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Cold Regions Research and Engineering Laboratory

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Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska

FY10 Data Report

Marianne E. Walsh and Charles M. Collins, Report Editors

JULY 2011

Cover photo: View of Eagle River Flats from Site Summit, Fort Richardson on 12 September 2003. Photo by Michael R. Walsh.

REMEDIATING AND MONITORING WHITE PHOSPHORUS CONTAMINATION AT EAGLE RIVER FLATS (OPERABLE UNIT C), FORT RICHARDSON, ALASKA

FY10 DATA REPORT

JULY 2011

Prepared for

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TABLE OF CONTENTS

I. EXECUTIVE SUMMARY .... 1 - 5

II. RISK ASSESMENT

II-1. Waterbird Use of Eagle River Flats from Aerial Surveys, April–October 2010 .... 7 - 24

II-2. 2010 Ground-based Waterfowl Mortality Surveys .... 25 - 46

III. REMEDIATION AND MONITORING STUDIES

III-1. Eagle River Flats Remediation Operations .... 47 - 55

III-2. Sediment Sampling and Monitoring for White Phosphorus .... 57 - 92

III-3. 2010 Weather Data for Eagle River Flats .... 93 - 103

I. EXECUTIVE SUMMARY

INTRODUCTION

This is the twenty-first annual contract report prepared by researchers from CRREL and other Federal agencies for the U.S. Army Garrison Fort Richardson, Public Works (now Joint Base Elmendorf Richardson, Alaska). The report describes results from research, remediation, and monitoring efforts addressing white phosphorus (WP) contamination in Eagle River Flats, an 865-ha estuarine salt marsh on Fort Richardson, Alaska. Fort Richardson is on the National Priority List, and Eagle River Flats (ERF) is designated Operable Unit C under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

Over the five-year period from 1999–2003, full-scale remediation was conducted at Eagle River Flats using six remote-controlled pumps to temporarily drain contaminated ponds, allowing the sediments to dry and the white phosphorus to sublime and oxidize. This effort successfully remediated about 90% of the ponds. From 2004–2007, limited remediation using one or two pumps was conducted to address the few remaining white-phosphorus-contaminated areas, mainly in the Northern C marsh area on the east side of Eagle River Flats. Then during February 2008 and again in March 2009 the majority of the remaining small areas of white phosphorus contamination were capped. Capping operations were conducted by hauling gravel over the thick ice cover that forms nearly each winter. Gravel was spread approximately 60 to 80 cm thick over a geotextile layer laid out on the ice over the contaminated area. When the ice cover melted later in the spring, the gravel cap settled, covered and capped the contaminated sediment.

Long-term monitoring, which includes sediment sampling, waterfowl aerial census flights, and ground-based waterfowl mortality surveys have been used to determine the effectiveness of the remediation. The monitoring has shown that the 20-year Remedial Action Objective of less than 1% of the fall dabbling duck population dying from white phosphorus poisoning has been achieved during each of the previous five years, although mortality was elevated in 2009 compared to the previous three years.

At the end of 2009, Fort Richardson merged with Elmendorf Air Force Base to form Joint Base Elmendorf Richardson (JBER). Future monitoring activities at OU-C will be under the direction of JBER Environmental personnel.

II-1. WATERBIRD USE OF EAGLE RIVER FLATS FROM AERIAL SURVEYS, APRIL–OCTOBER 2009

Dennis K. Marks and William D. Eldridge

U.S. Fish and Wildlife Service conducted 28 aerial surveys from 15 April to 19 October, 2010 to monitor waterfowl use within Eagle River Flats during the spring, summer, and fall. By the end of April, the majority of pond surfaces were completely clear of ice. Ponds began freezing by October 8 and were mostly frozen by mid to late October. Observers counted or estimated waterfowl numbers and recorded the numbers categorized by species or species group and by location on ERF using standardized study areas. As in past years, waterfowl counts on ERF in 2010 showed a small peak in mid-late April and early May whereas the major influx of waterfowl began late July to early August and peaked mid August to late September. Species composition for all birds surveyed in 2010 was comparable to that of previous years. Mallards (*Anas platyrhynchos*), northern pintail (*A. acuta*), and American wigeon (*A. americana*) accounted for more than 91% of all dabbling ducks recorded. Average number of ducks for all months surveyed in 2010 was higher than previous years and averaged 725 ducks/survey (582, 641, 578 and 670, for 2006-2009). For fall 2010, the average number of ducks observed was 993/survey; the counts for previous years were 912, 981, 837 and 904/survey for 2006-2009. High count for any survey was 2,601 ducks on 24 August. In fall, 84 percent of all duck observations were identified to 46 specific ponds and, as seen in previous years, the permanent ponds of areas A, CD and D were especially important to ducks. Areas C, Coastal East and Coastal West were relatively more important after flooding occurred in early fall. Swan numbers peaked in late September at 106 individuals; they were primarily observed, frequently with cygnets, on ponds in areas D and B, though small groups were also consistently observed on ponds in area CD. Fall goose migration was similar to other years with the main influx of geese arriving in mid to late August and persisting through mid October. Canada geese accounted for 94 percent of fall geese.

II-2. 2009 GROUND-BASED WATERFOWL MORTALITY SURVEYS

Charles M. Collins, Marianne E. Walsh, and Ann Staples

Ground-based surveys were again conducted in 2010 to determine waterfowl mortality. A core group of transects, in areas with known remaining white phosphorus contamination and other areas most frequented by waterfowl, was surveyed at least three times a week over the fall migration period (mid-August to mid-October). These transects covered the marshes of northern Area C and eastern BT Area and the major waterfowl feeding ponds in Area C. Other transects in remediated areas with waterfowl use and in areas with no known contamination were surveyed less frequently. During the mortality surveys conducted from 18 August to 15 October 2010, eight carcasses and fourteen feather piles were found along the surveyed transects. Gizzards were collected from all eight carcasses and all eight tested positive for white phosphorus.

If all mortalities are attributed to white phosphorus poisoning, the estimated mortality rate in 2010 was 0.4% of the fall dabbling duck population. Estimated rates in the previous years were 0.9% in 2009, 0.3% in 2008, 0.7% in 2007 and 0.6% in 2006. Given the uncertainty associated with these mortality rate estimates, all five years are below or not significantly different from the 20-year Remedial Action Objective of less than 1% of the fall dabbling duck population dying from white phosphorus poisoning. Mortality rates were 2.3% in 2005 and 3.0% in 2004, prior to the completion of pumping remediation.

III-1. EAGLE RIVER FLATS REMEDIATION OPERATIONS

Michael R. Walsh, Arthur B. Gelvin, and Stephanie P. Saari

The 2010 field season was the sixth year of the monitoring phase of the Eagle River Flats project as set out in the Record of Decision signed October 1998. In 2008, we transitioned from active remediation to capping, with pumping occurring only to provide a safer working environment for the sampling and monitoring projects. We continued this activity during the 2010 summer field season. All logistics except fuel were handled by CRREL. Once again, no helicopter support was required by the project, saving the project a substantial amount of funds.

System 3, the large, 189-L/s (3,000-gpm) shore-based unit was reinstalled in the sump connected to Pond 146. Installation of this system requires no helicopter support. Most of the discharge line remained in place over the winter so installation was relatively straightforward. The lengthening of the Spur Road extension was critical for the installation process as low water levels required us to place the pump further into the sump than in previous years. The system was activated at 189 L/s on 14 May. Minor problems were corrected on 15 May and the site was pumped down by the afternoon of 16 May. On 24 May, the pump was shut down for the summer.

September flooding tides commenced on the 7th and ended late on the 12th. The pump system was reactivated on 16 September and run through 20 September in support of the sampling effort. We ran out of fuel on 20 September, primarily because we lost approximately 300 gallons of fuel over the summer due to fuel theft. After shutdown, we shortened the power and control cables to facilitate installation in 2011. The mobile fuel tank was drained and cleaned out. Over five gallons of water and sludge were removed from the bottom of the tank. General maintenance was performed on the pumps and genset prior to storage. The pumps and the double-walled fuel tank were moved to the Conex storage area on the EOD pad. The genset and mobile fuel tank was stored at the Environmental yard, and the containment structure was cleaned, dried, and put in storage in a

Conex in the 992 yard. All pumps except the System 3 pump are now in the 992 yard.

Overall, this was a good season. Pumping of the areas in which sampling occurred enhanced mobility and safety. We are now able to operate without helicopter support. Although the equipment is showing its age, we are still able to operate sufficiently to support the sampling efforts at the Flats.

III-2. SEDIMENT SAMPLING AND MONITORING FOR WHITE PHOSPORUS

Marianne E. Walsh, Ronald N. Bailey, Michael R. Walsh, Charles M. Collins, and Jeff Bryant

Sampling of sediment was performed in Eagle River Flats in May and September of 2010 to meet the same objectives as in the past few years.

1. Assess continued clean status of ponds previously remediated using pond pumping. Determine if there is a rebound in contamination due to exposure of buried white phosphorus (WP) residue.
2. Determine if the gravel caps placed over isolated small areas of white phosphorus contamination completely covered the white phosphorus-contaminated sediments.
3. Locate any remaining small areas of white phosphorus contamination not previously identified.

White phosphorus was undetectable in most of the ponds that previously contained hot spots of white phosphorus and where the surface sediments were decontaminated by pond pumping or ditching (e.g. Area C Ponds 183, and 171; Bread Truck Pond 109). Pond 155 in Area C had detectable white phosphorus. Low concentrations were also detectable in two ponds in Area A.

The perimeter of gravel caps were sampled, and four caps were designated for expansion because of the presence of white phosphorus and of standing water that could serve as waterfowl feeding habitat.

Samples were collected from Pond 730, the drainage channels in Area C, and in previously unsampled water-covered areas on Racine Island to locate remaining white phosphorus hot spots. White phosphorus ordnance scrap was found in the southwest arm of Pond 730, and the sediment co-located with the scrap had high white phosphorus concentrations. A temporary geotextile/gravel cap was placed over the contaminated sediment. No additional white phosphorus was found within the drainage ditches of Area C, but two more water-covered areas on Racine Island did have white phosphorus. Capping or draining may be needed if waterfowl mortalities continue after all other known contaminated areas are capped.

Ordnance scrap continues to erode out the bank of Coastal East and Coastal West. A 4.2-inch white phosphorus mortar projectile was detonated by EOD in a gully near the river mouth May 2010. A protocol is needed to safely dispose of ordnance items that are found along the inlet so that contamination is not introduced into the river or inlet.

III-3. 2010 WEATHER DATA FOR EAGLE RIVER FLATS

Charles M. Collins, Chris Williams, and Tommie Hall

The Eagle River Flats meteorological station monitored the local wind speed and direction, air temperature, radiation, relative humidity and precipitation from 20 May to 19 September 2010. In the fall, instruments for precipitation were removed, but other measurements were continued over the winter.

Temperatures in Eagle River Flats were normal for June and below normal for July and August. Only 25 days had maximum temperatures reaching 20°C or higher. This compares to 2009 when 41 days reached 20°C. During the period of full-scale remediation from 2001-2007, each of the seasons had between 37 and 67 days of 20°C or higher.

Precipitation was above normal for June and July and normal for August. Both the evaporation and radiation data shows the persistent cloud cover for most of the summer with few long periods of clear skies.

II-1. WATERBIRD USE OF EAGLE RIVER FLATS FROM AERIAL SURVEYS, APRIL–OCTOBER, 2010

Dennis K. Marks and William D. Eldridge
U.S. Fish and Wildlife Service, Anchorage, AK

INTRODUCTION

Aerial surveys to monitor waterbird use of Eagle River Flats (ERF) during the spring, summer, and fall of 2010 were conducted by the U.S. Fish and Wildlife Service as part of the ongoing mortality and monitoring studies sponsored by the U.S. Army at Fort Richardson, Anchorage, Alaska. The purpose and history of these investigations have been presented elsewhere (Racine and Cate, Eds. 1996).

STUDY AREA

Eagle River Flats is a 870 hectares (ha) salt marsh complex on the south side of Knik Arm, approximately 10 kilometers (km) east of Anchorage. Sedge marshes, permanent and temporary ponds, mudflats, river channels and sloughs provide ample habitat for the fish and invertebrates, emergent and upland plants needed to support the more than 100 species of birds found on ERF (Steele et al. 2003). A detailed description of this area is presented in Racine and Brouillette (1995).

METHODS

Aerial surveys of ERF were flown from 15 April to 19 October, 2010. Surveys were scheduled to be conducted once a week in spring, twice a month during summer and twice a week in fall, and were flown with a fixed-wing aircraft at an airspeed of 130 to 170 km/hr and an altitude of 30 to 75 m. Total coverage of ERF was obtained by overlapping transects. Numbers of waterbirds were counted or estimated and recorded by species or species group with a voice recorder; bird numbers were classified by locations on ERF using standardized study areas developed for the ERF database by the Cold Regions Research and Engineering Laboratory (CRREL, Fig. II-1-1). Areas (ha) of permanent and intermittent ponds and standardized areas were obtained from digitized maps provided by CRREL and used to convert bird numbers to densities within the study areas. When possible, waterfowl were recorded by individual ponds within

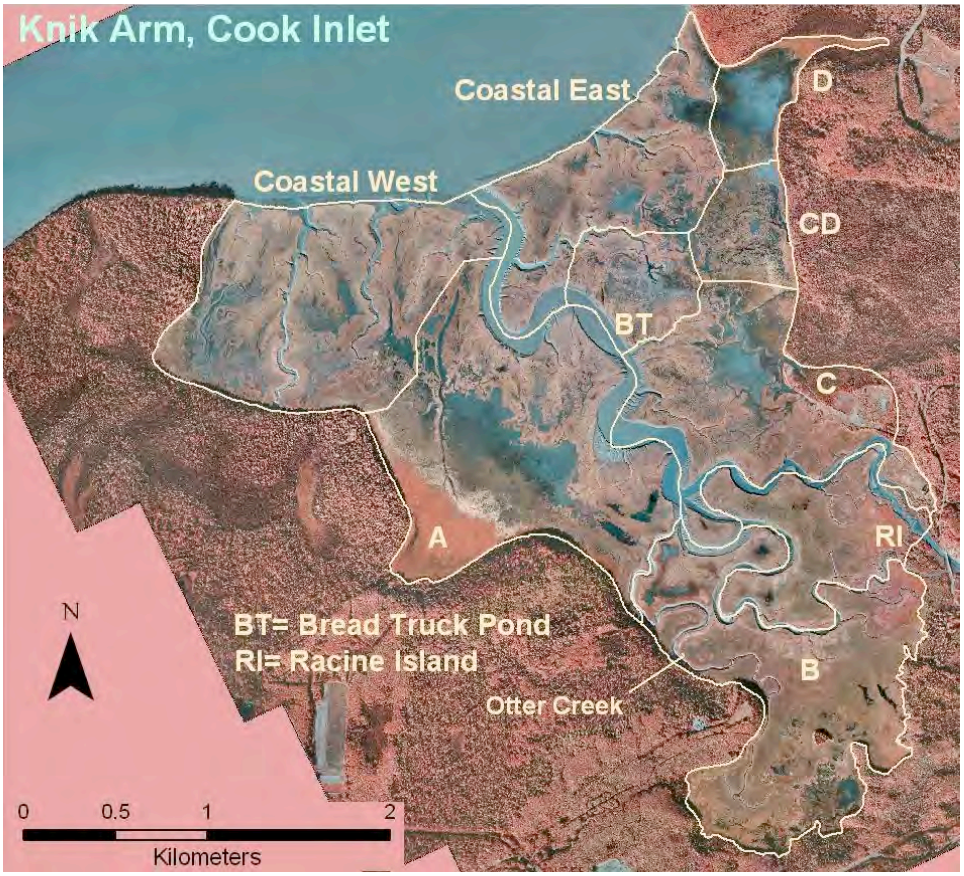

Figure II-1-1. ERF study area with standardized survey areas, ponds, sloughs and Eagle River.

each study area using a standardized pond-numbering system. Pond areas were used to calculate duck and swan densities, whereas total area was used to calculate goose densities as geese primarily use upland habitat on ERF.

RESULTS AND DISCUSSION

Environmental Conditions

In 2010, ERF experienced a slightly later spring breakup than in 2009. On 15 April, a thin layer of snow and skim ice covered > 95% of the wetland. By the end of April, the majority of pond surfaces were completely clear of ice. Flood tides occurred in mid-August, the second week of September and mid-October. Summer had higher precipitation than normal. Pond freezing occurred earlier than average. Ponds began freezing by October 8 and were mostly frozen by mid to late October despite inundation by tidal flooding. Summer moisture conditions are explained in detail elsewhere in this report (Collins et al.).

Abundance and Distribution of Waterbirds on ERF

Elevated military activity over the ERF Restricted Area and frequent poor flying conditions resulted in fewer aerial surveys completed than scheduled in 2010. Eighteen fall counts and a total of 28 aerial surveys were conducted throughout the 2010 season (Appendix II-1-A). Both the first spring survey and the final fall survey were not included in density estimates because ponds were frozen and the few birds present were restricted to tidal sloughs and Eagle River. The number of surveys used to classify observations by area for spring, summer and fall were 5, 4 and 17, respectively. Species composition for all birds surveyed in 2010 was comparable to that of previous years (Fig. II-1-2; Fig. II-1-3).

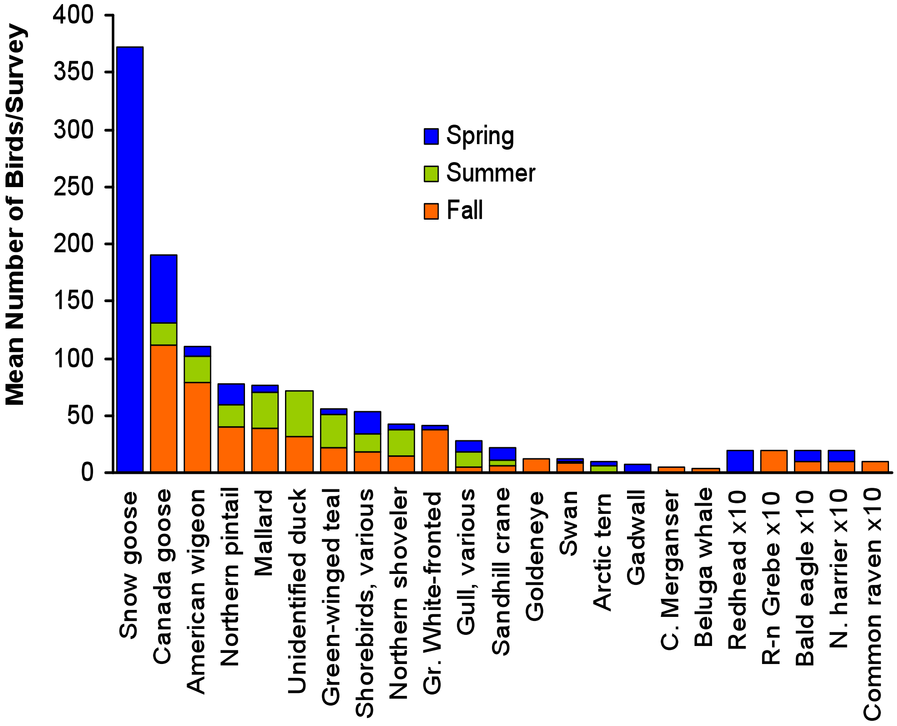

Figure II-1-2. Relative abundance (mean birds/survey) of all species or groups counted during ERF aerial surveys in 2010, listed in order of total abundance. For better resolution, bars of less common species were expanded to represent numbers of individuals multiplied by 10.

As in past years, waterfowl counts on ERF in 2010 showed a small peak in mid-late April and early May whereas the major influx of waterfowl began late July to early August and peaked mid August to late September (Fig. II-1-3). Of all ducks counted, nearly 98% were identified to species. Use of the nine study areas of ERF by waterfowl was similar to past years with highest concentrations observed in areas A, B, C, CD and D. Number, mean, percent of total, and density within each standardized area for waterfowl groups are presented in Appendix II-1-C.

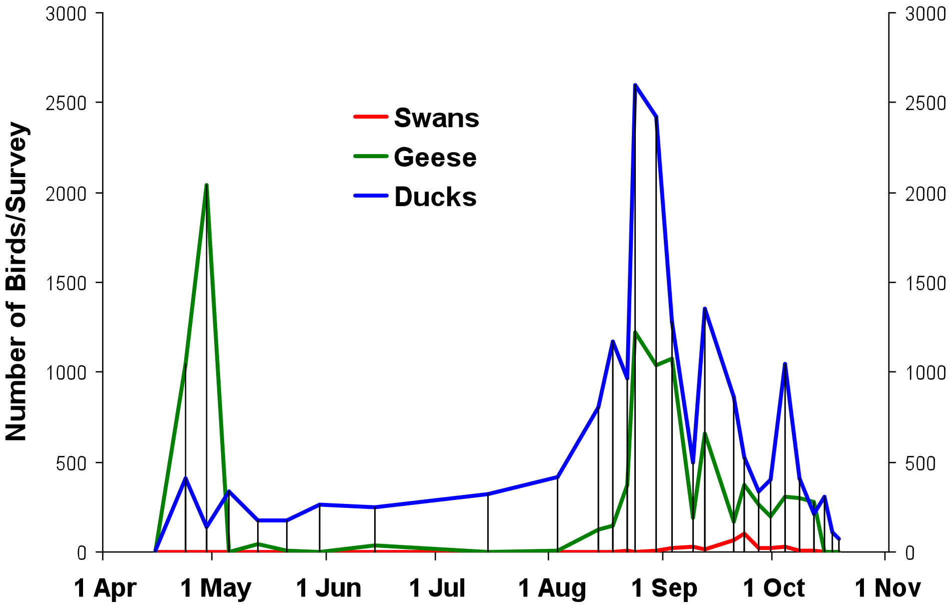

Figure II-1-3. Numbers of swans, geese, and ducks counted on ERF during aerial surveys in 2010. Vertical lines mark survey dates.

Ducks

Nine species of duck were identified on ERF in 2010 (Fig. II-1-2). Species composition in 2010 was very similar to previous years, and dabbling ducks comprised more than 98% of all identified ducks counted throughout the season. Mallards (*Anas platyrhynchos*), northern pintail (*A. acuta*), and American wigeon (*A. americana*) accounted for more than 91% of all dabbling ducks recorded; American green-winged teal (*A. crecca*), northern shoveler (*A. clypeata*) and gadwall (*A. strepera*) made up most of the remainder of identified dabbling ducks on ERF in 2010.

