eagle Bay and in the Eagle River.

2.2.7.7 Other Wildlife

In addition to birds, moose and coyotes frequent ERF. Black bears are occasionally observed in ERF in summer. Smaller mammals that use the flats also include beaver, muskrat, mink, weasel, wolverine, red fox, lynx, and numerous rodents (Quirk, 1991). In August, wood frogs thrive in ERF, where they comprise a major food source for sandhill cranes (Racine *et al.*, 1993).

Beluga whales have been observed entering the mouth of a drainage slough in the northwest corner of ERF, near the mouth of both Eagle River and a large drainage slough to the north, as well as close to the shoreline throughout Eagle Bay and approximately 1-1/4 mile up Eagle River. Sightings have occurred from June to the end of October. Whales have been observed vigorously chasing salmon up drainages along the river bank (Gossweiler, undated).

ERF is the only ordnance impact area for Fort Richardson; OB/OD Pad was formerly used as an explosive ordnance disposal site

2.3 Land Use

2.3.1 Military Land Uses at ERF

ERF is the only impact area for heavy artillery and mortars on Fort Richardson. Approximately 40 derelict cars and trucks have been placed individually or in groups as targets around ERF, as shown in Figure 2-5. U.S. Army personnel practice firing at the targets from more than 25 points, located at distances of up to 10 km (Racine *et al.*, 1992b).

OB/OD Pad is a 4-ha clearing with a 2-ha gravel pad constructed at least 20 years ago along the east side of ERF. Although no longer used to detonate outdated munitions, demolition of propellants on this pad apparently contaminated an area of the salt marsh in ERF (Racine *et al.*, 1992b). Three general types of munitions have been fired into ERF. These include high explosives (HEs), smokes, and illumination flares (Racine *et al.*, 1992b). Table 2-4 lists the munitions and corresponding

AGLE RIVER FLATS at E R FLATS FTR RICHARDSON, AK

File: OPUCERF.DBF

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-409	FERRELL	EN-G-MI	INH	ES-5		1

"Hot pond" needs to be defined. The partial paragraph at the top of the page refers to monitoring activities described above. The monitoring activities need to be or clarified or referenced so they can be found.

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-410	FERRELL	EN-G-MI	INH	df 1-3	para 1.2.1	2

Paragraph 1.2.1 seemingly fixes the cause of any ERF contamination as use for an ordnance impact area. The bullet on that page says that use of the OB/Od propellent demolition caused the contamination ..of ERF. (It's true only for a very small portion of the contamination at ERF.)

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-411	FERRELL	EN-G-MI	INH	df 2-1	p 2.1.2.	3

The extreme cold temperature of -18 C seems too warm.

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-412	FERRELL	EN-G-MI	INH	df 3-14		4

The physiologic mechanism of white phosphorous toxicity needs to be addressed. The mechanism for activitating WP may well destroy environmental persistance

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-413	FERRELL	EN-G-MI	INH	df 3-18		5

This section, 3-18, points out that WP concentrations measured lower in the same areas from one year to the next. The figures in section 4 need to show that decrease in WP concentrations or at least the time when the measurements were made. Although different areas were sampled in different years, (strict comparisons would be very difficult.) some comparisons from one year to the next would permit a more rational evaluation of remediation needs and the results of remediation actions. Such presentation would also clarify surport for the conclusions on page 4-26.

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-414	FERRELL	EN-G-MI	INH	df 4-14		6

Consistency in the use of symbols would help readability of figures. Fig. 4-13 lists symbol X for surface and cored samples. (surface and cored together?) This could be considered ambiguous. Fig 4-14 lists X to mean water. Is the change necessary?

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-415	FERRELL	EN-G-MI	INH	df 5-1		7

Not necessarily contrary to the statement in para 5.2 WP particles smaller than a critical size settle very slowly or for some purposes not at all.

AGLE RIVER FLATS at E R FLATS FTR RICHARDSON, AK.

File: OPUCERF.DBF

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-416	FERRELL	EN-G-MI	INH	df 5-2		8

Some where in the discussion of WP particles, munitions residue, varying ballistic properties depending on particle size needs to be addressed to provide for the fact that large particles travel greater distances, from kinetic energy, than do the smaller particles of identical material at identical starting velocities. The reverse is true for particles carried by air or water currents.

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-417	FERRELL	EN-G-MI	INH	df 5-5		9

The resistance to photolysis is fact as stated and WP does persist at ERF. However: WP is converted to red phosphorus by exposure to sunlight. The environmental persistence of WP should not be based on errors in fact.

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-418	FERRELL	EN-G-MI	INH	df 5-6		10

Additional emphasis is needed on the fact that the single most important factor influencing particle transportation is the size of the particles.