Average number of ducks for all months surveyed in 2010 was higher than previous years and averaged 725 ducks/survey (582, 641, 578 and 670, for 2006-2009). High count for any survey was 2601 ducks on 24 August. Spring duck numbers on ERF was higher than previous years (mean for spring 2010, 248

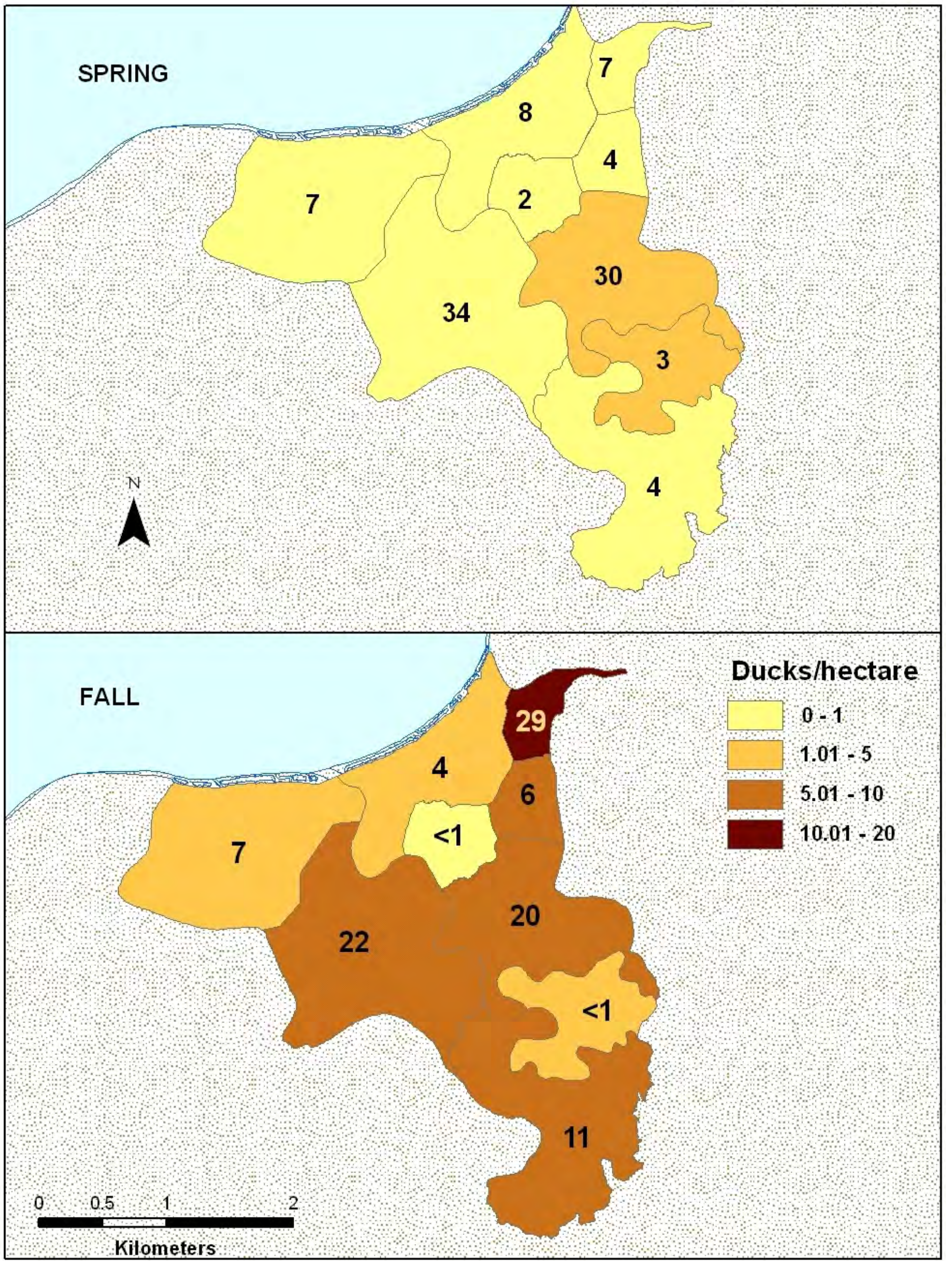

Figure II-1-4. Mean densities and distribution of ducks on ERF study areas in spring and fall 2010. Numbers within areas are the percent total ducks observed in each area. The area (ha) of permanent and intermittent ponds in each area was used to calculate densities.

ducks/survey; 142 in 2009). Combined, areas A and C make up around a third of the land mass and pond coverage on ERF and, as usual, had the highest spring concentrations of ducks in 2010 with 65 percent of all ducks counted (Fig. II-1-4, top; Appendix II-1-C).

Fall migration phenology for ducks during fall 2010 was very similar to previous years, with peak numbers occurring late August to mid September, though large numbers of ducks were present on ERF from mid August into mid October (Fig. II-1-3). The mean number of ducks observed in fall 2010 surveys (993/survey) was higher than in counts for previous years (912, 981, 837 and 904/survey for 2006-2009). Similar to previous years, distribution of ducks in fall showed highest numbers and densities in areas A, B, C, CD and especially D and, combined, accounted for almost 90% of the fall ducks counted in 2010 (Fig. II-1-4, bottom). Areas CW and the few ponds in area B were also consistently used by ducks.

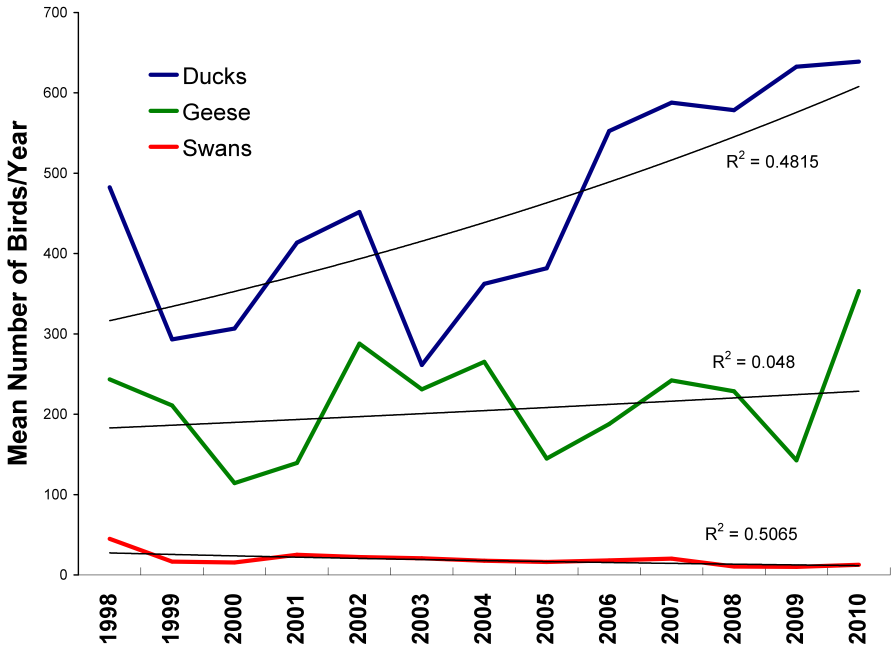

Figure II-1-5. Numbers of waterfowl counted during aerial surveys of ERF, 1998-2010, for ducks, geese and swans.

While long-term data show that aerial counts have had substantial annual variation (Appendix II-1-D), 13 years of surveys show that waterfowl have consistently used the wetland in past years and duck use even appears to be growing; counts significantly increased 1998-2010 ($P < 0.05$, Fig. II-1-5).

Of the four major habitat types used to classify duck locations in 2010 (ponds, river, slough and shoreline), ponds, as expected, were by far the most important. In the fall, 84 percent of all duck observations were identified to 46 specific ponds and, as seen in previous years, the permanent ponds of areas A, CD and D were especially important to ducks (Fig. II-1-6). Areas C, Coastal East and Coastal West were relatively more important after flooding occurred in early fall.

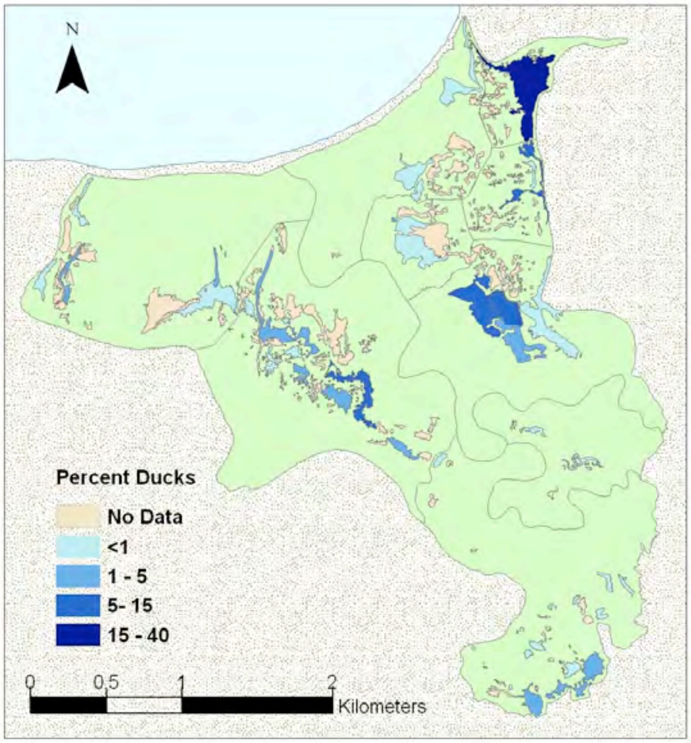

Figure II-1-6. Relative use of ponds by ducks, by percent, in fall 2010. Data are for duck observations classified to ponds; 96% of ducks observed in ponds were classified to pond number.

Duck use among study areas has changed throughout the years due to variation in weather and water levels, treatability study activities, a rotation of pond remediation and other efforts to reduce exposure of ducks to white phosphorus. Long- and short-term changes in pond shorelines due to pumping and natural flooding make it difficult to consistently identify the boundaries of some ponds. However, surveys of areas A and D continued to show increased ducks counts whereas observed numbers in areas B, Coastal West and Coastal East continued to show lowering levels of fall duck use relative to prior years (Fig. II-1-7, Appendix II-1-D).

Figure II-I-7. Standardized areas of ERF showing trends of relative duck use for fall 1997-2010 aerial surveys.

Geese

Counts of geese are highly variable from year to year, principally due to the intermittent influx of the lesser snow goose (*Chen caerulescens*), often the most abundant waterfowl species to visit ERF in the spring. In 2009, large flocks of snow geese were not observed on ERF; in 2010, 2,605 snow geese were counted on four spring surveys and accounted for more than 80 percent of spring geese. Canada geese (*Branta canadensis*) comprised 17 percent of spring goose numbers and greater white-fronted geese (presumed “tule” subspecies *Anser albifrons elgasi*) made up the remaining three percent. Timing of peak goose counts in 2010 was similar to those in previous years; spring peak counts of all three goose species occurred toward the end of April. Geese were primarily observed near the coast in Coastal West, Bread Truck (BT) and area C, mostly on the upland areas (Fig. II-1-8, top).

Only a small number of Canada geese use ERF during summer for nesting or brood-rearing. In fall 2010, 61 percent of all geese surveyed on ERF were counted in the fall; that number is more than 80 percent without spring snow geese. While many geese occupied ERF by late July, fall goose migration was similar to other years with the main influx of geese arriving in mid to late August and persisting through mid October. Canada geese were the most abundant of all fall geese counted, and accounted for 94 percent of fall geese, while greater white-fronted geese made up the remainder. Snow geese are often present in small numbers briefly on ERF in the fall, but were not observed in fall 2010. As in the past, the heavy use by geese occurred near the coast, though in 2010, geese were heaviest in areas A and C, mostly in the upland areas or the mud banks of Eagle River (Fig. II-1-8, bottom).

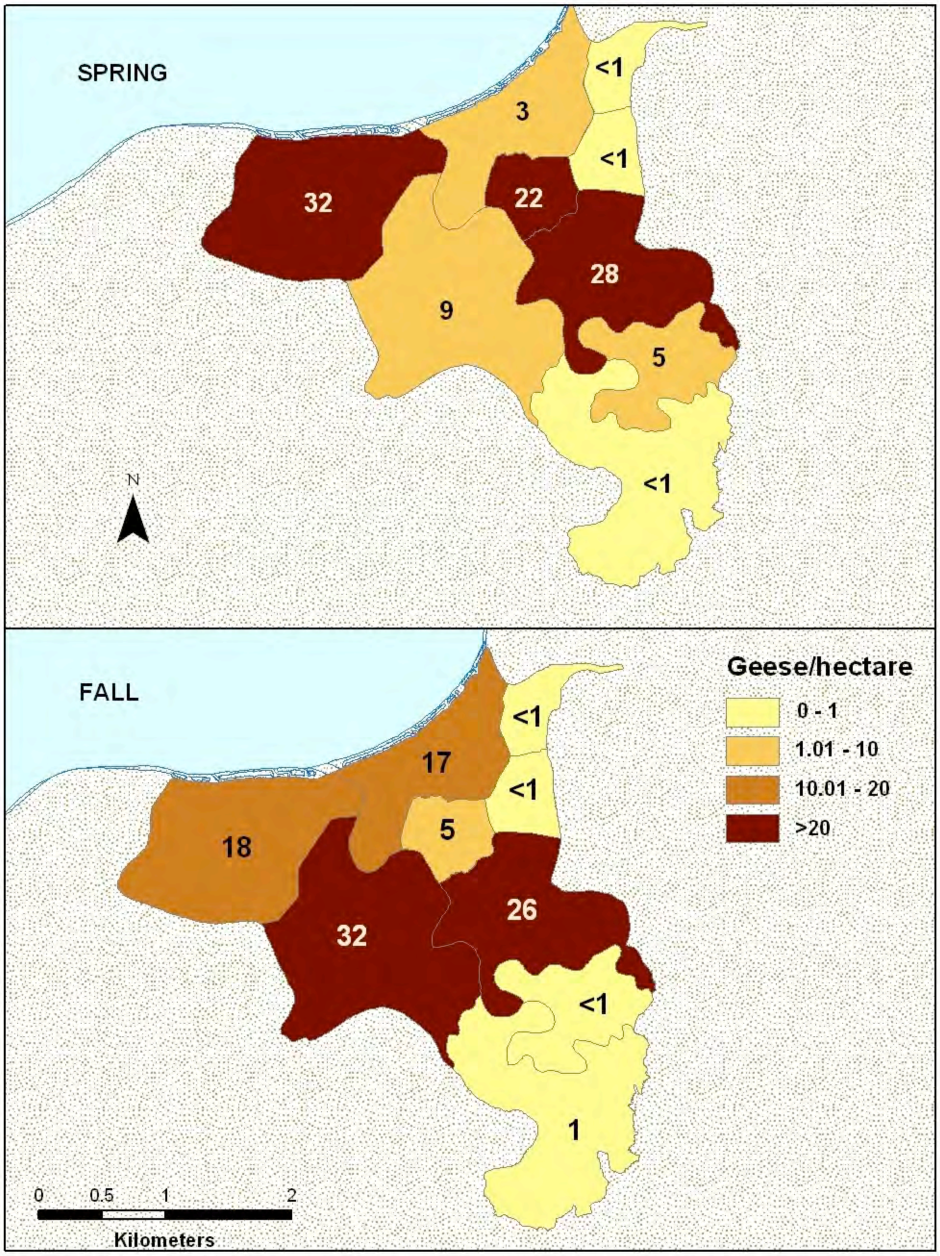

Figure II-1-8. Mean densities of geese on ERF study areas in spring and fall 2010. Numbers within areas are the percent of total geese observed in each area. Most geese are distributed in upland areas and total area (ha) within the boundaries of each area was used to calculate densities.

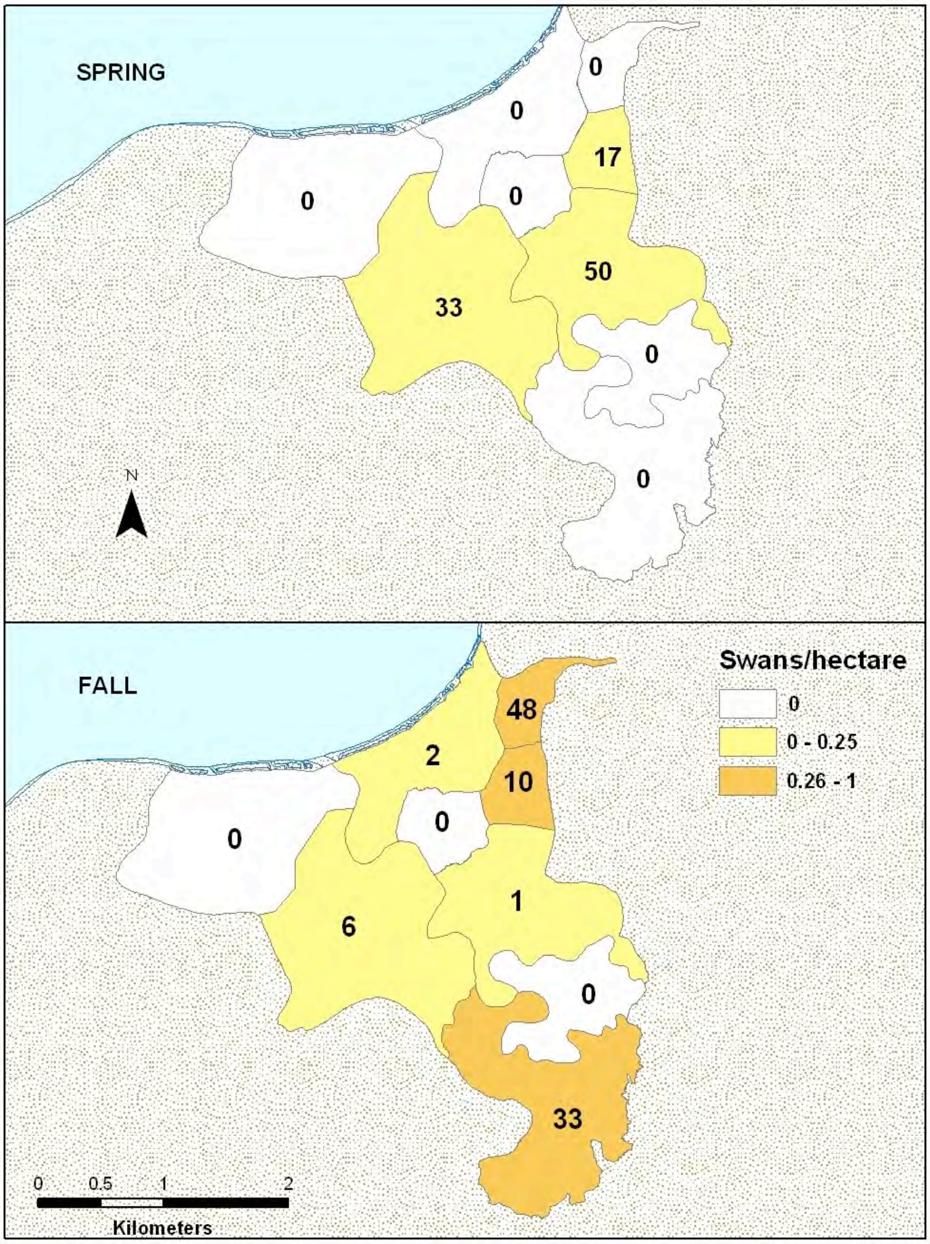

Figure II-1-9. Mean densities of swans on ERF study areas in spring and fall 2009. Numbers within areas are the percent of total swans observed in each area. The area (ha) of permanent and intermittent ponds in each area was used to calculate densities.

Swans

Both trumpeter swans (*Cygnus buccinator*) and tundra swans (*C. columbianus*) occur on ERF. While the two species cannot be distinguished from the air, trumpeter swans are far more common; tundra swans are considered uncommon on ERF (Steele et al. 2005). As is typical, swans only used ERF in small numbers during spring, with only six observed in 2010. Swans were much more abundant in fall and numbers peaked in late September at 106 individuals (average 26/survey; 113, 224, 92 and 58 for 2006-2009; appendix II-1-A). They were primarily observed, frequently with cygnets, on ponds in areas D and B, though small groups were also consistently observed on ponds in area CD (Fig. II-1-9).

Bald Eagles and other Raptors

Numbers of bald eagles (*Haliaeetus leucocephalus*) were low in 2010 (n=14), and were present on about a third of all surveys flown. Up to only two eagles were observed on a given survey including an adult with juvenile in area CW. Though never abundant in recent years, lower eagle numbers may be due to decreased mortality of waterbirds on ERF. Northern harriers (*Circus cyaneus*) were only observed four times, although in past years CRREL personnel observed them on a daily basis. Common ravens (*Corvus corax*) were only observed on one survey in fall 2010.

Shorebirds

Relatively few shorebirds were observed in 2010 compared to previous years and were most abundant on ERF in spring and summer (265 in 2010; 2022, 2380, 969 and 1200 for 2006 to 2009, Appendix II-1-A). All species of shorebirds were combined as they are difficult to identify from aircraft. Common species previously identified on ERF include greater and lesser yellowlegs (*Tringa* spp.), least sandpiper (*Calidris minutilla*), semi-palmated plover *(Charadrius semipalmatus*), short-billed dowitcher (*Limnodromus griseus*), pectoral sandpiper (*Calidris melanotos*) and red-necked phalarope (*Phaleropus lobatus*, Steele et al. 2005).

Gulls and Terns

Gull species were combined for aerial survey estimates (Appendix II-1-A). The most common species on ERF were mew gulls (*Larus canus*) and herring gulls (*L. argentatus*) but glaucous-winged (*L. glaucescens*) and Bonaparte's gulls (*Larus philadelphia*) were also observed. As of 2006, the mew gull colony formerly in area D has only consisted of a few pairs. Arctic terns (*Sterna paradisaea*) were common into July.

Sandhill Cranes

Sandhill cranes (*Grus canadensis*) were observed regularly on ERF from spring through mid September 2010 (Appendix II-1-A) and totaled 237 for all surveys (353,121 and 319 for 2007-2009). More than 20 were counted on several surveys and peaked at 72 birds in mid April. One pair of cranes nested in area C in 2006.

ACKNOWLEGEMENTS

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REFERENCES

Steele, B., L. Reitsma, C.M. Collins, M.E. Walsh, and M.R. Walsh. (2003) List of birds observed on Eagle River Flats 1991-2003. Eagle River Flats web site: http://www.crrel.usace.army.mil/erf/ecology/ecology-birds.html

Racine, C.H., and M. Brouillette (1995) Ecological inventory of Eagle River Flats, Alaska. In Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska. FY94 Final Report. Racine, C.H. and D. Cate, Eds. CRREL Contract Report to U.S. Army, Alaska, Directorate of Public Works. pp. 25–52.

Appendix II-1-A. Number of birds, by species or species group, observed for each aerial survey of ERF in 2010 (page 1 of 3).

	4/15	4/23	4/29	5/5	5/13	5/21	5/30	6/14	7/15	8/3
Ducks										
Mallard	3	111	38	34	12	19	121	169	50	309
Northern Pintail	5	294	86	211	64	57	39			55
American Wigeon			10	65	57	41	37		75	30
Northern Shovelor		7		16	36	41	55	35		
Am. Green-winged Teal			7	8	8	2	11	30	75	
Gadwall				1		14				
Redhead						2				
Goldeneye										
Common Merganser										
Red-necked Grebe										
Unidentified Duck								16	125	20
Total Ducks	8	412	141	335	177	176	263	250	325	414
Geese										
Canada Goose		480	4		45	4		35		5
Gr. White-fronted			5	2						
Snow Goose		570	2035							
Total Geese		1050	2044	2	45	4		35		5
Swans	2	2	3	1						1
Other										
Sandhill Crane		72		14		18	24	4	8	42
Arctic Tern				30	19	18	2	34	6	
Gulls[1]		2	58	209	12	46	120	41	5	5
Shorebirds				43	107	61		55		27
Common Raven	9									
N.Harrier		1								
Bald Eagle	1	1	1	1		1				
Beluga Whale										

[1] Gull species include Mew, Herring, Glaucous-winged, Bonaparte's

Appendix II-1-A (cont.). Number of birds, by species or species group, observed for each aerial surveys of ERF in 2010 (page 2 of 3).

	8/14	8/18	8/22	8/24	8/30	9/3	9/9	9/12	9/20	9/23
Ducks										
Mallard	103	415	392	1102	529	234	281	907	505	402
Northern Pintail	25	83	240	767	460	640	62	184	175	10
American Wigeon	455	480	160	660	1411	402	26	150	100	
Northern Shovelor			25	60	5					
Am. Green-winged Teal	220	170	140	12	16	2	17	115		55
Gadwall										
Redhead										
Goldeneye			12							
Common Merganser					4					
Red-necked Grebe				2						
Unidentified Duck		20					110		80	63
Total Ducks	803	1168	969	2603	2425	1278	496	1356	860	530
Geese										
Canada Goose	121	150	360	1020	961	995	190	655	165	375
Gr. White-fronted	2		15	200	81	77				
Snow Goose										
Total Geese	123	150	375	1220	1042	1072	190	655	165	375
Swans		2	7	1	10	21	26	15	66	106
Other										
Sandhill Crane			10	28	3	4	10			
Arctic Tern										
Gulls[1]				1			12			
Shorebirds				15		42				15
Common Raven			1							
N.Harrier				1	1					1
Bald Eagle	1				1	1	2		1	2
Beluga Whale				4						

[1] Gull species include Mew, Herring, Glaucous-winged, Bonaparte's

Appendix II-1-A (cont.). Number of birds, by species or species group, observed for each aerial surveys of ERF in 2010 (page 3 of 3).

	9/27	9/30	10/4	10/8	10/12	10/15	10/17	10/19	All Surveys
Ducks									
Mallard	167	231	809	317	189	310	109	70	7938
Northern Pintail	74		52	33	15				3631
American Wigeon	27	50	75	20					4331
Northern Shovelor									280
Am. Green-winged Teal	24	125	105	40	10				1192
Gadwall									15
Redhead									2
Goldeneye									12
Common Merganser			6						10
Red-necked Grebe									2
Unidentified Duck	45								479
Total Ducks	337	406	1047	410	214	310	109	70	17892
Geese									
Canada Goose	260	200	305	300	275				6905
Gr. White-fronted									382
Snow Goose									2605
Total Geese	260	200	305	300	275				9892
Swans	23	23	27	8	8				352
Other									
Sandhill Crane									
Arctic Tern									109
Gulls[1]	5								516
Shorebirds									365
Common Raven									10
N.Harrier									4
Bald Eagle		2							15
Beluga Whale									4

[1] Gull species include Mew, Herring, Glaucous-winged, Bonaparte's

Appendix II-1-B. Waterbird and habitats observed in Eagle River Flats 1991-2003 (from web site: *http://www.crrel.usace.army.mil/erf/ecology/ecology-birds.html*

Species	Status	Habitat
Red-Throated Loon	r	Permanent Pond
Common Loon	r	Permanent Pond
Horned Grebe	u	Permanent Pond
Great Blue Heron	+	
Trumpeter Swan	c	Permanent Pond
Tundra Swan	u	Permanent Pond
Canada Goose	c	Vegetated Mudflat
Cackling Goose	u	Vegetated Mudflat
Brant	u	Vegetated Mudflat
Greater White-Fronted Goose	c	Vegetated Mudflat
Snow Goose	c	Vegetated Mudflat
Mallard	c, B	Bulrush Marsh Permanent Pond
Northern Pintail	c	Permanent Pond Temporary Pond
American Wigeon	c, B	Permanent Pond Temporary Pond
Eurasian Wigeon	r	Permanent Pond Temporary Pond
Northern Shoveler	c	Permanent Pond Temporary Pond
Cinnamon Teal	+	
Blue-Winged Teal	r	Permanent Pond Temporary Pond
Green-Winged Teal	c, B	Permanent Pond Temporary Pond
Ring-Necked Duck	r	Permanent Pond
Greater Scaup	r	Permanent Pond
Lesser Scaup	r	Permanent Pond
Long-Tailed Duck (Oldsquaw)	r	Permanent Pond
Common Goldeneye	r	Permanent Pond
Bufflehead	r	Permanent Pond
Common Merganser	r	Permanent Pond

c = common, u = uncommon, r = rare, + =casual or accidental, B = confirmed breeder in ERF, b = probable breeder in ERF

Appendix II-1-C. Number, mean, percent of total, and density for each standardized area for waterfowl groups surveyed in 2010. Data are presented by season and standardized area. Density of ducks and swans used pond area; for geese, total area of each area was used.

Survey Area	Number			Mean (no./survey)			Percent of Total			Density (No./hectare)		
	Ducks	Geese	Swans	Ducks	Geese	Swans	Ducks	Geese	Swans	Ducks	Geese	Swans
Spring												
A	424	287	2	17.7	12.0	0.1	34.2	9.1	33.3	0.73	0.06	0.00
B	47			2.0	0.0	0.0	3.8	0.0	0.0	0.21	0.00	0.00
Bread Truck	32	705		1.3	29.4	0.0	2.6	22.4	0.0	0.12	0.56	0.00
C	377	888	3	15.7	37.0	0.1	30.4	28.2	50.0	1.05	0.34	0.01
CD	52		1	2.2	0.0	0.0	4.2	0.0	16.7	0.46	0.00	0.01
Coastal East	95	105		4.0	4.4	0.0	7.7	3.3	0.0	0.52	0.05	0.00
Coastal West	83	1010		3.5	42.1	0.0	6.7	32.1	0.0	0.22	0.27	0.00
D	91			3.8	0.0	0.0	7.3	0.0	0.0	0.32	0.00	0.00
Racine Island	40	150		1.7	6.3	0.0	3.2	4.8	0.0	1.17	0.09	0.00
Summer												
A	399	40	1	16.6	1.7	0.0	31.9	100.0	100.0	0.68	0.01	0.00
B	164			6.8	0.0	0.0	13.1	0.0	0.0	0.75	0.00	0.00
CD	107			4.5	0.0	0.0	8.5	0.0	0.0	0.95	0.00	0.00
Coastal East	155			6.5	0.0	0.0	12.4	0.0	0.0	0.85	0.00	0.00
D	427			17.8	0.0	0.0	34.1	0.0	0.0	1.52	0.00	0.00
Fall												
A	3292	2167	20	137.2	90.3	0.8	22.1	32.3	5.8	5.64	0.48	0.03
B	1653	60	114	68.9	2.5	4.8	11.1	0.9	33.2	7.51	0.02	0.52
Bread Truck	87	325		3.6	13.5	0.0	0.6	4.8	0.0	0.33	0.26	0.00
C	2972	1806	4	123.8	75.3	0.2	19.9	26.9	1.2	8.24	0.70	0.01
CD	876		34	36.5	0.0	1.4	5.9	0.0	9.9	7.80	0.00	0.30
Coastal East	659	1135	8	27.5	47.3	0.3	4.4	16.9	2.3	3.62	0.58	0.04
Coastal West	1024	1188		42.7	49.5	0.0	6.9	17.7	0.0	2.70	0.32	0.00
D	4302	6	163	179.3	0.3	6.8	28.9	0.1	47.5	15.29	0.01	0.58
Racine Island	35	20		1.5	0.8	0.0	0.2	0.3	0.0	1.03	0.01	0.00

Appendix II-1-D. Percent use of ERF study areas and major habitat types by ducks in fall for 14 years, 1997-2010.

Area/Habitat	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Coastal West	**9.9**	**17.6**	**18.8**	**7.9**	**6.0**	**3.4**	**7.2**	**4.7**	**5.6**	**2.5**	**1.6**	**4.5**	**5.4**	**6.4**
Ponds	5.6	9.1	10.9	5.8	5.4	1.9	1.1	1.7	1.4	1.7	1.6	3.1	4.6	6.3
Eagle River	<0.1	0.8	1.2	<0.1	0.2	1.1	5.3	2.9	4.0	0.5	<0.1	0.9	0.8	0.0
Knik Shoreline	4.3	7.6	6.6	1.8	0.2	<0.1	0.7	0.0	0.1	<0.1	0.0	0.5	<0.1	
Area A	**14.6**	**5.6**	**14.9**	**23.5**	**18.7**	**16.9**	**10.3**	**18.2**	**24.6**	**23.7**	**27.1**	**33.1**	**31.4**	**23.7**
Ponds	14.5	5.0	11.5	16.7	9.8	7.6	5.0	7.8	11.9	14.8	26.1	30.3	30.7	21.3
Eagle River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.1	1.6	2.8	0.7	2.4
Area B	**25.0**	**19.2**	**20.1**	**19.0**	**10.5**	**21.4**	**33.0**	**19.3**	**9.8**	**14.3**	**6.0**	**5.0**	**7.2**	**10.7**
Ponds	19.2	18.2	16.1	17.8	9.7	17.6	25.3	10.2	7.0	9.1	5.6	4.6	6.9	10.2
Eagle River	5.8	1.0	1.4	1.2	0.2	1.3	0.4	0.0	0.1	0.1	0.0	0.4	0.3	0.5
Otter Creek										0.4	0.2	<.01	<.01	
Racine Island	**0.6**	**1.1**	**1.5**	**0.7**	**0.2**	**0.1**	**0.6**	**1.0**	**0.4**	**<0.1**	**0.9**	**0.9**	**0.6**	**0.4**
Ponds	0.6	1.1	1.5	0.7	0.2	0.1	0.6	1.0	0.4	<0.1	0.9	0.9	0.4	0.4
Area C	**17.9**	**4.8**	**4.8**	**10.0**	**25.4**	**21.1**	**15.1**	**13.0**	**17.2**	**10.1**	**15.4**	**14.2**	**11.0**	**19.3**
Ponds	2.4	4.7	1.0	4.6	23.3	15.5	13.6	4.1	10.2	7.9	14.3	13.0	9.5	17.5
Eagle River	15.5	0.1	1.0	4.8	0.3	0.1	0.0	0.1	1.9	0.2	1.4	1.2	1.5	1.8
Area CD	**11.4**	**15.3**	**8.5**	**9.0**	**12.5**	**17.5**	**17.4**	**14.0**	**13.0**	**15.9**	**14.8**	**11.9**	**13.2**	**6.0**
Ponds	11.4	15.3	3.7	5.7	8.1	12.8	10.6	6.3	8.8	11.5	14.8	11.9	13.2	6.0
Bread Truck	**1.3**	**1.9**	**2.3**	**3.7**	**0.0**	**0.1**	**0.3**	**3.5**	**2.0**	**2.0**	**4.1**	**2.3**	**0.9**	**0.7**
Ponds	1.3	1.9	1.1	1.5	0.0	0.0	0.0	0.9	0.2	0.5	4.0	1.6	0.8	0.7
Eagle River	<0.1	<0.1	1.2	2.0	0.0	0.1	0.3	2.4	1.7	1.4	0.1	0.7	0.1	0.1
Coastal East	**9.1**	**21.1**	**9.1**	**6.6**	**3.6**	**0.7**	**4.4**	**7.2**	**11.6**	**7.2**	**4.4**	**4.6**	**4.9**	**5.2**
Ponds	2.8	9.3	5.0	4.5	5.4	0.4	0.0	3.3	5.8	6.3	3.9	2.1	4.2	4.7
Knik Shoreline	6.3	11.7	0.9	1.4	0.2	0.0	0.0	0.2	0.2	0.0	0.1	2.5	0.0	0.4
Area D	**10.7**	**13.4**	**20.0**	**19.7**	**23.1**	**19.0**	**11.8**	**19.0**	**15.7**	**24.3**	**25.8**	**23.5**	**25.4**	**27.6**
Ponds	10.7	13.4	13.3	19.6	23.1	18.9	10.3	16.7	15.7	24.0	25.8	23.5	25.4	27.6

II-2. 2010 GROUND-BASED WATERFOWL MORTALITY SURVEYS

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INTRODUCTION

2010 was the seventh year that we used ground-based waterfowl mortality surveys to determine rates of waterfowl mortality due to white phosphorus poisoning in Eagle River Flats. These mortality surveys have been a very successful, cost effective, and repeatable process for determining waterfowl mortality, which in turn, indicates the success of remediation activities. The success of the ground-based mortality surveys contrasts with the telemetry method of determining mortality by capturing and equipping a small subsample of wild ducks in Eagle River Flats with radio collars used from 1996 through 2002. The extremely high costs and unreliability of the helicopter support to capture the ducks and the great variability in the mortality data produced made that method problematic. The key to the success of the ground-based waterfowl mortality surveys has been using the same straightforward methods based on intimate knowledge of the site and the same key personnel for all seven years.

The ground-based mortality transects currently being used for the mortality surveys were first established in 2004 in the marshes of northern Area C and eastern BT Area and near the major waterfowl feeding ponds in Area C that had been remediated. A similar ground-based mortality transect method was used successfully in the early 1990’s during the initial investigations of waterfowl deaths (Racine et al. 1992). We designed and located the ground-based mortality transects based on our knowledge of known remaining areas with white phosphorus contamination and long-term observations of waterfowl usage in Eagle River Flats. In the surveys conducted to determine waterfowl mortality since 2004, we have counted a high of 111 dabbling duck mortalities (2004) and a low of 12 (2008) (Collins et al. 2005 – 2010).

The mortality rate of dabbling ducks in Eagle River Flats was chosen as the short- and long-term indicator for determining the effectiveness of remediation in white-phosphorus-contaminated sediments in Eagle River Flats. The Remedial

Action Objectives (RAOs) specified in the Record of Decision (ROD) (CH2M Hill 1998) signed in October 1998 are:

> "Within 5 years of the ROD being signed, reduce the dabbling duck mortality rate attributable to white phosphorus to 50 percent of the 1996 mortality rate attributable to white phosphorus. Radio tracking and aerial surveys suggest that about 1,000 birds died from white phosphorus at ERF in 1996. Therefore, the allowable number of duck deaths from white phosphorus would be approximately 500. *[Mortality rate in 1996 was 15% of the total annual fall population of dabbling ducks. So this goal would be equivalent to about 7.5% of the total annual fall population of dabbling ducks.]*
>
> Within 20 years of the ROD being signed, reduce the mortality attributable to white phosphorus to no more than 1 percent of the total annual fall population of dabbling ERF ducks. Currently, that population is about 5,000. Therefore, the allowable number of duck deaths from white phosphorus would be approximately 50. This long-term goal could be adjusted based on future population studies conducted during the monitoring program."

The use of the mortality of a percentage of the fall dabbling duck population as the remedial action goal, rather than a sediment cleanup level, is unusual for a CERCLA site and is somewhat problematic in that both the fall duck population and the fall duck mortality numbers need to be measured each year, neither of which is a simple task. At the time of the ROD, and continuing to date, a clean up level has not been established for white phosphorus in sediment. Because the overall goal was to reduce duck mortality, the long-term remedial action objective was expressed as a percentage of the fall population of dabbling ducks.

METHODS

Waterfowl mortality surveys were conducted in Eagle River Flats during the fall 2010 migration period from mid-August to mid-October except during periods of flooding tides (approximately four days when area wasn't accessible). As in the six previous years, the 2010 mortality surveys used three types of ground-based transects. The first type, the core group of transects, covered the major feeding ponds in Area C with the highest waterfowl use. These ponds had been remediated in previous years by pond pumping. Also included were the known remaining areas of white phosphorus contamination (the marshes of northern Area C and eastern BT Area) as well as transects in a portion of Area C that had been remediated but were in proximity to the areas of known contamination. This core group of transects was surveyed three times a week with additional surveys conducted during peak migration periods whenever personnel were available.

The second type of transects covered other areas used by waterfowl that have been remediated or have no known contamination. These included transects in Area A covering ponds that have undergone remediation, the Pond 40 transect in the C/D area only accessible by canoe, and a grid transect covering much of the remaining area of C/D. These transects were covered less frequently than the core transects, generally on a weekly basis.

The third transect type included transects along the forest edge to the east of Eagle River Flats. These were checked only once during the fall near the end of the fall migration period for feather piles from carcasses carried into the woods by predators and scavengers.

Transect Survey Procedure

Ground-based transect lines for all the surveys are shown in Figure II-2-1. The first of the known contaminated areas within the core group, the Ditch transect, covers small pools in the Northern C marsh where two large interconnected drainage ditches were excavated for pumping remediation. The second, Duck Ponds transect, covers the small ponds in the eastern BT area that were drained with a small ditch system excavated in July 2004. Transects were also positioned around the perimeter of the large waterfowl feeding ponds previously treated by pumping – Pond 183 in Area C and Pond 730 in western C/D Area. Transects in this core survey group include:

Northern C Marsh Ditch Transect	1,040 m total transect length
Pond 183 Transect	900 m
Pond 730 and Duck Ponds Transects	2,360 m combined length

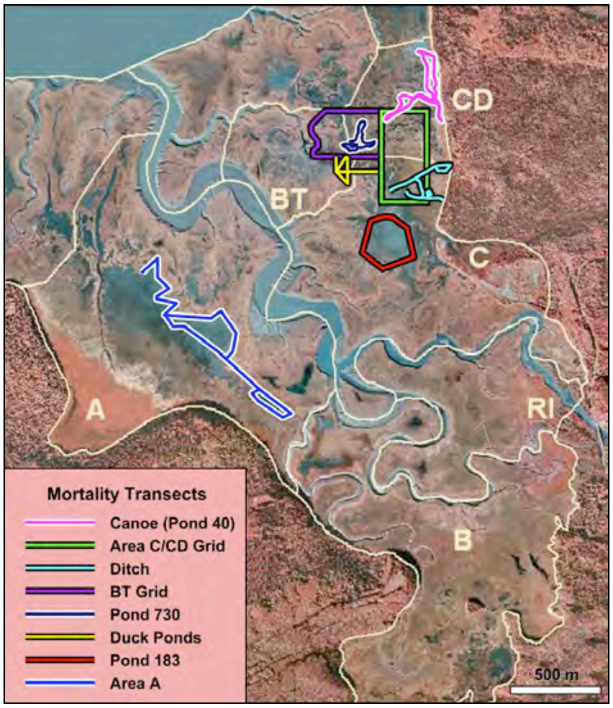

Figure II-2-1. Mortality transects monitored at Eagle River Flats during 2010.

Total lane length of the four transects covers approximately 4,300 m; this allows a pair of observers to walk the entire distance in about four hours.

The second transect type includes:

Area A	2,600 m plus 4,250 m round-trip walking access
Canoe Transect of Pond 40	1,440 m plus 2,400-m round-trip walking access
C/D Grid Transect	1,500 m
BT Grid Transect	1,500 m

The Area A transect takes approximately five hours to survey, including the walking time to access the area. It is approached via an access trail from Lower Cole Point, the nearest point where a vehicle can be driven, that follows Otter Creek and the western edge of Eagle River Flats. The transect starts at the south end of Pond 290, follows the east side of Pond 290, then heads along the east side of the Northern A pond complex and back, returning along the west side of Pond 290.

The Canoe Transect starts along the east shore of C/D and follows the entire edge of Pond 40, a large, deep, and complexly shaped pond system in the northern C/D area. The C/D grid transect covers a 250 × 500-m grid laid out through the C/D marsh, and the BT transect runs west from the C–C/D transect to the BT gully, south along the east side of the gully, then east along the north side of the Duck Ponds.

Forest-edge transects consist of four 400-m long transects heading into the forest perpendicularly from the salt marsh boundary on the eastern side of Eagle River Flats and one 50 × 200-m quadrat located along the forest edge east of Northern C Marsh.

Transect locations were originally surveyed with a Trimble Pathfinder Pro XR Global Positioning System. The centerline of the 10-m wide lanes was marked with 1.5-m orange fiberglass markers with the tops painted fluorescent lime-green. Past experience with these fiberglass markers in Eagle River Flats shows that they are highly visible from a great distance. They also survive winter ice conditions well and can be expected to last for a number of years, thus facilitating the re-establishment of the transect lanes each year. All of the transects fiberglass markers were still in place when inspected this year. Lane widths were delineated with pairs of 1.2-m wood lath with lime-green painted tops, spaced 10-m apart and placed every 50 or 100 m along the survey lanes. The wooden laths were replaced or repainted as needed. During the installation and marking of the 10-m wide lanes, the UXO technician swept the lane width between pairs of lath for the presence of UXO. None were found. This allowed the survey team to subsequently walk the lane periodically to conduct the mortality surveys without UXO technician escort.

All transects were observed similarly during the mortality surveys. A two-person observation team walked (or canoed in case of the Canoe Transect) each of the transect lanes in turn, visually scanning for waterfowl carcasses or feather pile remains of carcasses. The observers especially checked the nooks and crannies within standing bulrush along the water edges of ponds. When a carcass or feather pile was found, the team recorded the date, location (UTM coordinate using a GPS system or estimated from UTM-gridded photo maps of the areas), species, and an estimate of the carcass freshness. A unique sequential sample identification number was assigned (e.g. MORT 001, MORT 002, etc.) to all carcasses and feather piles. The location was marked with a PVC pin flag annotated with the identification number and date. If the carcass was in good condition, it was collected and brought back to the laboratory in Building 992 on Fort Richardson. There the gizzard was removed for later white phosphorus analysis. The carcass was then preserved in the freezer for later screening for H5N1 avian influenza. Further discussion of the carcass-handling procedure follows below.