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-419	FERRELL	EN-G-MI	INH	df 5-14	Tbl-5	11

The footnotes to this table contain typos.

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-420	FERRELL	EN-G-MI	INH	df 5-15		12

The paragraph on phosphates raises the problem of agal blooms. Have such excess algae occurred at ERF? Could such excess occur? Why is this information included?

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-421	FERRELL	EN-G-MI	INH	df 5-16	Pa.5.6.1	13

Probability is normally used as a ratio. It needs detailed definition for the usage in this section. Hazard probability is used almost as one word. Additional definition is needed. High hazard probability, Medium probability, and low hazard probability need some bounds of meaning. What is the difference between each?

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-422	FERRELL	EN-G-MI	INH	df 5-19	Pa.5.6.2	14

The next to final sentence in the first paragraph of this section contains typos? The availability of WP in sediment, for ingestion or dermal contact, is not proven or supported by this paragraph.

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
7068481-423	FERRELL	EN-G-MI	INH	df 5-23	Pa.5.10.2.	15

Perhaps the reason, for ingestion of particles is not relevant regards toxicity, but such information might be usefull for controlling exposure.

Would a supply of gizzard grit help protect the waterfowl or make the situation worse?

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File: OPUCERF.DBF

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post It
7068481-424	FERRELL	EN-G-MI	INH	df 5-24	Pa.5.11.	16

Is there any data relevant to the continued toxicity of WP toxicity after digestion by waterfowl.

7068481-425	FERRELL	EN-G-MI	INH	df 8-15		17

Reference to the laboratory exposure and death of Hyalella and Chironomus should be deleted or expanded to include the life expectancy of the creatures.

7068481-426	FERRELL	EN-G-MI	INH	df 9-5	par 9-2	18

The recommendations listed need to include specific actions that will reduce or eliminate the risks found. Section 10 referenced here needs to include specific actions.

7068481-427	FERRELL	EN-G-MI	INH	df 10-1	par 10.1	19

The third bullet has a "Preliminary Remediation Goal as an absolute value". Then addresses a reduction. Please clarify. Much of chapter 10 is rerun of items included else where in the report. References rather than statements could be used.

7068481-428	FERRELL	EN-G-MI	INH	df 10-10	tbl. 10-5	20

Where WP has been demonstrated the date of sample needs to be included.

7068481-429	FERRELL	EN-G-MI	INH	App-43	tbl. 3-6	21

This table needs to include controls and blanks.

7068481-430	FERRELL	EN-G-MI	INH	A-76	3.3.2	22

Much of the discussion in not clear. Specimens versus species needs to be made clear. The observers should all be trained to recognize species and identify what species the available specimens represent. Difficulties in observing individual specimens will result in a few unavoidable errors.

RL .EW
COMMENTS PROJECT:Draft Final Remedial Investigation Report
LOCATION: Operable Unit C, Fort Richardson, Alaska

U.S. CORPS OF ENGINEERS CENPA-EN-EE-TE	DATE: REVIEWER: Marlowe Dawag PHONE:753-2872	ACTION TAKEN BY:_____	
	COMMENTS	A - ACCEPTED N - NOT ACCEPTED W - WITHDRAWN	ACTION TAKEN
ITEM NO.	section, pg., para.		
1	General	Liked the use of the margins for "key points" of each section/page.	
2	Fig 3.1	Liked the format of the timeline, however print of "Milestones" is too light. Suggest darkening print.	
3	Table 3-2	Under Bird Behavior/Characteristics- "...and behavior during nonhazing birds." This did not make sense. Suggest inserting the word "of" between "nonhazing" and "birds".	
4	Fig 4-1	A bit difficult to differentiate the solid shapes especially when they overlap.	
5	Sect. 4.2 para 4	Text in this paragraph states area B shows no locations w/ detectable WP. However, Fig 4-1 does show a few locations w/ detectable WP within area B. This may be due to the small print of the characters used to depict "hits". If possible, please clarify.	
6	Sect 4.2.4 para 2	"Sampling was conducted area C/D...". Please insert the word "in" between "conducted" and "area".	
7	Sect 5.4.3 pg 5-14; 1st line	Delete 2nd "oxide" in "...Phosphorus pentoxide oxide..."	