If the mortality was a feather pile rather than a carcass, similar information was recorded, including date, location, identification number, and species (if it could be determined from the feathers). Feather piles are the remains of waterfowl that have either died from white phosphorus poisoning and then post-mortem been predated by raptors or other predators, or are waterfowl killed and eaten by a predator. A feather pile can range from just a pile of feathers plucked from the carcass prior to consumption up to both feathers and skeletal remains. The amount of remains of a feather pile usually depends on the predator. An eagle will eat almost all of a carcass, including bones, leaving only the feathers. On the other hand, a northern harrier, if feeding on a fresh carcass, will feed on the flesh, leaving almost all of the skeletal remains and the feathers. When located, the feather piles were also marked using PVC pin flags with an identification number and date, which prevented recounting on future surveys.

Waterfowl Carcass Handling Procedure

Personal protective equipment worn by personnel handling waterfowl in the field consisted of rubber gloves; when in the laboratory, Level D protection (gloves, eye protection, and a N95 disposable particulate respirator) were worn whenever dissecting waterfowl and gizzards. The survey team collected all found carcasses that were not too decayed to handle. Each carcass was brought to the laboratory in Building 992 where the gizzard was removed. A razor blade was used to cut a 5-cm slit in the carcass just below the breastbone. The gizzard was pulled out through the slit and cut at each end to sever it from the digestive tract. The gizzard was then opened using a razor blade and the gizzard contents removed by rinsing the contents with distilled water into a glass vial. The vial was sealed with a Teflon-lined cap, then the date, mortality identification number, and location information was recorded on the sample vial and the vial stored in the refrigerator. Approximately once every two weeks, the gizzard content sample vials were shipped to the CRREL-Hanover chemistry laboratory, where the contents were analyzed for the presence of white phosphorus on a gas chromatograph using EPA Method 7580 (U.S. EPA 1995).

Throughout the field season, the status of testing for highly pathogenic avian influenza (HPAI) was followed closely using the system posted on a website entitled HEDDS (**H**ighly Pathogenic Avian Influenza **E**arly **D**etection **D**ata **S**ystem) http://wildlifedisease.nbii.gov/ai/. During 2010, over 11,200 waterfowl samples collected in Alaska and over 36,000 collected in the United States were analyzed for HPAI. None tested positive. If any positive samples had been reported, additional safety measures would have been implemented during the mortality surveys as outlined in the safety and health plan. These could have included additional levels of personal protection equipment or even the suspension of mortality surveys if deemed necessary.

Period of Observations

The mortality surveys were conducted during the fall migration period from 18 August to 15 October 2010. At the conclusion of the surveys in October the ponds on Eagle River Flats were frozen up enough to preclude any additional surveys. Aerial survey flights continued until 19 October, when just a few ducks were still present in Eagle River Flats, mainly along the river (Marks and Eldridge, this volume). Over 100 individual transect surveys were conducted over the nearly 9-week period. The core mortality transects were surveyed three to four times a week (generally Monday, Wednesday, and Friday) except during periods of flooding tides when they were suspended for safety reasons. The secondary transects were surveyed approximately weekly and the forest edge transects were surveyed once at the end of the migration period.

Again this year, because of close coordination with Range Control, there were only minor scheduling conflicts with other ranges for training that impacted the conducting or timing of mortality surveys during the fall migration.

RESULTS

Mortality Data

During the mortality surveys conducted from 18 August to 15 October 2010, eight carcasses and fourteen feather piles were found along the surveyed transects. Gizzards were collected from all eight carcasses and all eight tested positive for white phosphorus.

Over the past several years we have tried to address the concern of whether to fully count feather piles as mortalities attributable to white phosphorus poisoning by attempting to collect any tissue and fatty tissue associated with skeletal parts or skin attached to the wing feathers. In theory there should be enough white phosphorus residue in the subcutaneous fat attached to skin that a small skin sample should be able to be tested to determine if the waterfowl died from white phosphorus. However, of the dozen or more tissue samples collected over the last two years, only one tested positive for white phosphorus. This sample was a small piece of viscera left in the recently predated feather pile collected last year. This year we analyzed three tissue samples from three of the fourteen feather piles; none tested positive. We are coming to the conclusion that, except in unusual cases such as the section of viscera, testing small tissue samples from feather piles is normally going to give either negative or inconclusive results. In other words, a negative result based on a small tissue sample can't be ruled out as potentially positive. Because of the uncertainties in determining the cause of death of the waterfowl by the evidence left by the feather piles, we assume all fourteen of the feather piles are attributable to white phosphorus poisoning. This gives a conservative estimation (an overestimation) of mortality rate due to white phosphorus poisoning. Therefore, using this assumption we attribute all twenty-two mortalities to white phosphorus poisoning—eight carcasses that tested positive, three feather piles that tested negative, and eleven feather piles that were not tested. Waterfowl mortalities have been in a decreasing trend since the ground-based mortality surveys began in 2004 except for the spike in mortalities in 2009. Mortalities identified in 2004, 2005, 2006, 2007, 2008, 2009, and now 2010 are 111, 49, 25, 35, 12, 44, and 22 respectively.

Table II-2-1 summarizes by transect the 2010 seasonal waterfowl mortalities attributed to white phosphorus poisoning. Figure II-2-3 gives an overview of all 2010 duck mortality locations in Eagle River Flats. Figure II-2-4 provides an expanded view of the mortalities in Areas C and C/D, including the Pond 730 and Ditch transect areas in Northern C Marsh. On both figures red stars represent locations of carcasses and yellow stars represent feather piles. Detailed data about each mortality including date, species, collector, and location (UTM coordinates) are given in Appendix Table II-2-A1.

Table II-2-1. Summary of 2010 mortality results by transect. Mortalities are identified as either carcasses or as feather piles.

Transect	Carcass	Feather pile
Ditch Transect	5	6
Pond 730 Transect	3	3
Pond 183 Transect	0	2
Duck Pond Transect	0	0
BT Transect	0	0
C/D Transect	0	0
Other Area C	0	0
Canoe (Pond 40) Transect	0	0
Forest Transects	0	0
Area A Transect	0	3
Total	**8**	**14**

Figure II-2-3. Locations of 2010 duck mortalities in Eagle River Flats. Carcasses locations are shown as red stars and feather piles as yellow stars.

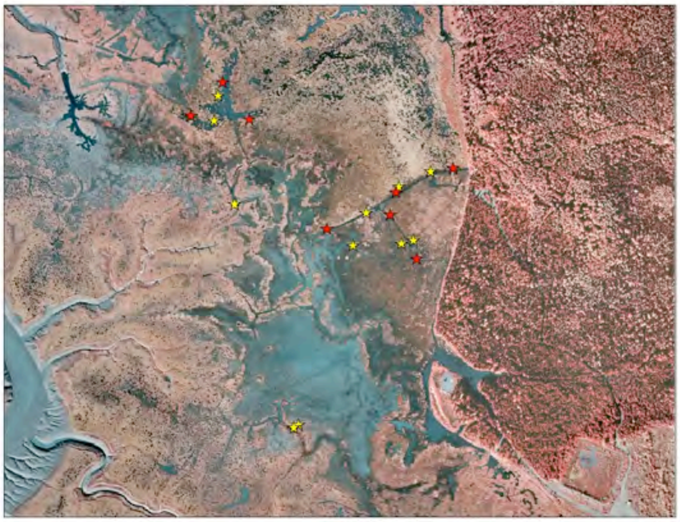

Figure II-2-4. Location of 2010 duck mortalities in Areas C and C/D. Carcasses locations are shown as red stars and feather piles as yellow stars.

During the 2010 transect surveys six mortalities (three carcasses and three feather piles) were found around the Pond 730 transect. This is a noticeable reduction from the 21 mortalities found in 2009 (Table II-2-2). The reductions can be attributable to several factors. Last year was a very dry year up until mid-September 2009 and most of the mortalities occurred before mid-September when water levels were low. We are hypothesizing that because of the shallower than normal water levels, ducks were able to access small unknown hot spots of contamination in the Pond 730 area that would normally have been in deeper water and inaccessible to dabbling ducks (Collins et al. 2010). This year was a more normal year and water levels were higher throughout the fall migration period. Secondly, a previously unknown white phosphorus-contaminated hot spot was identified in May 2010 in the western end of Pond 730 (Walsh, M.E. et al., this volume). A temporary 4.5-m by 6-m geotextile cap was placed over the hot spot in June to keep waterfowl from feeding there through the fall. The temporary cap may have prevented additional mortality in this area during the fall migration period. This temporary geotextile cap was replaced with a permanent gravel cap in March 2011.

No mortalities were found along the Canoe transects this year. This may also reflect fewer ducks being poisoned in the nearby Pond 730 area because ducks often feed in the Pond 730 area then move over to the much deeper Pond 40 along the Canoe transect to loaf and rest.

Eleven mortalities (five carcasses and six feather piles) were found along the Ditch transects, an increase from last year. The reason for the increase is unknown. Small areas of contamination adjacent to capped areas that were identified last year and again this spring (Walsh, M.E. et al., this volume) may account for the mortalities. In addition, the raised, dry tops of the numerous gravel caps in this area may be convenient feeding locations for raptors resulting in a concentration of feather piles in this area.

Table II-2-2. Summary of mortality results by transect from 2004 through 2010.

Transect	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Ditch Transect	64	25	6	13	4	5	11
Pond 730 Transect	17	7	9	9	5	21	6
Pond 183 Transect	9	1	3	1	0	0	2
Duck Pond Transect	3	3	0	1	0	0	0
B/T Transect	0	0	0	0	0	0	0
C/D Transect	6	3	2	3	0	0	0
Canoe Transect	6	4	1	0	2	8	0
Other Area C	3	2	0	2	1	1	0
Area A Transect	1	4	2	7	0	9	3
Woodland Transect	2	0	0	0	1	0	0
TOTAL	**111**	**49**	**25**	**36**	**12**	**44**	**22**

Three duck mortalities, all feather piles, were observed in Area A this year, a large decrease from the nine mortalities (four carcasses and five feather piles) last year. Known contaminated ponds in Area A were pumped and treated over several years from 1998 to 2002. Repeated sediment sampling for white phosphorus in the major ponds since then has been negative (Walsh, M.E. et al. 2007, 2008). The two locations in Area A where some white phosphorus was detected in the late 1990s were resampled this year. Trace amounts of white phosphorus were found (M.E. Walsh et al. this volume).

One partial carcass of a trumpeter swan was found along the Area A transect adjacent to Pond 226 on 14 September. The carcass was partially predated but the gizzard was recovered. The contents were analyzed and tested positive for white phosphorus indicated the swan died of white phosphorus poisoning. This is the first swan carcass found in several years in Eagle River Flats. This carcass is not used in calculations of duck mortalities.

Two duck mortalities were found on the Pond 183 transect, both were remains left by eagles on top of the tower. No duck mortalities were found on the Duck Ponds, BT, C/D, or Woodland Transects this year.

One swan feather pile was found in the woods south of Woodland transect #4 where it had been carried into the woods and consumed by wolves. There was no evidence as to whether the swan died before being predated or had been caught and killed by the wolves. This swan feather pile was also not used in the calculation of the duck mortality for Eagle River Flats.

Estimates of Waterfowl Population and Mortality Rate

To calculate the estimated fall dabbling duck mortality rate for Eagle River Flats requires an estimate of both the total duck population using Eagle River Flats and the total number of ducks that die from white phosphorus. The same method has been used for the last seven years. The fall duck population estimate was made using the aerial census population data collected over the summer and fall by the U.S. Fish and Wildlife Service (Marks and Eldridge, this volume). Estimating a total duck population from periodic aerial census data is complicated by lack of information on how many ducks seen on one census flight were the same ones present during the previous census. However, the radio-collar tracking (telemetry) data collected between 1996 and 2002 by the National Wildlife Research Center (NWRC 2004) enables us to estimate the turnover rate, which is the number of ducks that leave Eagle River Flats between censuses. The turnover rate estimate is used to estimate the number of ducks that may fly into Eagle River Flats, feed and potentially be exposed to white phosphorus poisoning, then fly out prior to the next aerial census flight. In the years of their studies, NWRC calculated the turnover rate for each census period based on the turnover of the radio-collared mallards used in the telemetry study. Turnover is defined as the proportion of ducks that remained on ERF between two aerial censuses (or 1 – [the proportion that left]). Because we do not calculate turnover rate each year, we estimated it by using the average turnover rate of 0.83 that was based on the long-term average turnover rate for the entire length of the telemetry studies (NWRC 2004).

Using a combination of the NWRC population estimate model, the aerial census data, and the average turnover rate, a population estimate was determined for each census period (Table II-2-3). The NWRC model uses the total dabbling duck population, i.e. the sum of each of the duck species plus the unknown or unidentified ducks, and then adjusts this total for the average turnover to determine estimated total duck population for that census period. The total increase in duck population for each census period was then estimated by subtracting the previous period’s adjusted population from the current period’s adjusted population. If the current period’s population was higher than the previous period then the difference was the total increase in duck population for that period. If the current period’s population was lower than the previous period, then there was no net increase in the duck population for that period. At the end of the season, the total increases for each census period were summed to give the total estimated dabbling duck population for the season.

Table II-2-3. NWRC population model for 2010 using the aerial count by species of ducks plus unidentified ducks. Total is adjusted for average turnover rate. Positive changes in population from one period to the next are summed to obtain total population estimate.

Observation Date	Aerial Count	Unknown Dabblers	Total Dabblers	Adjusted for Turnover	Population Change
8/3/10	394	20	414	499	499
8/14/10	803	0	803	967	469
8/18/10	1128	20	1148	1383	416
8/22/10	969	20	989	1192	0
8/24/10	2601	0	2601	3134	1942
8/30/10	2425	0	2425	2922	0
9/3/10	1278	0	1278	1540	0
9/9/10	401	80	481	580	0
9/12/10	1356	0	1356	1634	1054
9/20/10	850	10	860	1036	0
9/23/10	517	13	530	639	0
9/27/10	337	0	337	406	0
9/30/10	406	0	406	489	83
10/4/10	1047	0	1047	1261	772
10/8/10	410	0	410	494	0
10/12/10	214	0	214	258	0
10/15/10	222	0	222	267	10
				Total Fall Dabbling Duck Population	**5,245**

Using this method, the total fall 2010 dabbling duck population was calculated to be 5,245 birds. The observed mortality was 22, giving a mortality rate of the fall 2010 dabbling duck population in Eagle River Flats of 0.4%. This compares to a mortality rate of 0.9% in 2009, 0.2% in 2008, 0.7% in 2007, 0.6% in 2006, 2.3% in 2005, and 3.0% in 2004 (Table II-2-4.)

One caveat has to be pointed out in the aerial observation data this year. From 13 through 19 September heavy fog was present over Eagle River Flats and the entire Anchorage area and no aerial survey flights were conducted during this seven-day period due to the fog. This period of fog coincided with the peak of the fall duck migration with large numbers of ducks present in Eagle River Flats as observed from the ground. Consequently, the fall dabbling duck population is probably underestimated using the model. In turn, the fall duck mortality is probably overestimated.

Table II-2-4. Total dabbling duck populations, duck mortalities, and mortality rates for 2004 through 2010 in Eagle River Flats.

Item	2004	2005	2006	2007	2008	2009	2010
Duck Population	3,659	2,130	4,479	5,279	5,895	4,760	5,245
Mortality Number	111	49	25	35	12	44	22
Mortality Percentage	3.0 %	2.3 %	0.6 %	0.7%	0.2%	0.9%	0.4%

Uncertainties in Waterfowl Population and Mortality Rate Estimates

A number of uncertainties may be involved when determining a mortality rate:

- Inaccuracies in counting waterfowl numbers during the aerial census flights.
- Variable periodicity of aerial flights, which might miss peaks of waterfowl population.
- Application of an average turnover rate instead of a site- and time-specifiec turnover rate.
- Imprecision in counting WP-poisoned waterfowl on the ground:
  - Missing carcasses along a transect.
  - A small contaminated area not covered by a transect.
  - Waterfowl that feed in a known contaminated area (with transects) but fly to another area without transects or are carried to a non-transect area by a scavenger or predator.

- Birds killed by causes other than WP poisoning, but for which no evidence exists to rule out WP poisoning due to post-mortem predation (the feather pile issue).

There is no agreed upon procedure to quantify these uncertainties. The turnover rate calculated from the NWRC telemetry study varied each year of the study from approximately 0.7 to 1, with the average of 0.83. Previously we evaluated the accuracy of the method for calculating total population of ducks using an average turnover value (Collins et al. 2005). During years when actual turnover rates from telemetry data were available, we determined the fall population calculated with both an average turnover rate and actual turnover rates from telemetry data. Population estimates using both methods were similar. Using the aerial survey census data, the average turnover ratio with the NWRC Population Model, and the best professional judgment of the experienced senior staff lead to the belief that the actual fall population of dabbling ducks my vary by plus or minus 20% from the calculated population.

Uncertainties in dabbling duck mortality are related primarily to the limited area covered by the established transects. This uncertainty may skew the mortality count low. However, following the extensive remediation over the last 15 years, the number of contaminated places where waterfowl can feed during fall migration has been tremendously reduced. In addition, other open water areas where waterfowl concentrate, such as Areas B and D, have never been found to be contaminated with white phosphorous (Racine et al. 1992, 1993). An additional uncertainty is related to counting all feather piles as ducks dying from white phosphorus, even without being able to confirm white phosphorus poisoning by laboratory analysis. Inasmuch as very few feather piles have sufficient sample remaining to submit for WP laboratory analysis, the counting of all feather piles as WP-poisoned ducks results in a conservative (perhaps a very conservative) mortality count. This uncertainty may skew the mortality count high. These two major uncertainties may offset each other. Based on field observations, our experience and knowledge of Eagle River Flats and our best professional judgment, we estimate that the duck mortality may be as much as 50% higher than the duck mortalities actually counted on our surveyed transects.

Combining our estimated uncertainties for carcass counts and population estimates produces a range in mortality rates of between 0.3% and 0.8% of the estimated fall 2010 dabbling duck population, bracketing the calculated rate of 0.4% (Table II-2-5). These same ranges of uncertainties are applied to the data since 2004 (Table II-2-6). These data show that the mortality rate has been below the long-term goal of 1% mortality rate of the fall dabbling duck population since 2006.

Table II-2-5. 2010 Mortality rate with estimated error bars.

Parameter	Amount
Fall Population Estimate	5,245
Range in Population Estimate (± 20%)	4,196 – 6,294
Range in Mortalities (+ 50% of those counted)	22 – 33
Calculated Mortality Rate	0.4%
Mortality Rate Range Estimate	0.3% – 0.8%

Table II-2-6. Mortality rates for 2004 – 2010 with estimated uncertainties.

Year	Fall Population Estimates (±20%)	Mortality (+50%)	Calculated Mortality Rate	Mortality Rate Uncertainty
2004	2,927 – 4,391	111 – 167	3.0%	2.5 –5.7%
2005	1,704 – 2,556	49 – 74	2.3%	1.9 –4.3%
2006	3,583 – 5,375	25 – 38	0.6%	0.5 –1.1%
2007	4,223 – 6,335	35 – 53	0.7%	0.6 –1.3%
2008	4,716 — 7,074	12 – 18	0.2%	0.2% – 0.4%
2009	3,808 – 5,712	44 – 66	0.9%	0.7% – 1.7%
2010	4,196 – 6,294	22 – 33	0.4%	0.3% – 0.8%

Figure II-2-4 plots the estimated fall dabbling duck population each year from 1996 through 2010. The range of uncertainties for the population estimates are based on the same assumptions used for the transect mortality analysis above. The figures also show periods of full remediation and limited remediation for reference. Fall duck population numbers were depressed during the years when full-scale remediation was underway, but have rebounded during the last five years.

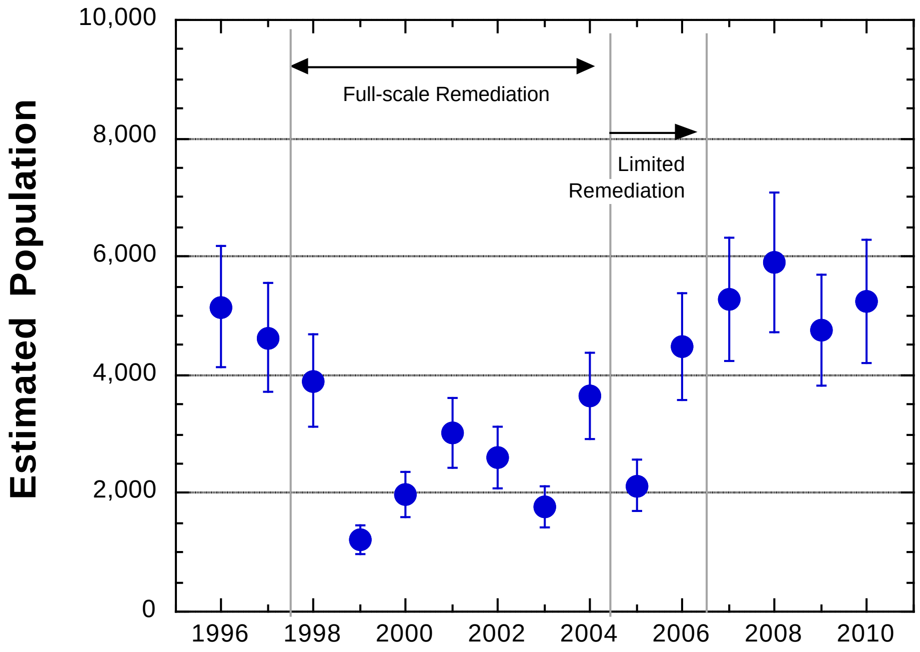

Figure II-2-4. Estimated fall dabbling duck population as determined from the aerial census data collected by the U.S. Fish and Wildlife Service and the NWRC duck population model. Periods of full-scale and limited remediation are shown for reference. The fall duck population numbers were depressed during the years when full-scale remediation was underway, but has since rebounded.

Figure II-2-5 plots the estimated number of duck mortalities each year from 1996 through 2010. Duck mortalities from 1996-2002 were determined from the NWRC telemetry studies. Mortality data are missing for 2000 and 2003 when telemetry studies were not conducted because no helicopters were available to support the project. Mortalities from 2004 through 2010 were determined from ground- based transect surveys. The range of uncertainties for the mortalities are based on the same assumptions used for the transect mortality analysis. However, greater uncertainties are involved with the telemetry methods (NWRC 2004) and actual The range of uncertainties for the 1996-2002 mortalities may be larger.

Figure II-2-6, which combines the duck population and duck mortalities plots, emphasizes that mortality numbers have been dramatically decreasing over the last several years while the duck population has been increasing.

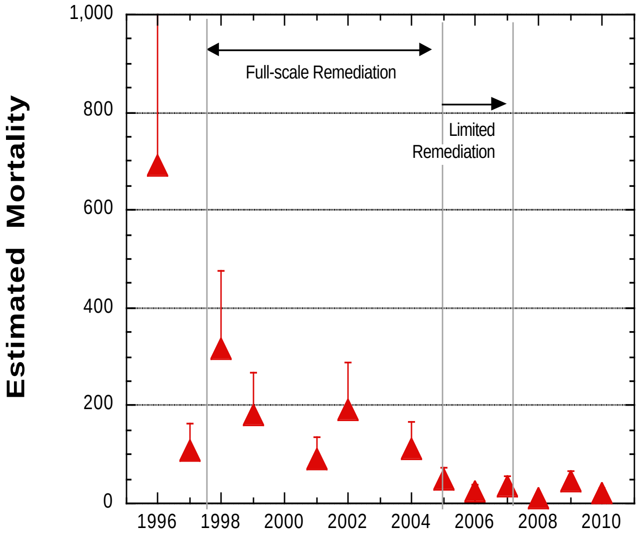

Figure II-2-5. Estimated number of duck mortalities for fall migration periods. Mortalities from 1996—2002 were determined from NWRC telemetry studies. Telemetry studies were not conducted in 2000 and 2003. Mortalities from 2004—2010 are from ground-based transect surveys.

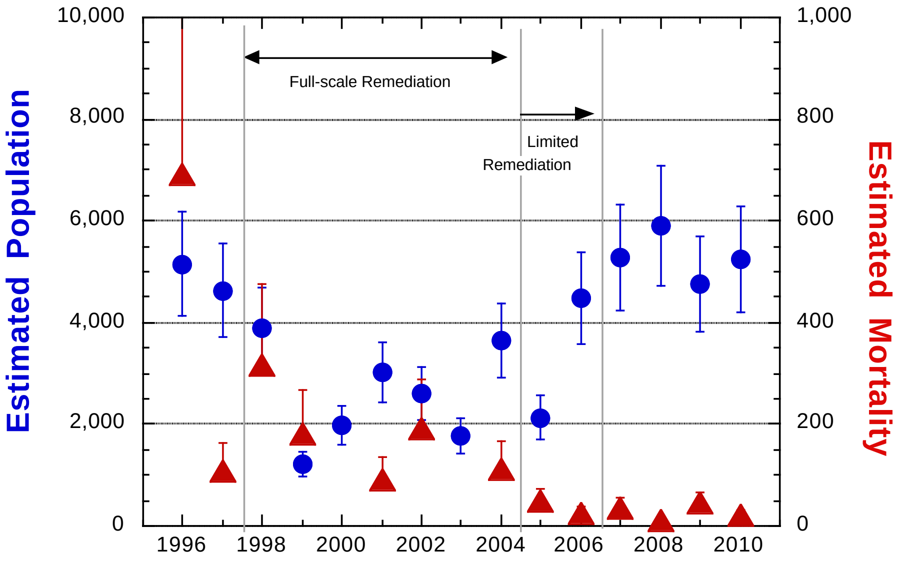

Figure II-2-6. Estimated fall dabbling duck population (circles) and number of duck mortalities (triangles). The number of mortalities continues to remain low despite a recent increase in the fall duck population. Population scale (left) is an order of magnitude higher than the mortality scale (right).

Figure II-2-7 plots mortality rate as a percentage of the total fall dabbling duck population from 1996 through 2010. Again, the range of uncertainties for the 1996-2002 data, determined from the telemetry studies, may be larger than shown. Also shown are the five-year short-term and 20-year long-term Remedial Action Goals. The downward trend in mortality rates is pronounced, with the long-term remedial action goal of less than 1% mortality of the fall dabbling duck population being met in each of the last five years. This reflects the tremendous amount of remediation that has occurred over the last 15 years. In order to truly determine if the 20-year remedial action goal of less than 1% mortality rate has been met, annual monitoring of mortality should continue for the next two years until the next 5-year review. This is especially important if use of Eagle River Flats is changed from the present winter-only use.

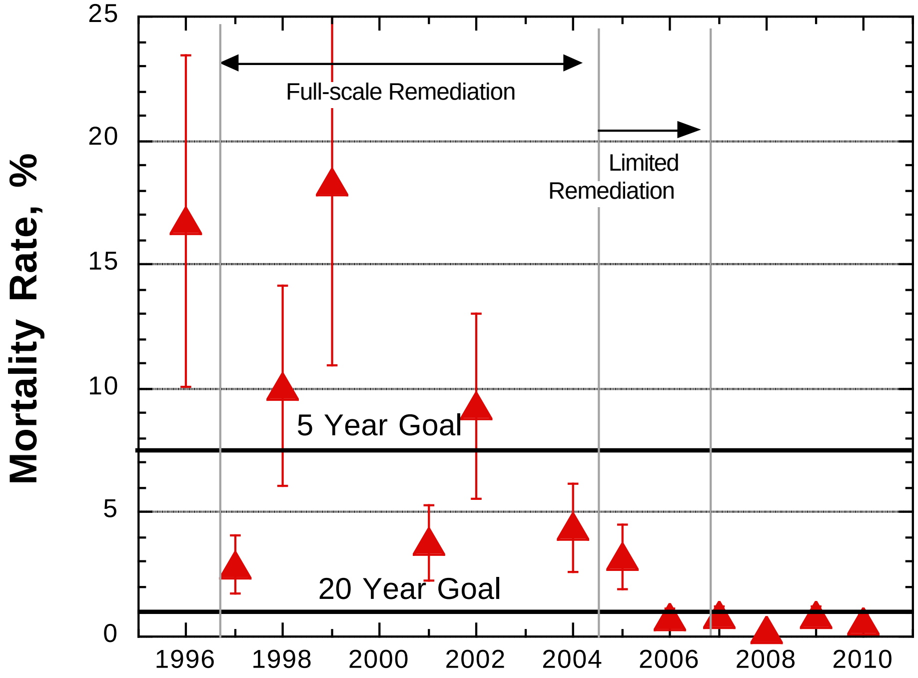

Figure II-2-7. Plot of estimated duck mortality rate as a percentage of fall Eagle River Flats dabbling duck population from 1996 – 2010. Included are the estimated mortality rates from 1996 – 2002 determined with NWRC waterfowl telemetry studies and the 2004 – 2010 mortality rates determined from the ground-based mortality surveys. Missing are data for 2000 and 2003 when waterfowl telemetry data were not collected. Also shown are the 5-year (short-term) and 20-year (long-term) Remedial Action Objectives.

CONCLUSIONS

Waterfowl mortality due to white phosphorus poisoning has decreased significantly in Eagle River Flats following completion of full-scale active remediation of the white phosphorus-contaminated areas. The apparent increase last year over the previous three years was suprising, but we believe it is due to unusually dry conditions during the first half of the fall migration season. Because of the shallower than normal water levels, ducks were able to access small unknown hot spots of contamination in the ponds that would normally have been in deeper water and inaccessible to dabbling ducks. We are gratified to see the mortality decrease from last year as we returned to normal water conditions during the fall migration period. Even with the spike in mortality last year, the mortality rate has been below the long-term Remedial Action Objective of 1% mortality of the fall dabbling duck population for the last five years. Further capping of the few additional areas of identified contamination in March 2011 will further help this trend. However, in order to truly determine if the 20-year remedial action goal of less than 1% mortality rate has been met, annual monitoring of mortality should continue for the next two years. This will be especially important if use of Eagle River Flats is changed from the present winter-only use to more year-round use. Presently, the Long Term Monitoring Plan calls for annual mortality monitoring through 2012, the date of the next Five-Year Review.

REFERENCES

CH2M Hill (1998) Record of Decision for Operable Unit C, Fort Richardson, Alaska. Contract document no. DAC85-95-D-0015, Delivery order 0012. CH2M Hill, Anchorage, AK. Contract Report to U.S. Army Corps of Engineers, Alaska District, and U.S. Army, Alaska. September.

Collins, C.M., M.E. Walsh, B.B. Steele, L.R. Reitsma, J. Zufelt, and A. Staples (2005) 2004 Ground-based waterfowl mortality surveys. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY04 Data Report. Collins, C.M. and D.W. Cate, Eds. ERDC/CRREL Contract Report to U.S. Army Garrison, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 97-110.

Collins, C.M., M.E. Walsh, B.B. Steele, L.R. Reitsma, J. Zufelt, and A. Staples (2006) 2005 Ground-based waterfowl mortality surveys. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY05 Data Report. In Bigl, S.R. and C.M. Collins, Eds. ERDC/CRREL LR-06-6. Contract Report to U.S. Army Garrison, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 19-40.

Collins, C.M., M.E. Walsh, B.B. Steele, L.R. Reitsma, J. Zufelt, and A. Staples (2007) 2006 Ground-based waterfowl mortality surveys. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY06 Data Report. Bigl, S.R. and C.M. Collins, Eds. ERDC/CRREL LR-07-1. Contract Report to U.S. Army Garrison, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 19-42.

Collins, C.M., M.E. Walsh, A. Staples, and J. Zufelt (2008) 2007 Ground-based waterfowl mortality surveys. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY07 Data Report. In Bigl, S.R. and C.M. Collins, Eds. ERDC/CRREL LR-08-04. Contract Report to U.S. Army Garrison, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 23-42.

Collins, C.M., M.E. Walsh, A. Staples, and K. Bjella (2009) 2008 Ground-based waterfowl mortality surveys. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY08 Data Report. Bigl, S.R. and C.M. Collins, Eds. ERDC/CRREL LR-09-02. Contract Report to U.S. Army Garrison, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 23-44.

Collins, C.M., M.E. Walsh, and A. Staples (2010) 2009 Ground-based waterfowl mortality surveys. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY08 Data Report. Bigl, S.R. and C.M. Collins, Eds. ERDC/CRREL LR-10-11. Contract Report to U.S. Army Garrison, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska.. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 23-42.

NWRC (2004) Interim waterfowl mortality monitoring report Operable Unit C–Eagle River Flats Impact Area Fort Richardson, Alaska. Contract Report to U.S. Army Garrison, Alaska, Directorate of Public Works. USDA/APHIS/WS, National Wildlife Research Center, Fort Collins, CO. August 2004. 362 pp.

Racine, C.H., M.E. Walsh, C.M. Collins, S. Taylor, B.D. Roebuck, L. Reitsma, and B. Steele (1992) Remedial investigation report: White phosphorus contamination of salt marsh sediments at Eagle River Flats, Alaska. CRREL Contract Report to USATHAMA (CETHA-IR-CR-92004). U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland.

Racine, C.H., M.E. Walsh, C.M. Collins, D. Lawson, K. Henry, L. Reitsma, B. Steele, R. Harris, and S.T. Bird (1993) Phase II: Remedial Investigation Report: White phosphorus contamination salt marsh sediments at Eagle River Flats, Alaska. CRREL Contract Report to USATHAMA (CETHA-IR-CR-93063). U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland.

U.S. EPA (1995) Method 7580: White Phosphorus (P_4) by Solvent Extraction and Gas Chromatography. In Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846), Update III. 7580-1 to 7580-20, U.S. Environmental Protection Agency, Office of Solid Waste, Washington, D.C.

Walsh, M.E., R.N. Bailey, and C.M. Collins (2007) Long-term monitoring and sampling of sediments of ponds treated for white phosphorus. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY06 Data Report. Bigl, S.R. and C.M. Collins, Eds. ERDC/CRREL LR-07-1. Contract Report to US Army, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 61-112.

Walsh, M.E., R.N. Bailey, and C.M. Collins (2008) Long-term monitoring and sampling of sediments of ponds treated to remove white phosphorus. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY07 Data Report. Bigl, S.R. and C.M. Collins, Eds. ERDC/CRREL LR-08-04. Contract Report to U.S. Army, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 61-114

Table II-2-A1. Detailed data on the 22 duck mortalities in 2010 (page 1 of 2).

ID [1]	Date	Type [2]	Species	Found By [3]	Gizzard Collected?[4]	Northing	Easting	Nearest Landmark
1	8/18/10	FP	Mall	AS, AG, DE	No	355263	6801557	Area C, South sump-Ditch
2	8/19/10	FP	Mall	AS, DE	No	354195	6800598	Area A, just SE of Pond 258 on Path
3	8/27/10	FP	Mall	AS	No	355139	6801546	Area C, SE gravel cap between ditches
4	8/30/10	FP	Mall	AS	No, (tissue -)	355233	6801666	Area C, north ditch, E of gravel cap
5	8/30/10	Carcass	Mall	JP	Yes +	355269	6801520	Area C, NE end of south ditch
6	9/1/10	FP	Pintail?	JP	No, (tissue -)	354899	6801630	Area C, NE side of Pond 730
7	9/3/10	FP	GWT	JP	No	355028	6801182	Area C, tower, pond 183
8	9/7/10	FP	Mall	AS	No, (tissue -)	354856	6801800	Area C, west wing of Pond 730
9	9/7/10	Carcass	Mall	JP	Yes +	354874	6801878	Area C, north tip of Pond 730
10	9/7/10	Carcass	Mall	JP	Yes +	355087	6801580	Area C, north side of north ditch
11	9/7/10	FP	Pintail	AS	No	355166	6801613	Area C, south side of north ditch
12	9/7/10	Carcass	Mall	JP	Yes +	355227	6801655	Area C, north middle of north ditch
13	9/7/10	Carcass	Mall	JP	Yes +	355344	6801703	Area C, north end of north ditch
15	9/17/10	Carcass	Mall	AS	Yes +	354928	6801802	Area C, south side of NE wing of Pond 730
16	9/18/10	FP	Mall	MEW, CMC	No	355238	6801550	Area C, E of cross ditch, W of S sump.
17	9/22/10	Carcass	Pintail	MB	Yes +	354809	6801811	Area C, west wing of Pond 730
18	10/4/10	Just the bill	Mall	MB, LW	No	355019	6801177	Area C. Tower in Pond 183
19	10/4/10	FP	Mall	MB, LW	No	354865	6801851	Area C, NW Pond 730
20	10/5/10	FP	Mall	MB, LW	No	353784	6800770	Area A. NE side of Pond 246
21	10/5/10	FP	Mall	MB, LW	No	353705	6801154	Area A, north tip of Pond 226
22	10/6/10	FP	Mall	MB, LW	No	355298	6801697	Area C, north ditch
23	10/6/10	Carcass	Mall	MB, LW	Yes +	355215	6801609	Area C, center section of ditches

[1] Mort ID Number; [2] FP–Feather Pile;
[3] AS – Ann Staples, AG – Art Gelvin, DE – Don Ebersol, JP – Jessiqua Parker, MB –Matthew Brody, LW – Levi Wood, CMC –Charles Collins, MEW – Marianne E. Walsh
[4] Gizzard or tissue tested negative (–) or positive (+) for WP.

Table II-2-A1. Detailed data on the 22 duck mortalities in 2010 (page 2 of 2).

ID [1]	Date	Type [2]	Species	Found By [3]	Gizzard Collected?[4]	Northing	Easting	Nearest Landmark
In addition the following two swan remains were found. They were not used in determining duck mortality.								
14	9/14/10	Carcass	Trump Swan	AS, JP	Yes +	353753	6800906	Area A, middle of Pond 226
24	10/15/10	FP, wings and legs	Swan Sp	AS, MB	No	355391	6801317	South of the Woodland transect, eaten by wolves

[1] Mort ID Number; [2] FP–Feather Pile;
[3] AS – Ann Staples, AG – Art Gelvin, DE – Don Ebersol, JP – Jessiqua Parker, MB –Matthew Brody, LW – Levi Wood, CMC –Charles Collins, MEW – Marianne E. Walsh
[4] Gizzard or tissue tested negative (–) or positive (+) for WP.

III-1. EAGLE RIVER FLATS LIMITED REMEDIATION OPERATIONS

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INTRODUCTION

The 2010 field season was the seventh year of the monitoring phase for the Eagle River Flats remediation project as set out in the Record of Decision (RoD) signed in October of 1998 (CH2M Hill 1998). Since the 2003 season, limited active (pumping) and passive (controlled draining) remediation operations have been conducted to address the remaining known locations of white phosphorus (WP or P_4) contamination. Residues from the detonation of several white phosphorus rounds and the number of mortalities in the Northern C-Marsh and Pond 730 are indicators that persistent contamination occurs in these areas (Figure III-1-1).

C-Marsh area requires remediation to fulfill the mortality endpoint obligation of the RoD. The RoD specifies the use of pumping to remove overlying water in contaminated areas to conduct active remediation. When active remediation is no longer feasible from a technical and economic standpoint, capping is to be conducted. With the fall in the median mortality rate to the remediation goal of <1% in 2006 and 2007, the remediation project managers decided to put active pumping remediation efforts on hold and concentrate project resources on capping the remaining hot spots. After a successful test of capping a small, contaminated pond near the intersection of Areas C, D, and Bread Truck in the winter of 2007, we conducted winter capping operations on a larger scale in 2008 and 2009. Capping operations were canceled in 2010 after heavy equipment broke through the ice off Clunie Point.

Improvements to the site and our procedures continue to be implemented. Fuel theft was once again a problem this year, probably due to the increase in diesel fuel prices but also because Range Control will not allow us to chain off access to the equipment. We are now able to place the pump in the sump at Pond 146 directly with a sky-lift, eliminating the need for any helicopter support. We continue to assume a greater range of tasks related to operations, reducing both costs and time required to fulfill the mission.

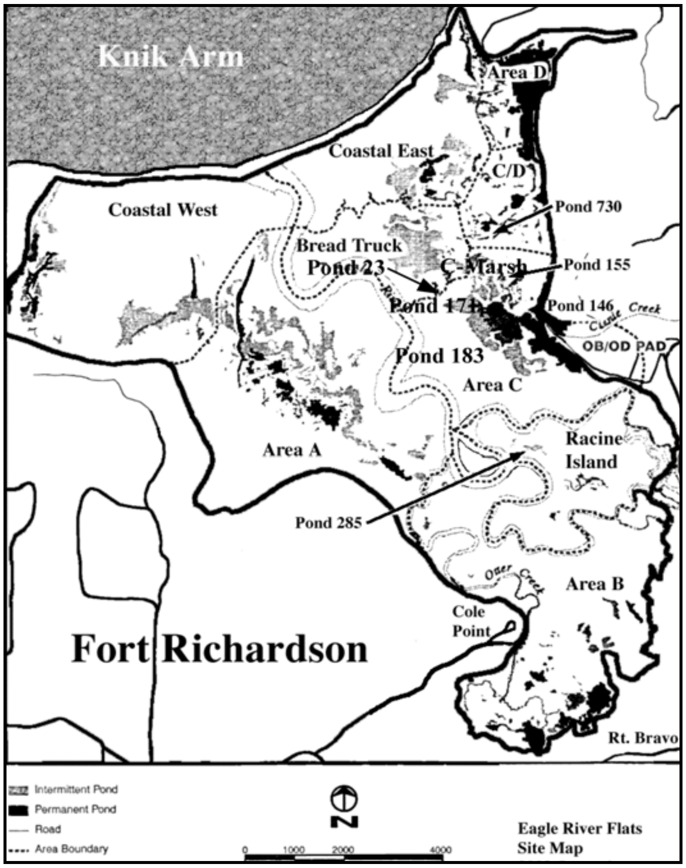

Figure III-1-1. Map of Eagle River Flats showing areas and pond identification numbers.

Since the active remediation efforts have stopped, the pump systems are not needed to drain and treat contaminated areas. However, to ensure ease of mobility and to enhance on-site safety, the deployment of a single pumping unit continues for the periods over which sampling activities are to be conducted. Appendix III-1-A provides a synopsis of our work at ERF this year.

DEPLOYMENTS AND IMPLEMENTATION

Capping

The first deployment of the year was in mid-March to conduct the capping of the contaminated craters, ponds, and ditches in northern C-Marsh. Six sites were identified as containing sufficient WP to be a hazard to wildlife and marked with fiberglass markers the previous fall. The objective was to cap as many of these locations as feasible while ERF was covered with ice. A thick ice cover usually forms each winter through successive tidal flooding and allows safe access to the sites by heavy equipment.

In anticipation of the capping work, about 300 cubic meters of 3” (8-cm) minus clean crushed ballast had been stockpiled at the entrance to the EOD Pad. Prior to the heavy equipment arrival, access lanes to the various sites were swept with a magnetometer by a UXO technician. Ice thickness was measured at several locations using a manual auger and tape measure. Water lenses within the ice off Clunie Point caused some concern but it was felt that the overall ice thickness was sufficient to attempt a deployment. Snow cover was unusually thick this year (March 2010). The snow both weighed down the ice, causing minor flooding, and insulated the underlying ice and water, preventing quick freeze back. The dozer was sent out ahead to plow the access lanes over the ice because of its low ground pressure. After it was out about a half hour, the loader was taken out to widen the plowed roads. The loader almost immediately broke through a thin section of ice (Figure III-1-2). The dozer returned and winched the loader back onto the ice. Both pieces of equipment were returned to Clunie Pad as the dozer had also been breaking through the ice. We returned the next day after a cold, windy night, and rechecked the ice thickness. It was insufficient to permit safe operations, and following the recommendation of our UXO technician we called off operations for the year.

Figure III-1-2. Loader off Clunie Point with wheels through the ice.

Pumping

Active remediation at ERF has been put on hold pending the results of a five-year trend analysis of the mortality rate among dabbling ducks. The goal of <1%

of the fall population dying from white phosphorus poisoning has been met since 2006, but in 2009 the margin was very slim: 0.9%. In 2010, the mortality rate fell to 0.4%, near the low of 0.2% achieved in 2008. When the estimated error is taken into account, the mortality rate ranges are 0.5 – 1.1% in 2006, 0.6 – 1.3% in 2007, 0.2 – 0.4% in 2008, 0.7 – 1.7% in 2009, and 0.3 – 0.8% in 2010 (Collins et al. 2010, Collins et al. in this report). The calculated mortality rate 5-year running average is <0.6%, with a worst-case 5-year running average of just over 1%. A spike in the mortality rate may cause us to not achieve the goal in any particular year or over the five-year running average, which could result in the requirement of additional active remediation by pumping. For this reason, pumping has not been halted, and we retain the capacity to redeploy pump systems in a remediation capacity.

Although active remediation is not being conducted, other activities are still occurring at ERF over the summer. These include sampling and monitoring, mostly in Area C south of the Bread Truck and in Pond 730. These areas can be at least partially drained by a pump located in the Pond 146 sump located off the EOD Pad. The project managers believed that placing a pump in Pond 146 would expedite sampling and increase the safety of the operations by allowing easier access to work areas and better visibility of any UXO.