OUC 0029825

ITEM NO.	section, pg., para.	COMMENTS	A - ACCEPTED N - NOT ACCEPTED W - WITHDRAWN	ACTION TAKEN
8	Pg. 6-4 Margin Text	"...the field work in 1969 were..." Should the year be 1996? Please correct.		
9	Sect. 6.6	This CSM section is not as clear as the CSM for the ERF. Suggest describing the source, release/transport mechanism, exposure medium, exposure route and receptors, if applicable.		
10	pg. 8-18 3rd para.	"These studies were not conducted..." What health and safety concerns arose in 1996 preventing the collection of data? UXO? Continuation of artillery practice?		
11	pg. 8-32 2nd para	"...and ingests 200 and 100 mg of sediment, respectively, of sediment..." Delete 2nd "..of sediment.."		
12	pg. 9-2 2nd para	Change "Opening burning" to "open burning".		
13	pg. A-52	What new health and safety requirements? Suggest specifying the requirement or the source.		
14	pg. A-66 2nd para	This statement doesn't make sense; "...only four eggs hatched...These may not have been affected by WP because they were no longer connected to the hens' circulatory system." Wouldn't all the eggs, once laid, be disconnected from the hens' system? Hatching may be attributed to factors relating to the incubation of the eggs or factors relating to the concentration of WP in the eggs; it is difficult to determine the exact cause. It may be more valid to state that the specific explanation for the eggs hatching is unknown.		

OUC 0029826

ITEM NO.	section, pg., para.	COMMENTS	A - ACCEPTED N - NOT ACCEPTED W - WITHDRAWN	ACTION TAKEN
15	Sect 10-1 1st bullet	2nd sentence. Suggest editing into shorter sentences.		
16	pg. A-23 2nd para	Check percentages stated; particularly the 29 percent figure.		
17	pg. A-59	The percentages stated in the first paragraph do not match those stated in the margin text. Suggest reconciling the percentages.		
18	pg. A-77 2nd para	"The reasons for the failure..." Suggest examples of possible factors attributed to the failure.		
19	Table 4-1 Appendix A	The values in listed for mortality ratio columns for "All ERF" and the OB/OD pad are confusing to read due to the parentheses and breaks in between digits. Please correct.		
20	pg. B-8 Margin Text	If one just reads this text alone, it would seem irrelevant to the context of the report. Please insert "used in this assessment" in the text.		

OUC 0029827

HTRW-CX COMMENT TRANSMITTAL

03/19/97

Comments Transmitted to		Commander, Alaska District
	Attention	CENPA, Joann Walls
	Submittal #	004770 · 64662
	Action	Comments are transmitted with this record.
Project Information	Location	Fort Richardson
	Site	Eagle River Flats
	Project	Operable Unit C
	Doc Title	Draft Final Remedial Investigation Report, Operable Unit C (OU-C), Fort Richardson, AK.
	Phase	Draft Final
	Designed by	Ch2m Hill, Anchorage

DISCIPLINE	ACTION[1]
Chemistry	NC
Compliance	RCA
Cost Engineering	NT
Geotechnical	NC
Health & Safety	NT
Health Physics	NT
Innovative Tech	NT
Process Engineer	NT
Risk Assessment	NC

SIGNIFICANT OR UNRESOLVED TECHNICAL COMMENTS

REQUESTED ACTION

To further our understanding of the issues that affect this project and your district's execution, please provide this office a copy of annotated responses to comments made by your office, other agencies and interested parties.

HTRW-CX Point of Contact

Robert Curnyn
Telephone: (402) 697-2625

Transmittal of comments approved by:

Donald L. Ohnstad, P. E.
Chief, Environmental Studies
and Llaison Branch

[1]NC = Reviewed; No Comments
NT = No tech involvment
RCA = Reviewed, Comments Attached
CT = Conferred/Deferred to District Counterpart
SCA = Reviewed w/Significant Comments attached

[X] CENPA-EN-EE-Al Joann Walls
[ ] NPD
[ ] CEMRO-HX-S Robert Curnyn
[ ] CEMRO-HX-S (Files)

64662: OU-C RI Report at Ft Richardson, AK - Dra

Temp ID	Last Name	Office Symbol	Discipline	Page/Sheet	Room Dtl	Post IT
647583-67	FRYE	CEMRO-HX-T	ENV	Sect. 7.2.1	Page 7-5	

Federal CWA Ambient Water Criteria are not ARARs as they are not legally enforceable standards. However, for OU-C, the ADEC water quality regulations would be ARARs. Please correct Table 7-1 and the text accordingly.

The ADEC Hazardous Waste Management Regulations are listed as potential chemical-specific ARARs. Both hazardous and solid waste regulations are not going to be chemical-specific ARARs, but rather action-specific, as they do not come into play until such action occurs that results in the generation of solid and/or hazardous waste. Please put solid and hazardous waste regulations into the action-specific ARAR section.

As of 1 July 1996, ADEC no longer manages its hazardous waste program. A memo to EPA from ADEC Division of Air and Water Quality in 1996 stated that due to funding and resource shortages, the State would no longer be in the hazardous waste management business and that Federal RCRA requirements would be implemented under the authority of EPA Region X. Please remove the ADEC hazardous waste regulations from the list of ARARs and add the Federal RCRA regulations thereto.