The deployment for the pumping project occurred in mid-May 2010. Water levels were unusually low at ERF when we arrived. On 13 May, the equipment was transported to ERF. On 14 May, System 3, which has a theoretical capacity of up to 189 L/s (3000 gpm), was installed in Pond 146 using the sky lift. The pump was test run at 189 L/s without any problems. On 15 May, the system was not operating properly. Troubleshooting the system revealed a bad timing relay on the pump start circuit and a float switch lead that had been chewed through by the resident muskrats. Both components were replaced and the system was back in operation in a few hours. By the morning of 16 May, the pump as cycling. The switches were adjusted, and by that afternoon the area was pumped down. The system was fully fueled, with 1,896 liters (500 gals) delivered on the 15th. The system was shut down on 24 May after 45 hours of operation. The fuel levels were 7/16 full in the mobile tank with a full 500-gal backup tank.

We returned to ERF on 16 September. The spare fuel tank was down substantially, missing about 300 gallons. Range had cut the cable we had put across the road to restrict access and prevent fuel theft and we were not allowed to replace it. The pump was reactivated at 189 L/s. Shortly after, a clamp on the 12” discharge hose leading off the pump gave out and we shut the system down for repairs. Replacement clamps were installed and the system restarted. An inspection of the discharge line revealed another broken clamp near the discharge end of the line. This joint was not under pressure and was repaired the following day. The remaining fuel from the secondary tank was pumped to the mobile tank, raising the level from <1/4 full to about 3/8 full. On 18 September, the generator was shut down at 1420 hrs to conserve fuel over the weekend. There was only

1/8 tank remaining. The system was reactivated at 0900 hrs on 20 Sept and ran for six hours before running out of fuel. At the time, the pump was starting to cycle, indicating the area had been drawn down if not completely drained.

At this time, we carried out maintenance on the equipment. The two power cables were shortened to facilitate assembly and disassembly of the system. The same was done for the main switch feedback cable from the control to the pump. The pump and double wall tank were moved to the Conex storage area on the EOD Pad and the mobile tank and genset moved to the Environmental Storage Yard off Otter Creek Road. The remainder of the fuel, water, and sludge were drained out of the mobile fuel tank and the vessel flushed with clean diesel fuel drained from the tank earlier. Over 5 gallons of water and rust-laden sludge were removed from the tank and sent to waste control on Fort Richardson. Oil and filters were changed out of the genset on 23 September. The next day, maintenance was performed on the System 3 pumps. All pumps except the System 3 pump were moved to the CRREL yard at Building 992.

Figure III-1-3. Leveled genset pad from Spur Road extension.

EVALUATION

No areas were capped during 2010 because of unsafe ice conditions on Eagle River Flats. Thick snow and recent flooding tides had softened the ice resulting in weak areas located in several widely dispersed areas on ERF. We attempted to operate on two days, but conditions were such that, heeding the advice of our UXO technician, we halted operations.

Appendix III-1-B gives an abbreviated historical chronology of all pumping operations starting in 1997 through the current year. **Table III-1-1** gives the statistics for this year's pump operations.

Table III-1-1. 2010 Pump operation statistics.

Parameter	Start	Stop	Total
Genset Hours	4239	4339	100
Pump 1* Hrs	2829.4	2908.8	79.4
Pump 1 Cycles	8811	8899	88
Pump 2* Hrs	1382.7	1454.7	72
Pump 2 Cycles	995	1016	21
Fuel Status (gals)	≈800	0	800**

*Pump 1: 2000 gpm / 126 L/s, Pump 2: 1000 gpm / 63 L/s.

** Approximately 300 gallons lost due to fuel theft on the site.

The 2010 season was a mixed success. The capping operation had to be cancelled because of insufficient ice, and we had to shut the pump system down early because of fuel theft. The operation of the pump system to support sampling and monitoring was successful, though, enabling a safer environment and more efficient operations. As a result of shutting the pump system down between the May and September deployments, we conserved enough fuel to draw down the operating areas for the fall deployment. Some maintenance was conducted on the pump system over the summer, a reflection of the age and use of the equipment. Based on feedback from other project coordinators, we recommend deploying the pumps next season.

BEYOND THE 2010 SEASON

Based on the preliminary results of the 2010 season, the likelihood that active remediation using pumping will be required in the future is low, unless the situation changes on ERF. A single pump, used for limited time periods and based in Pond 146 to support the monitoring activities will continue to be needed. We do recommend, however, that the additional pump systems be kept in inventory and operationally available as a contingency measure in case training activities at ERF disturb any white phosphorus residues and we find it necessary to address the contamination with pumping.

We are planning to address the contaminated areas not capped in March 2010 as well as additional contaminated areas discovered during the 2011 field season. The ballasting rock remains stockpiled on the EOD Pad.

REFERENCES

CH2M Hill (1998) Record of decision for Operable Unit C, Fort Richardson, Alaska. Contract document no. DAC85-95-D-0015, Delivery Order 0012.

Collins, C.M, M.E. Walsh, A. Staples, and J.E. Zufelt (2010) Ground-based waterfowl mortality surveys. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. Bigl, S.R. and C.M. Collins, Eds. ERDC/CRREL LR-10-11. Contract Report to U.S Army, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. pp. 23-42.

Cummings, J.L., P.A. Pipas, C.H. Racine, R.E. Johnson, J.B. Bourassa, J.C. Carlson, K.H. Sheffer, K.L. Tope, and J.E. Davis (2003) Movement, distribution, and relative risk of mallards using Eagle River Flats. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY02 Final Report. Collins, C.M. and D.W. Cate, Eds. CRREL Contract Report to U.S Army, Alaska, Directorate of Public Works. pp. 23–43.

APPENDIX III-1-A. CHRONOLOGY OF EVENTS FOR THE 2010 SEASON

Date	Event
January	Develop pumping, capping, monitoring, and sampling master schedules
March	Schedules to appropriate parties. 9-10 MAR: Mobilize for capping ops: Briefings, organizing, and clearing areas. 11 MAR: Plowed access to EOD Pad, Clunie Pad. Started clearing roads to capping sites on flats. Ice thickness variability problems. 12 MAR: Checked ice thickness again. Insufficient. Cancelled operations. 13 MAR: Demobilization.
May	12-13 MAY: UXO clearance. Stage / set up pump equipment. 13 MAY: Test fired genset. Maintenance on genset (fuel hoses). 14 MAY: System operational and running. 15 MAY: Maintenance work on system. Replaced low water switch on pump and timer relay on genset. 16 MAY: Pump cycling. 24 MAY: Pump shut down.
September	16 SEP: Pump restarted 20 SEP: Pump shutdown for season. Out of fuel. 21 SEP: Shortened power and control cables. Start breaking down equipment. 22 SEP: Pulled pump. Stored on spare tank and pump on EOD Pad. Discharge line repair and maintenance. 23 SEP: Maintenance on generator performed. Cleaned out mobile fuel tank. 24 SEP: Pump maintenance. Cleaned up EOD Pad. Other pumps to 992 yard. End of season.

APPENDIX III-1-B. SYSTEM DEPLOYMENT DATA FOR PUMPING PROJECT

Appendix B contains a brief history of pumping activity since the start of large-scale pump tests during the remediation investigation phase of the project. The period of full-scale remediation occurred from 1999 through the 2003 season.

Table III-1-B-1. Pond pumping activity at ERF.

Year	Start Date	Stop Date	Pond	Pond Area (Ha)	Duration (Days)	Description	Predicted Flood Tides	Flooded (Days)	O&M Support
1997	16-May	13-Sep	183	2.87	121	System 1: 126 L/s	20 - 24 Jul	7	CH2M Hill
							18 - 23 Aug	10	
1998	1-Jun	27-Aug	183	2.87	88	System 1: 126 L/s	23 -25 Jun	0	CH2M Hill
	25-Jun	27-Aug	258	1.72	64	System 2: 126 L/s	1-12 Aug	5	
	27-May	28-Aug	146	5.54	94	Sys. 3: 63/126/189		(No flood in Area A)	
	23-Jun	27-Aug	256	0.39	66	System 4: 126 L/s			
	28-May	27-Aug	290	0.91	92	System 5: 126 L/s			
	1-Jun	27-Aug	155	0.35	88	System 6: 63 L/s.			
1999	26-May	21-Sep	183	2.87	129	System 1: 126 L/s	12 - 17 Jun	7	Weldin
	27-May	21-Sep	730	0.78	128	System 2: 126 L/s	12 - 15 Jul	0	
	21-May	23-Sep	146	5.54	136	Sys. 3: 63/126/189	11 - 13 Aug	0	
	26-May	21-Sep	258	1.72	129	System 4: 126 L/s			
	27-May	21-Sep	256	0.39	128	System 5: 126 L/s			
	26-May	21-Sep	155	0.35	129	System 6: 63 L/s.			
2000	11-May	15-Aug	183	2.87	97	System 1: 126 L/s	2 - 5 Jun	0	Weldin
	11-May	16-Aug	258	0.39	98	System 2: 126 L/s	1 - 5 Jul	5	
	8-May	17-Aug	146	5.54	102	Sys. 3: 63/126/189	30 Jul-3 Aug	10	
	11-May	16-Aug	256	1.72	98	System 4: 126 L/s			
	12-May	16-Aug	730	0.78	97	System 5: 126 L/s			
	11-May	17-Aug	155	0.35	99	System 6: 63 L/s.			
2001	10-May	8-Sep	183	2.87	122	System 1: 126 L/s	21 - 24 Jul	7	Weldin
	10-May	8-Sep	75	0.1	122	System 2: 126 L/s	19 - 23 Aug	9	
	3-May	13-Sep	146	5.54	134	Sys. 3: 63/126/189			
	10-May	8-Sep	730	1.72	122	System 4: 126 L/s			
	10-May	8-Sep	246	1.32	122	System 5: 126 L/s			
	10-May	8-Sep	155	0.35	122	System 6: 63 L/s.			

Table III-1-B-1 (cont.). Pond pumping activity at ERF.

Year	Start Date	Stop Date	Pond	Pond Area (Ha)	Duration (Days)	Description	Predicted Flood Tides	Flooded (Days)	O&M Sup-port
2002									
	30-May	22-Aug	BC	–	86	System 1: 126 L/s	25 -28 May	2	Weldin
	18-May	22-Aug	75	0.1	97	System 2: 126 L/s	10 -12 Aug	2	
	15-May	27-Aug	146	5.54	105	Sys. 3: 63/126/189			
	18-May	22-Aug	246	1.32	97	System 4: 126 L/s			
	20-May	22-Aug	730	1.72	95	System 5: 126 L/s			
	20-May	22-Aug	155	0.35	95	System 6: 63 L/s.			
2003									
	24-May	10-Sep	C-So	–	110	System 1: 126 L/s	14 - 15 Jun	2	Weldin
	24-May	10-Sep	C-No	–	110	System 2: 126 L/s	30 - 31 Jul	1 (?)	
	19-May	10-Sep	146	5.54	116	Sys. 3: 63/126/189			
	24-May	10-Sep	730	1.72	110	System 4: 126 L/s			
	24-May	10-Sep	BC	–	110	System 5: 126 L/s			
	24-May	10-Sep	155	0.35	110	System 6: 63 L/s.			
2004									
	13-May	28-Aug	146	5.54	106	Sys. 3: 63/126/189	3-4 June	12	CRREL
							3-4 July	7	
							1-2 Aug	4	
2005									
	21-May	14-Sep	146	5.54	117	System 3: 126 L/s*	22-25 July	10	CRREL
	26-May	13-Sep	BC	–	111	System 5: 126 L/s	19-23 Aug	10	
2006									
	15-May	29-Aug	146	5.54	107	Sys. 3: 63/126/189	10-14 Aug	12	CRREL
	19-May	28-Aug	C-So		102	System 4: 126 L/s			
	19-May	28-Aug	BC	–	102	System 5: 126 L/s			
2007									
	21 May	25 Aug	146	5.54	34**	Sys. 3: 63/126/189	None	0	CRREL
	24 May	23 Aug	BC		91	System 4: 126 L/s			
	24 May	22 Aug	C-So	–	90	System 5: 126 L/s			
2008									
	6 Jun	11 Jun	146	5.54	6	Sys. 3: 63/126/189	None	0	CRREL
	19 Aug	27 Aug	146	5.54	9	Sys. 3: 63/126/189	None	0	CRREL
2009									
	16 May	27 May	146	5.54	12	Sys. 3: 63/126/189	None	0	CRREL
	10 Sep	16 Sep	146	5.54	7	Sys. 3: 63/126/189	None	0	CRREL
2010									
	14 May	24 May	146	5.54	10	Sys. 3: 63/126/189	None	0	CRREL
	16 Sep	20 Sep	146	5.54	10	Sys. 3: 63/126/189	None	0	CRREL

**63 L/s Pump down for the season shortly after start up.

III-2. SEDIMENT SAMPLING AND MONITORING FOR WHITE PHOSPHORUS

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INTRODUCTION

Sampling of sediment was performed in Eagle River Flats in May and September of 2010 to meet the same objectives as in the past few years.

1. Assess continued clean status of ponds previously remediated using pond pumping. Determine if there is a rebound in contamination due to exposure of buried white phosphorus (WP) residue.
2. Determine if the gravel caps placed over isolated small areas of white phosphorus contamination completely covered the white phosphorus-contaminated sediments.
3. Locate any remaining small areas of white phosphorus contamination not previously identified.

METHODS

Sediment Samples

Multi-increment sampling methods were developed to monitor white phosphorus at Eagle River Flats and have been described in detail in previous reports (Walsh et al. 2008). Three types of multi-increment samples were collected in 2010 to meet the objectives above.

The grid multi-increment sampling method was developed in 1996 (Walsh et al. 1997) as an alternative to using penned sentinel ducks to determine if sufficient WP mass to poison waterfowl was present in a defined area. The spacing between increments was 1.82 m, which coincides with a 10% chance of missing a 2-m diameter white phosphorus-ordnance impact point, if one exists (Gilbert 1987, Walsh et al. 1997). Several 5.46 × 20-m decision units were established in various ponds between 1997 and 2000; these decision units have been re-sampled over the years. In 2010, grid multi-increment samples were collected from decision units within Area C Ponds 183, 171, and 155 and in Area BT Pond 109 (Figure III-2-1).

Figure III-2-1. Aerial image (Aero-Metric 2010) with pond identification numbers for ponds sampled in 2010.

Systematic-random multi-increment samples are used to sample larger decision units and linear features such as drainage channels and the perimeter of gravel caps. They are formed by collecting sediment aliquots at evenly spaced intervals (e.g., one to two meters) starting at a random location within a decision unit. This method was used in 2010 to sample around the perimeter of the gravel caps, in drainage channels in Area C, in Pond 730, and in previously unsampled water-covered areas on Racine Island (Figure III-2-1).

Sieved multi-increment samples were used to sample large areas (entire ponds) and to intensively sample smaller areas by taking increments of sediment at 1- to 2-m intervals and placing them in a sieve bucket (0.59 mm mesh). The sediment was stirred underwater during collection to remove the fine grain fraction. The mesh retains white phosphorus particles that, if present, would pose significant hazard to waterfowl. This method was used in 2010 in Ponds 226 and

258 in Area A at two locations where white phosphorus was detected in the 1990s (Figure III-2-1).

At magnetic anomalies, discrete samples were collected to determine if the metal was a white phosphorus ordnance item. Each discrete sample was composed of at least 120-mL of sediment collected adjacent to the metal ordnance item. Sediment next to metallic anomalies was collected in Pond 730, on Racine Island, and in a gully in Coastal East.

Ordnance Survey

Sampling in 2003 and 2004 showed that high white phosphorus concentrations are co-located with white phosphorus ordnance scrap. In 2010, our UXO technician performed surveys for metallic scrap using a Schonstedt in and around each of the ponds that we sampled and along the eroding banks of Coastal East and Coastal West.

Laboratory Analysis of Sediments for White Phosphorus Residues

All samples were stored at 4°C in the dark and were tightly sealed to prevent loss of moisture. Samples were analyzed using procedures described in EPA SW-846 Method 7580 [White Phosphorus (P_4) by Solvent Extraction and Gas Chromatography]. Each whole sediment multi-increment sample (0.6–3.8 kg) was thoroughly mixed by stirring and kneading. The wet sample was spread to a thickness of 1 cm, then at least 30 small aliquots were taken to form a 200-g subsample. Sufficient water was then added to form a slurry. Discrete samples were thoroughly mixed and then a 40-g portion of the sediment was mixed with water to form a slurry. Sieved multi-increment samples were not subsampled. Instead, the entire sample was transferred to a sufficiently large glass jar and enough water added to cover the sample.

The presence of white phosphorus was determined using solid-phase microextraction and gas chromatography. If white phosphorus was detected, the white phosphorus concentration was estimated by extracting the white phosphorus from the sample with solvent (isooctane) and analyzing the extract by gas chromatography (nitrogen–phosphorus detector). The gas chromatograph was calibrated daily using freshly prepared standards in the range of 1.8 to 88 µg/L. A linear calibration model was used to calculate the white phosphorus concentrations in the sediment extracts. If needed, extracts were diluted with isooctane to be within the calibration range.

RESULTS AND DISCUSSION

Sediment Sampling in Remediated Ponds to Assess Continued Clean Status

Pond 183

Pond 183 is the large (2.9 hectare) permanent pond (Figure III-2-1), formerly known as “C Pond.” This pond was the focus of many investigations in the 1990s due to high waterfowl mortality within and around the pond and widespread white phosphorus contamination. In the summer of 1997, Pond 183 was dewatered during the pond pumping treatability study. Due to the success of that study, the pond was subsequently pumped for several more years during the full-scale remediation phase. In the most heavily contaminated part of this pond, we demonstrated in 1996 that grid multi-increment (then called “composite”) sampling was much more efficient and preferable to using penned ducks for detecting white phosphorus (Walsh et al. 1997).

In 1997 to 2001, 2003, 2008, and 2009 we sampled the same decision unit and documented the decline in white phosphorus concentrations (Table III-2-1). White phosphorus has been not detectable since 2001 and was not detectable when we sampled again in September of 2010 (Table III-2-1), confirming the continued clean status (Appendix Table III-2-A1). Additionally, hundreds of ducks were observed feeding in this pond on 18 September 2010 when persistent fog prevented them from migrating out of ERF. The fact that so many ducks can feed in this pond without any observed mortality (accumulation of waterfowl carcasses) is evidence that the surface sediments are remediated.

The west side of Pond 183 and the adjacent intermittent pond are near a target array for live-fire training. The tail assemblies from mortar projectiles (Figure III-2-2) and fresh craters are evidence of this training. The sediment within and around fresh impact craters should be monitored for white phosphorus that may be brought to the surface by detonations.

Pond 146

Pond 146 is a permanent pond (5.5 hectare) on the east side of Area C (Figure III-2-1). This pond was used for the dredging treatability study in 1994 to 1996, and then it was pumped annually beginning in 1998. Two decision units have been monitored since 1999. The sediments of Pond 146 dried sufficiently after pumping to remove the white phosphorus, and concentration have been below the method detection limit since 2002. Pond 146 was not sampled in 2010, but we did monitor water levels (Figures III-2-3 and III-2-4). This pond has a low threshold for flooding. The pond refilled when the predicted tide height was 30.4 ft. (Anchorage Tidal Datum) which corresponds to a mean sea level of 14.5 ft (4.4 m). This pond is heavily used by waterfowl. Ducks were routinely observed within this pond during the time that the sampling team was present (14 – 21 May 2010 and 18 – 23 September 2010). Again, there was not observed waterfowl mortality.

Table III-2-1. White phosphorus concentrations found in grid multi-increment samples collected from decision units in Area C. Data are shown for all field replicates.

Location	Date	White Phosphorus Conc. (µg/g)
Pond 183 (C 100m)	4 June 1997	0.019, 0.061, 0.069, 0.073, 0.085
	4 September 1997	0.0054, 0.0063, 0.0063, 0.0065, 0.010
	22 August 1998	0.0054, 0.0061, 0.0074, 0.0084, 0.044
	15 September 1999	0.0011, 0.0021
	16 August 2000	0.00042, 0.00067
	11 September 2001	0.0001†, 0.0002
	15 September 2003	<0.0002, <0.0002
	25 August 2008	<0.0002, <0.0002
	16 September 2009	<0.0002, <0.0002
	23 September 2010	<0.0002, <0.0002
Pond 155	21 August 1998	0.023
	7 June 1999	0.45
	14 September 1999	0.018, 0.015
	19 August 2000	0.034, 0.044
	8 September 2001	0.0052, 0.0044
	26 August 2002	0.0034, 0.0082
	13 September 2003	0.0012, 2.25
	24 May 2005	0.006, 0.32
	8 September 2005	0.0006, 0.0022
	28 August 2006	0.0056, 0.0013
	23 August 2007	<0.0002, 0.0002
	20 August 2008	0.0005, 0.0023
	16 September 2009	<0.0002, <0.0002
	18 September 2010	0.0003, 0.0009
Pond 171	17 May 2000	0.029
	11 September 2001	0.0008, 0.0055
	26 August 2002	0.01, 0.0005
	11 September 2003	0.0002, <0.0002
	28 August 2006	<0.0002, <0.0002
	22 August 2008	<0.0002, <0.0002
	16 September 2009	<0.0002, <0.0002
	18 September 2010	<0.0002, <0.0002

†Detected but below method detection limit (0.0002 µg/g)

Figure III-2-2. Evidence of winter training on the west side of Pond 183 (image from 2009)

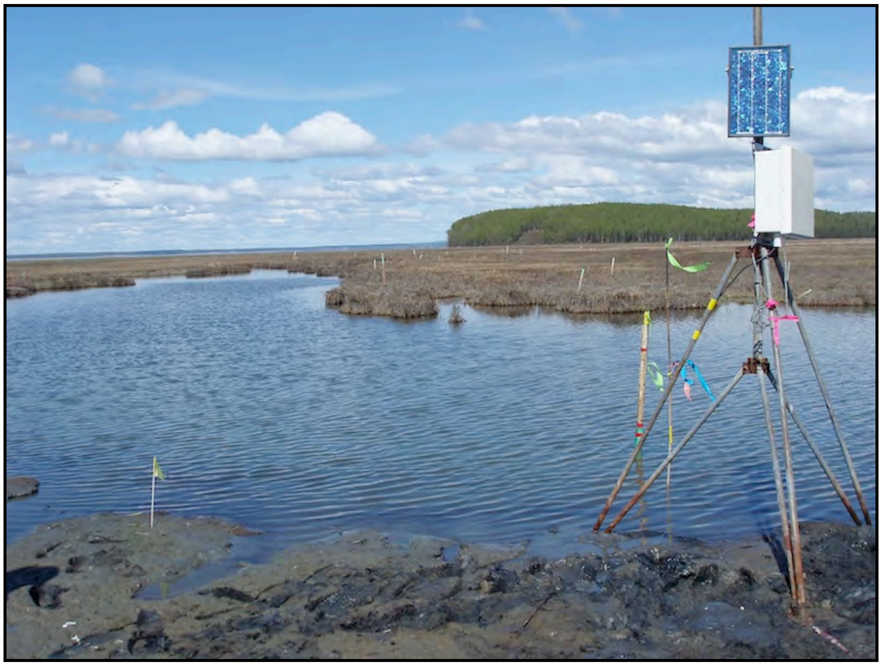
Pond 155

Pond 155 is a small (0.35-hectare), permanent pond located within the bulrush marsh in northern Area C (Figure III-2-1). It is connected to the western end of the south drainage ditch in the C Marsh. White phosphorus has persisted in the surface sediment despite some desaturation of the surface sediment by pond pumping. Drying the sediment in this pond was never as extensive as in Ponds 183 and 146. No white phosphorus ordnance scrap has been found in this pond; although white phosphorus ordnance scrap and white phosphorus unexploded ordnance has been found nearby. Samples collected in 2008 had low concentrations of white phosphorus (Table III-2-1), but white phosphorus was not detectable in 2009. In 2010, low concentrations of white phosphorus were detected again. Annual monitoring of this pond should continue for several years because this pond appears to have a source of white phosphorus in the underlying sediments.

Pond 171

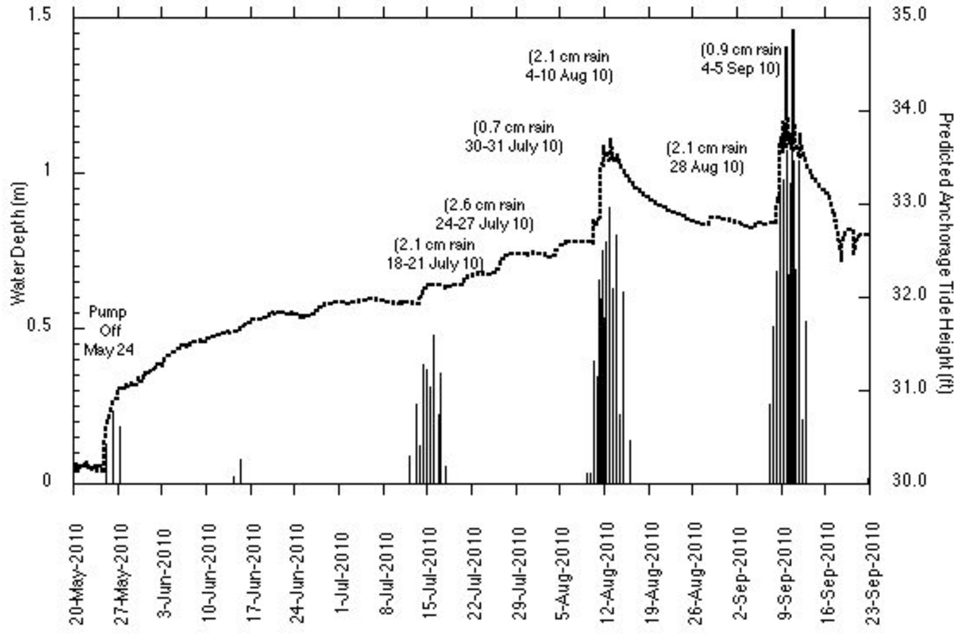
Pond 171 is a small (0.6-hectare), permanent pond located between Pond 183 and the bulrush marsh in northern Area C (Figure III-2-1). White phosphorus was detected within this pond in May 2000 and white phosphorus ordnance scrap was found in the subsurface sediment in 2004 within the 5.46 × 20-m decision unit. Shallow drainage ditches were extended to this pond in 2001 so that it could be drained by the pump located in Pond 146. By 2003, the white phosphorus concentrations had declined to the detection limit in one field replicate and below the detection limit in the other. White phosphorus was not detectable in samples collected in 2006, 2008, 2009, nor 2010 within the decision unit (Table III-2-1).

a. Pond 146

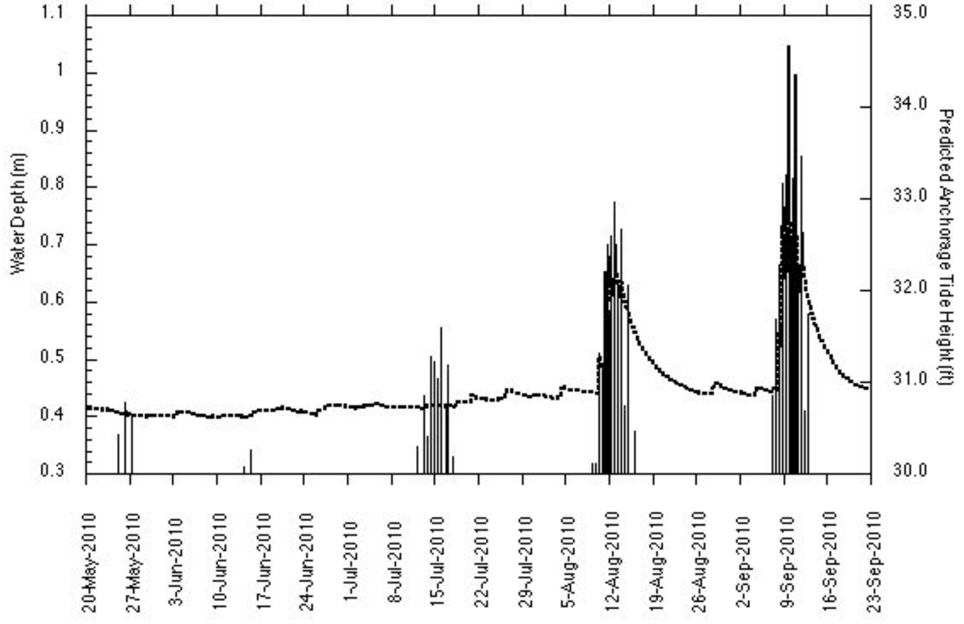


b. Pond 730

Figure III-2-3. Dataloggers to monitor water levels in Ponds 146 and 730 (images taken in May 2010)



a) Pond 146



b) Pond 730

Figure III-2-4. Water levels measured in Ponds 146 and Pond 730 plotted with the predicted Anchorage tide height.

Pond 109

Pond 109 was a large (3.3-hectare), permanent pond (Figure III-2-1) that was drained in 1996 by the extension of a naturally advancing gully. Prior to draining, waterfowl mortality was high, as was predation of poisoned ducks by scavengers. In 1997, the results from multi-increment grid sampling indicated that the highest white phosphorus concentrations were in the middle of the pond. Two decision units that were sampled in 1997, labeled BT South 100-m and BT North 100-m, have been sampled several times. Samples have not been collected from BT North 100-m since 2003 due to the dramatic change in habitat from a shallow pond, to a bare mudflat to a halophytic wet meadow. White phosphorus was undetectable in 2001 and 2003, and we have no reason to suspect that the surface sediments would present a risk to waterfowl.

We have continued monitoring the BT South 100-m decision unit (Figure III-2- 5) where the white phosphorus concentrations declined below the method detection limit by 2001. White phosphorus was undetectable in 2003, 2008, 2009, and 2010 (Table III-2-2). Like Area C Pond 183, this pond is near a target array and future monitoring should include sediment sampling of fresh craters.

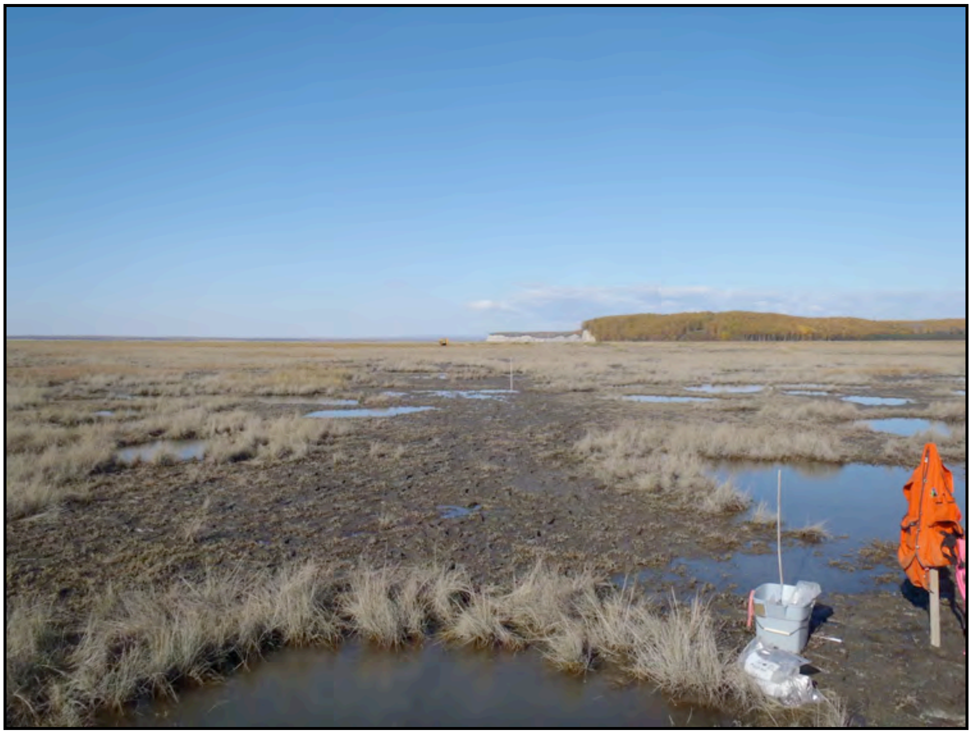


Figure III-2-5. View across former Pond 109 looking north over BT South 100-m decision unit in September 2010.

Table III-2-2. White phosphorus concentrations found in grid multi-increment samples collected from decision units in the Bread Truck Pond. Data are shown for all field replicates

Location	Date	White Phosphorus Conc. (µg/g)
BT South (100-m)	4 June 1997	0.0030, 0.0033, 0.0040, 0.0061, 0.0079
	4 September 1997	0.0006, 0.0007, 0.0009, 0.0011, 0.0012
	22 August 1998	0.0008, 0.0010, 0.0015, 0.0024, 0.012
	15 September 1999	0.0005, 0.008
	18 August 2000	0.00023, 0.00026
	10 September 2001	<0.0002, <0.0002
	16 September 2003	<0.0002, <0.0002
	22 August 2008	<0.0002, <0.0002
	16 September 2009	<0.0002, <0.0002
	23 September 2010	<0.0002, <0.0002

Area A

Area A, located on the west side of the Eagle River, was sampled extensively during the 1990s and early 2000s and low concentrations of white phosphorus were found sporadically. Five permanent ponds were treated by pond pumping between 1998 and 2004. White phosphorus was not detected in the ponds after they were treated. However, we did find a 155-mm WP projectile at the edge of an intermittent pond in Area A in 2006, and at least some waterfowl carcasses are found most years along the mortality monitoring transects. Even though the presence of waterfowl carcasses has not proven to be a true indicator of white phosphorus in the sediments because ducks can fly for at least several hours after ingesting white phosphorus, we continued the search for a source of white phosphorus in the permanent ponds of Area A in 2010.

In 2010, we chose to focus on specific locations within two ponds in Area A where some white phosphorus was detected in 1998 and 1999 (Figure III-2-6). These ponds were sampled before we learned of the co-location of white phosphorus residue and at least part of the original white phosphorus projectile. Ponds 226 and Ponds 258 were sampled previously using the grid multi-increment method, where sediment was collected from 5.5-m X 20-m units with.82 m square grid spacing between increments. Each pond had one positive sample (Figure III-2-6). In September 2010, we went to the center point of each positive grid unit and collected triplicate sieved multi-increment samples from within a 10 m radius of the center point (Figure III-2-7 and III-2-8). We used the sieved multi-increment method because it mimics the way the dabbling ducks feed in the sediment and allows us to intensively sample a water-covered area.

In the three sieved samples from Pond 226 we detected 0.036, 0.036, and 0.077 µg white phosphorus. For comparison, the mass of white phosphorus that would be acutely poisonous to a mallard is 4 mg (Sparling et al. 1997) or about 100,000 times greater than the mass we detected. Similarly, in the three sieved samples from Pond 258, we detected 0.068, 0.049, and 0.035 µg white phosphorus.

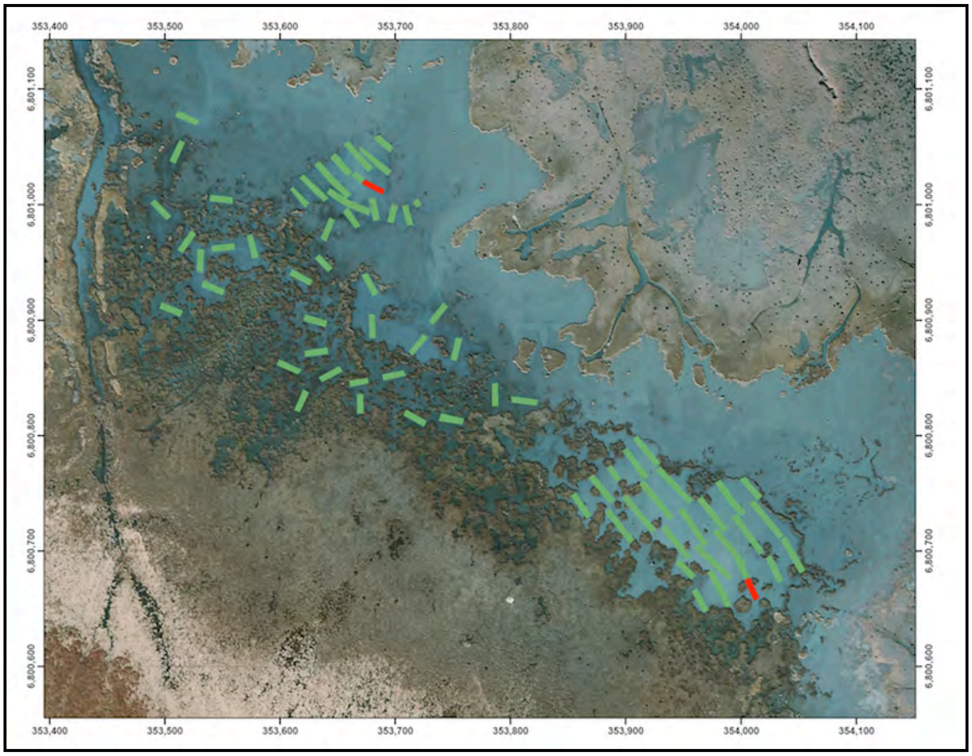


Figure III-2-6. Aerial image of Area A showing locations where multi-increment sediment samples were collected in the 1990s. Green indicates that white phosphorus was not detected and red indicates white phosphorus was detected. Pond 226 is to the north and Pond 258 to the south.

Sampling Around the Perimeter of Gravel Caps

In 2003 we found that high concentrations of white phosphorus were co-located with metallic remnants of detonated white phosphorus ordnance. In 2004, we performed a systematic magnetometer survey of the Area C Marsh and the southeast section of Area BT to find localized areas of very high white phosphorus concentrations that corresponded to the points of impact of white phosphorus projectiles. Between 2003 and 2004, we found 81 locations with white phosphorus and ordnance scrap. In 2005 and 2006, 24 highly contaminated locations were re-sampled, many of which showed a definite decrease of white phosphorus concentration in the surface sediment after pumping remediation. However, most of these locations were not dry for long enough to decontaminate sufficiently to be no threat to waterfowl. In May 2007, we sampled each location where white phosphorus ordnance scrap was found and white phosphorus concentrations had exceeded 1 µg/g at a sampling event. Based on the sampling results (Walsh et al.

Figure III-2-. Sampling of Pond 226 in Area A on 21 September 2010.

Figure III-2-8. Sampling of Pond 258 in Area A on 21 September 2010.

2008) or the presence of white phosphorus ordnance scrap, the location was marked for capping. A total of 23 discrete locations and six areas were designated for capping (Walsh et al. 2008). In February 2008, 16 discrete locations and five areas were capped by covering with geotextile and gravel. The remaining locations were capped in March 2009. The perimeters of the gravel caps in

Area C were sampled in May 2009 (Figure III-2-5), and white phosphorus was detectable around 12 of them. Concentrations were low except around the cap at the "south ditch junction" where 1.7 µg/g of white phosphorus was found. Follow-up sampling in September 2009 showed that the cap needed to be extended to the west to cover the contaminated sediment.

In May 2010, the caps were inspected and seven caps were chosen for additional sampling. The selection (Figure III-2-9 and Appendix Table III-2-A3) was based on the presence of depressions that held standing water adjacent to the caps; these depressions could serve as duck dabbling habitat. Based on the results of the sampling, three locations were chosen for extensions of the existing caps (Appendix III-2-A3).

Figure III-2-9. Location of gravel caps and sample identification numbers. Sediment around the perimeters of the caps were sampled in May 2009. The aerial image was taken on 20 August 2009 (Aero-Metric).

Sampling of Sediment to Locate Remaining Small Areas of White Phosphorus

Area BT and C

The southwest portion Pond 730 in Area BT and the drainage ditches in Area C are two locations where small areas of white phosphorus might be present. This statement is based on the finding of waterfowl carcasses, persistent standing water, ordnance scrap, and previous detection of white phosphorus in the sediments. Waterfowl use both locations for feeding and resting.

Pond 730: Pond 730 is located on the western boundary of Area C/D with Area BT. Pond 730 has been sampled intermittently for several years due to the accumulation of waterfowl carcasses during fall migration. No white phosphorus has been detected in the main body of the pond, but small amounts of white phosphorus have been detected in the southwest arm (Figure III-2-11).

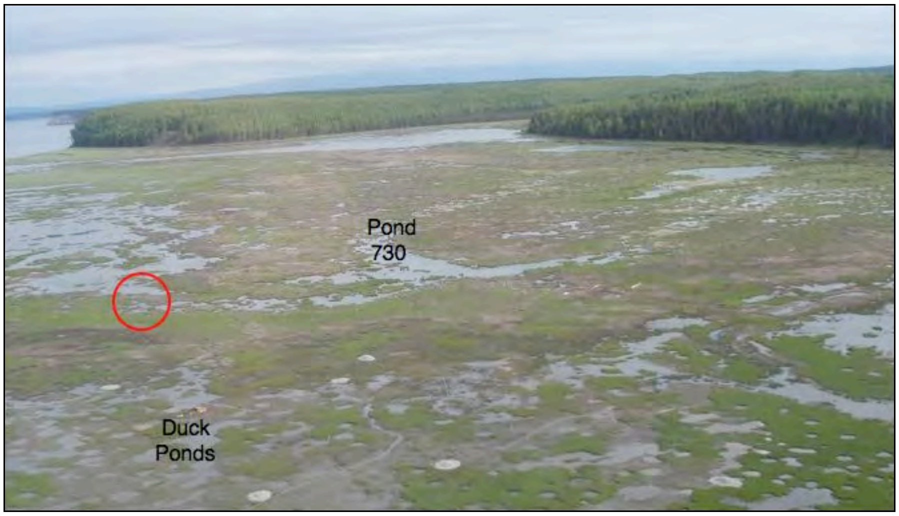
In 2009, we divided the southwest arm into 10-m wide sampling units and collected whole-sediment and sieved multi-increment samples from each unit. A very small mass of white phosphorus (0.0006 µg/g) was detectable in one sample: the sieved multi-increment sample from the far southwest corner of the pond (sample labeled Pond 730 SW 0-10 m). This is the same region that we detected some white phosphorus in 2004. Several searches for magnetic anomalies have been conducted over the years, and various types of ordnance scrap have been found. The most significant find was in 2009. An empty 4.2-in mortar projectile with a burster was found; this item was consistent with the form of a white phosphorus projectile, but white phosphorus was not detected in the sediment co-located with the scrap.

In May 2010, we went back to the part of the pond where white phosphorus was detected in 2009 (corresponding to sample Pond 730 SW 0-10 m), and divided the previously sampled area into four subareas labeled SW, SE, NW, and NE quadrant. Each quadrant was 5-m X 8.25-m. Prior to sediment sampling within each quadrant, two pieces of ordnance scrap were found at the NE/SE quadrant boundary. Both surface and subsurface sediment co-located with each piece of scrap was collected for analysis.

White phosphorus was detected (Appendix Table III-2-A2) in the SE and NE quadrant (0.0002 and 0.009 µg/g, respectively). White phosphorus was also detected in the sediment that was co-located with the ordnance scrap. The surface concentrations were low (0.0001 and 0.07 µg/g), but the subsurface concentrations were high (33 and 1,800 µg/g). The concentration (1,800 µg/g) corresponding to the subsurface sediment from the second piece of scrap means that approximately 2 mg of white phosphorus is found in each gram of sediment, so only 2 g of sediment would have a lethal mass of white phosphorus for a dabbling duck.

Given this result, a temporary geotextile and gravel cap was placed over this area (Figure III-2-12) on July 12, 2010. In September, the sediment around the perimeter of the temporary cap was sampled, and no white phosphorus was detected (Appendix Table III-2-A2).

a. Locations in or near Pond 730 that were sampled in 2010. The numbers are small pools, none of which had detectable white phosphorus. The rectangle corresponds to the area resampled in 2010 and white phosphorus was detected. The red X is the location of white phosphorus ordnance scrap found in 2010.



b. Aerial oblique view showing the location (red circle) where white phosphorus was detected in 2009. Gravel caps are visible in the foreground, showing the proximity of locations where high concentrations of white phosphorus were found in 2004.

Figure III-2-11. Pond 730 southwest arm.

Figure III-2-12. Ground view of the southwest arm of Pond 730 where white phosphorus ordnance scrap was found in May 2010 and a temporary geotextile/gravel cap put in place in July 2010.

C Marsh Ditches: The ditches in the C Marsh were installed to promote drainage to the various sumps and enhance the drying of the surrounding surface sediments. These ditches bisected some of the most contaminated sediments in ERF. Unfortunately, when the ditches are filled with water, waterfowl are attracted to them in surprisingly high numbers, and several waterfowl carcasses were subsequently found along the ditches. Based on sampling of the ditches, four areas were capped during the winters of 2008 and 2009. When we sampled the cap perimeters in the May 2009, we detected white phosphorus at a relatively high concentration near the cap at the intersection of the cross ditch and south ditch. In September 2009, we found that the white phosphorus was located within the south ditch on the west side of the cap.

In 2010, we intensively resampled two portions of the drainage system: the cross ditch and the western part of the north ditch (Figure III-2-13). The length of the cross ditch that was sampled was 70 m. We divided the area into 5-m long sampling units (Figure III-2-14), yielding 14 samples, none of which contained detectable white phosphorus. Similarly, an 80-m long area in the north ditch was subdivided into 10-m long sampling units (Figure III-2-15). White phosphorus was not detected in any sample.

Figure III-2-13. Aerial image showing locations (outlined in yellow) within the drainage ditches that were sampled in 2010. White phosphorus was not detected.

Figure III-2-14. View looking south down the cross ditch. A 70 m long area was subdivided into 5-m long sampling units. White phosphorus was not detected in any sample.

Figure III-2-15. View looking east along the North Ditch. An 80-m long area was subdivided into 10-m long sampling units. White phosphorus was not detected in any sample.

Racine Island

Racine Island was first sampled in 1993 and was found to be severely contaminated with white phosphorus (white phosphorus concentrations greater than 1000 µg/g). To reduce the exposure of dabbling ducks, two ponds (#293 and #297) were drained by ditching in 1998. Pond 285 was covered with AquaBlok in 1994; it was subsequently drained by ditching in 2001. These activities removed most of the permanent open water habitat on Racine Island.

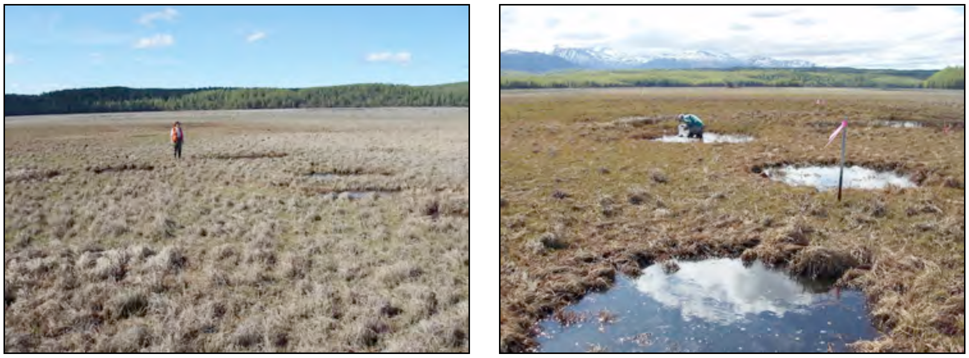
Due to the limited accessibility, Racine Island had not been monitored to the same degree as other remediated areas. Access to Racine Island by foot requires that river water levels be low enough to cross the channel south of the main channel at Bravo Bridge. Then a "border low shrub," an area of difficult terrain, must be traversed before reaching the former open water habitats.

In September 2009, we sampled a 12 × 20-m area of open water with stands of *Hippurus tetraphylla*. Duplicate multi-increment sediment samples were collected, and white phosphorus was detectable in both samples. This area is labeled 09RI_DU01 in Figure III-2-16 and III-2-17.

Figure III-2-16. Aerial image showing previous sample locations in Pond 285 on Racine Island and sampling units in 2010. The red color corresponds to samples with white phosphorus. White phosphorus was not detectable in the green colored units.

Figure III-2-17. Ground view on Racine Island of 09RI_DU01 (image taken in May 2010) where white phosphorus was detected in 2009.

In May 2010, we sampled four areas north of 09RI_DU01 (Figure III-2-16 to 19). The areas were clusters of craters that held standing water. White phosphorus was detected in the crater closest to 09RI_DU01. In September 2010, we sampled another water-covered area. The area was 15-m X 37-m with open water and sedge. Ordnance scrap was found within this area, and sediment co-located with the scrap contained 0.08 µg/g white phosphorus. Two multi-increment samples were collected within the 15-m X 37-m area. One sample did not have increments taken near the ordnance scrap and the other sample purposely had increments taken near the ordnance scrap. White phosphorus was detected only in the second sample (0.01 µg/g), indicating that the white phosphorus was very localized.



a) White phosphorus was not detected in the cluster of craters (10RI_DU01)

b) White phosphorus was detectable in the small pools (10RI_DU04) shown in this image.

Figure III-2-18. Ground views of sampling on Racine Island in May 2010. White phosphorus was detectable in the small pools (10RI_DU04) shown in this image.

The relative risk to waterfowl of white phosphorus poisoning on Racine Island is unclear. The aerial surveys indicate low waterfowl use of Racine Island, which is likely due to limited habitat. However, waterfowl that feed in some of the locations that we sampled are potentially exposed to a lethal dose of white phosphorus. Further monitoring will be needed and remedial options should be explored. Draining by ditching is feasible; capping may be feasible if the area can be accessed in the winter.

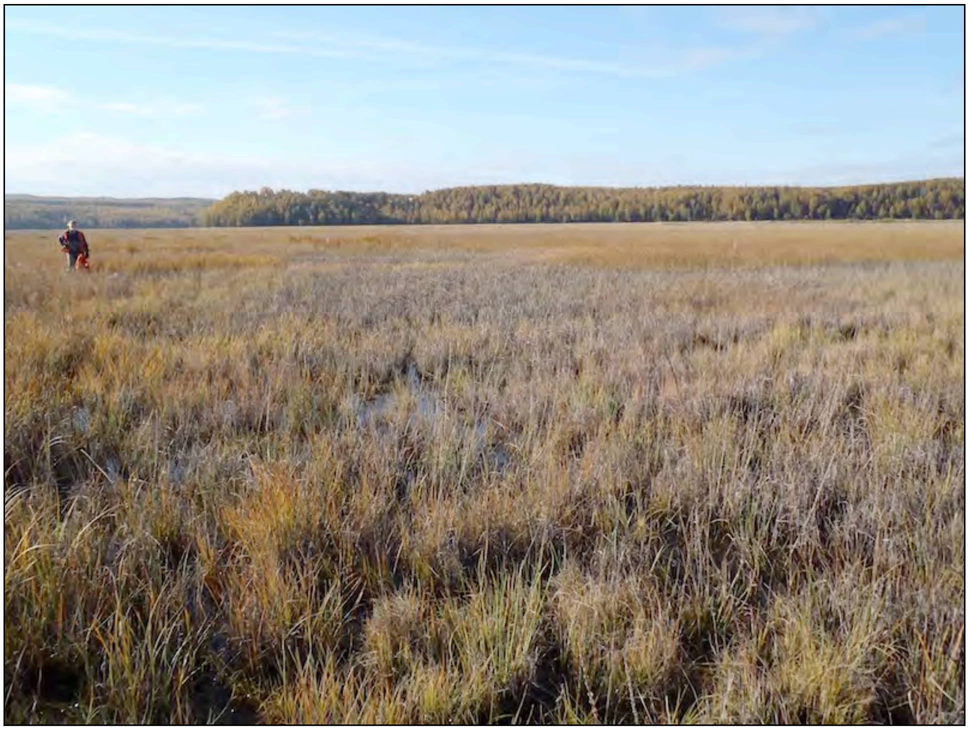


Figure III-2-19. Ground view of the area (10RI_DU05) on Racine Island in September 2010 where white phosphorus ordnance scrap was found and white phosphorus was detected.

Area Coastal East and Coastal West

In the fall of 2007, Natural Resources personnel observed a duck convulsing at the mouth of the Eagle River. The duck was collected and the gizzard contents contained white phosphorus. In June 2008, we observed ordnance fragments eroding out of the river bank at the river mouth, and Jeff Bryant (UXO technician) found two corroded 4.2-in WP mortar projectiles on the barren mudflat within 100-m of the mouth. In May 2009, as a follow-up, the edge of the shore and adjacent mudflat were swept with a magnetometer. The search for magnetic anomalies was started at the river mouth and ended approximately 900 m to the northeaster along the edge of the shore. No additional ordnance items were found although the bank showed signs of continued erosion cutting into the mudflat.

In May 2010, we were informed (Richard Nenahlo, personal communication) that a team from the Fort Richardson EOD, while clearing a path for the beluga monitoring program, recently found another 4.2 inch white phosphorus projectile and a 155-mm projectile. These two ordnance items were detonated in a gully near the mouth of the river (Figure III-2-20 and III-2-21). On 15 May 2010, we collected surface sediment from inside the detonation crater and within 1-m of the edge of the crater. White phosphorus concentrations were 0.34 µg/g inside and 4.5 µg/g outside the crater. Subsurface sediment was collected from the crater in September 2010. White phosphorus concentration was 100 µg/g.

When ordnance is found on the mudflat, the ordnance should be moved if at all possible up onto the drier vegetated mudflat prior to detonation as was done in June 2007. The sediment in the detonation crater in 2007 dried over the summer and white phosphorus was not detectable by August 2007. In contrast, detonation on a wet mudflat or in a gully will result in white phosphorus contamination of the sediment where it will persist and will likely be washed into the river.

Also in May 2010, the banks of Coastal East and Coastal West (Figures III-2-21 to 25) were monitored for additional ordnance items visually and with a magnetometer. Both banks are eroding, and ordnance scrap is evident. Our search did not reveal any ordnance that was potentially explosive or that contained white phosphorus, but an annual inspection would be prudent given the boat traffic on Cook Inlet.

Figure III-2-20. Ground view crater from the detonation of a 4.2-inch WP mortar projectile in a gully in May 2010.

Figure III-2-21. Aerial image of the bank of Coastal East (area outlined in yellow) that was monitored for ordnance in May 2010. The length along the north shore was 600 m and along the river was 180 m. Also shown is the detonation site for a 4.2-inch WP mortar projectile.

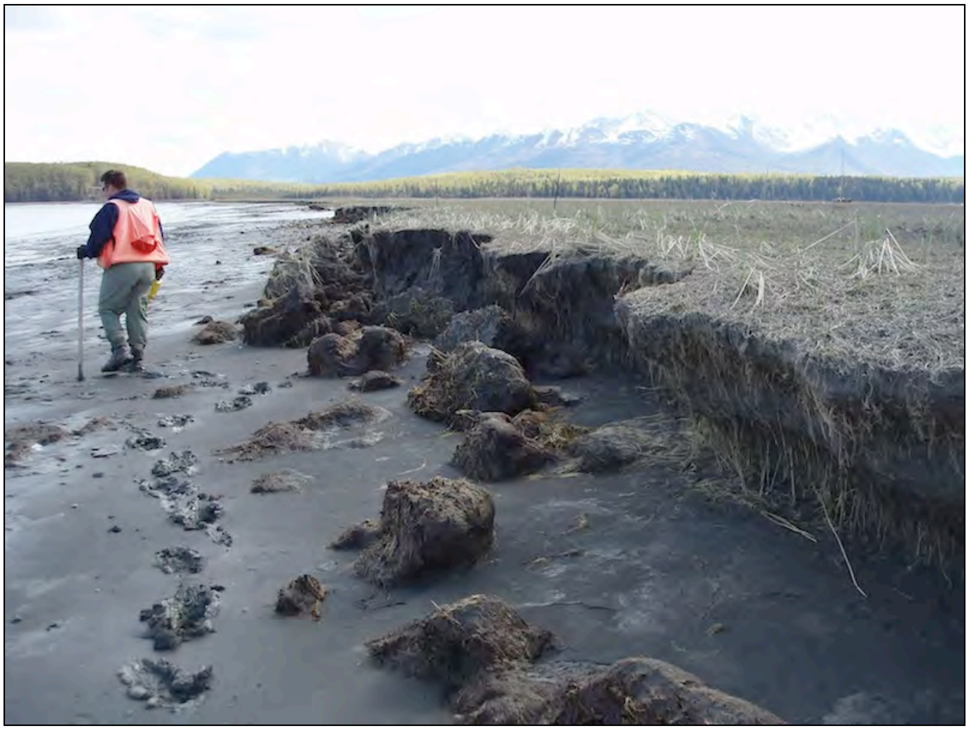


Figure III-2-22. Ground view of the bank of Coastal East showing continued erosion.

Figure III-2-23. Aerial image of the bank of Coastal West (area outlined in yellow) that was monitored for ordnance in May 2010. The lengths along the shore were 350 m between the gullies and 500 m between the gully and river.

Figure III-2-24. Ground view of the bank of Coastal West showing erosion similar to that in Coastal East.

Figure III-2-25. Example of ordnance scrap found along the bank of Coastal West where an empty Illumination projectile was found.

CONCLUSION

Grid multi-increment samples were collected in September 2010 from the decisions units within the ponds that previously had the highest white phosphorus concentrations prior to treatment. White phosphorus was undetectable in all but one of the ponds that previously contained hot spots of white phosphorus and where the surface sediments were decontaminated by pond pumping or ditching (e.g. Area C Ponds 183, and 171; Bread Truck Pond 109). Pond 155 in Area C had detectable white phosphorus.

Multi-increment sieved samples were collected from the only two locations in Area A where white phosphorus was detectable in the 1990s. White phosphorus was detectable in each sample, but the mass of white phosphorus was less than one-tenth of a microgram. These detections may indicate the presence of white phosphorus at higher concentrations in the subsurface sediment, but the surface sediment should not present a risk to waterfowl.

The perimeter of seven gravel caps in Area C were sampled in May 2010. High concentrations were not found, but four caps were designated for expansion because of the presence of standing water that could serve as waterfowl feeding habitat.

More samples were collected from Pond 730 focused on the southwest arm where white phosphorus was detected in 2009 and 2004. Most significantly, white phosphorus ordnance scrap was found and the sediment co-located with the scrap had high white phosphorus concentrations. A temporary geotextile/gravel cap was placed over the contaminated sediment.

Additional samples were collected from the drainage ditches in the C Marsh. No additional white phosphorus was found. Two locations that were found last year were scheduled for capping in March 2010.

White phosphorus was detected at two more water-covered areas on Racine Island. Capping or draining may be needed if waterfowl mortalities continue after all other known contaminated areas are capped.

In early May 2010, Fort Richardson EOD found and detonated a 4.2-inch white phosphorus mortar projectile in a gully near the river mouth. Subsequently, a magnetometer survey along the bank and mudflat of Eagle Bay on the east and west side of the river mouth revealed a several pieces of ordnance scrap eroding out the bank. A protocol is needed to safely dispose of ordnance items that are found along the inlet so that contamination is not introduced into the river or inlet.

REFERENCES

Aero-Metric (2010) Eagle River Flats. October 5, 2010. Digital Orthophoto. Aero-Metric, Anchorage, AK.

Gilbert, Richard O. (1987) Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold, New York, New York.

Sparling, D.W., M. Gustafson, P. Klein, and N. Karouna-Reiner (1997) Toxicity of white phosphorus to waterfowl: Acute exposure to Mallards. *Journal of Wildlife Diseases,* 33(2): 187-197.

U.S. Environmental Protection Agency (1995) Method 7580: White phosphorus (P_4) by solvent extraction and gas chromatography. In Test Methods for Evaluating Solid Waste, Physical/chemical Methods (SW-846), Update III. 7580-1 to 7580-20. USEPA, Office of Solid Waste, Washington, D.C.

Walsh, M.E., C.M. Collins, R.N. Bailey, and C.L. Grant (1997) Composite sampling of white phosphorus contaminated sediments. CRREL Special Report 97-30.

Walsh, M.E., R.N. Bailey, and C.M. Collins (2008) Long-term monitoring and sampling of sediments of ponds treated to remove white phosphorus. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY07 Data Report. Bigl, S.R. and C.M. Collins, Eds. ERDC/CRREL LR-08-04. Contract Report to US Army, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 61-114.

Appendix Table III-2-A1. Multi-increment sediment samples from established grids. Location coordinates are UTM (m) Zone 6N NAD27.

Area	Location	Position	Easting	Northing	Date Collected	Field Rep	Sample Mass (kg)	WP Conc. (µg/g)	Notes
Grids									
C	Pond 171	C Marsh	355160	6801419	09/18/10	Rep 1	1.5	<0.0002	
						Rep 2	1.4	<0.0002	
	Pond 155	SW Grid	355115	6801543	09/18/10	Rep 1	1.6	0.0003	
						Rep 2	2.0	0.0009	
	Pond 183	C 100 m +	355026	6801315	09/23/10	Rep 1	1.9	<0.0002	
						Rep 2	2.1	<0.0002	
BT	Pond 109	BT South 100 m +	354521	6801735	09/23/10	Rep 1	1.5	<0.0002	
						Rep 2	1.4	<0.0002	
		BT South 100 m -	354521	6801715	09/23/10	Rep 1	1.7	<0.0002	
						Rep 2	1.7	<0.0002	

Appendix Table III-2-A2. Multi-increment sediment samples to locate areas with white phosphorus.

Area	Location	Position	Easting	Northing	Date Collected	Field Rep	Sample Mass (kg)	WP Conc. (µg/g)	Notes
Random									
C	Cross Ditch	0 to 5 m	355228	6801543	05/14/10		0.8	<0.0002	
		5 to 10 m	355227	6801548	05/14/10		0.4	<0.0002	
		10 to 15 m	355226	6801553	05/14/10		0.5	<0.0002	
		15 to 20 m	355224	6801558	05/14/10		0.6	<0.0002	
		20 to 25 m	355223	6801563	05/14/10		0.6	<0.0002	
		25 to 30 m	355222	6801567.5	05/14/10		0.7	<0.0002	
		30 to 35 m	355221	6801572.5	05/14/10		0.6	<0.0002	
		35 to 40 m	355220	6801577	05/14/10		0.7	<0.0002	
		40 to 45 m	355219	6801582	05/14/10		0.7	<0.0002	

Appendix Table III-2-A2 (cont). Multi-increment sediment samples.

Area	Location	Position	Easting	Northing	Date Collected	Field Rep	Sample Mass (kg)	WP Conc. (µg/g)	Notes
Random									
	Cross Ditch	45 to 50 m	355218	6801587	05/14/10		0.6	<0.0002	
		50 to 55 m	355217	6801592	05/14/10		0.9	<0.0002	
		55 to 60 m	355216	6801597	05/14/10		0.7	<0.0002	
		60 to 65 m	355215	6801602	05/14/10		0.9	<0.0002	
		65 to 70 m	355214	6801607	05/14/10		0.8	<0.0002	
C	North Ditch West of Sump	0 to 10 m	355111	6801588	09/20/10		1.7	<0.0002	
		10 to 20 m	355120	6801593	09/20/10		1.7	<0.0002	
		20 to 30 m	355129	6801598	09/20/10		2.0	<0.0002	
		30 to 40 m	355138	6801602	09/20/10		2.0	<0.0002	
		40 to 50 m	355147	6801606	09/20/10		1.8	<0.0002	
		50 to 60 m	355156	6801611	09/20/10		1.7	<0.0002	
		60 to 70 m	355165	6801616	09/20/10		1.7	<0.0002	
		70 to 80 m (at sump)	355173	6801621	09/20/10		2.2	<0.0002	
		Lobe (3-m X 3-m) N of 70 to 80 m	355177	6801622	09/20/10		2.4	<0.0002	
BT	W of Pond 730	Pool 1	354777 E to 354766 W	6801816 E to 6801819 W	05/17/10		0.85	<0.0002	Looks like relic drainage
		Pool 2	354770	6801823	05/17/10		0.74	<0.0002	Round pool with bulrush
		Pool 3	354761	6801820	05/17/10		0.72	<0.0002	Round
		Pool 4	354757	6801833	05/17/10		0.65	<0.0002	Figure-eight shape
		Pool 5	354771	6801811	05/17/10		0.58	<0.0002	Looks like a crater

Appendix Table III-2-A2 (cont). Multi-increment sediment samples.									
Area	**Location**	**Position**	**Easting**	**Northing**	**Date Collected**	**Field Rep**	**Sample Mass (kg)**	**WP Conc. (µg/g)**	**Notes**
Random									
BT	Pond 730 Southwest Arm (0 to 10 m_	SW quadrant 5-m X 8.25-m	354787	6801812	05/17/10		2.0	<0.0002	Starting at Mortality Transect Point 730-5 (354783, 6801808)
		SE quadrant 5-m X 8.25-m	354791	6801810	05/17/10		3.1	0.00015	WP ordnance anomaly
		NW quadrant 5-m X 8.25-m	354791	6801819	05/17/10		1.9	<0.0002	
		NE quadrant 5-m X 8.25-m	354794	6801816	05/17/10		1.5	0.009	WP ordnance anomaly
		Pond 730 0-10 m around temporary cap	354791	6801813	09/22/10	1	1.6	<0.0002	
			354791	6801813	09/22/10	2	1.0	<0.0002	
Racine Island	10RI_DU01	Racine Island Crater Cluster 1	355394	6800566.75	05/20/10	1	3.1	<0.0002	~10 craters(GPS Points 5-8)
			355394	6800566.75	05/20/10	2	2.2	<0.0002	
	10RI_DU02	Racine Island Crater Cluster 2	355352	6800594	05/20/10	1	3.1	<0.0002	~20 craters (GPS Points 9-13)
			355352	6800594	05/20/10	2	2.4	<0.0002	
	10RI_DU03	Pool	355363	6800554	05/20/10		1.4	<0.0002	(GPS Point 14)
	10RI_DU04	Crater Cluster 3	355360	6800540	05/20/10		1.9	0.016	6 craters (GPS Point 15)
	0RI_DU05	Water-Sedge	355420	6800525	09/22/10	1A	3.2	<0.0002	62 m ESE of GPS Point 15
			355420	6800525	09/22/10	1B	3.2	<0.0002	
			355420	6800525	09/22/10	2A	1.8	0.012	With sediment co-located with anomaly
			355420	6800525	09/22/10	2B	1.8	0.013	

Appendix Table III-2-A3. White phosphorus (WP) concentrations (µg/g) detected at locations that were capped with gravel in March 2008 and February 2009. UTM coordinates are in NAD 1927 Zone 6N. The coordinates for the capped locations correspond to the center of the cap and are derived from the Aero-Metric photo taken on 30 September 2008 and 20 August 2009.

Sample ID	Capped (Mon-Year)	Easting	Northing	Collection Date	Area	Depth	WP Conc. (µg/g)	Field Notes
03DIS03		355187	6801456	05/23/03	C	0 to 5 cm	1.3	4.9 m X 2.5 m. WP mortar fin.
				05/29/07		0 to 5 cm	**4.04**	Sampled E of drainage ditch and N of metal stake. Log across area. Water depth 15 cm.
03DIS03 cap perimeter	Feb-2008	355185	6801454	06/10/08	C	0 to 5 cm	0.0008, 0.003	
		355185	6801454	05/16/09	C	0 to 5 cm	0.065, 0.002	Center point UTM coordinates based on Aero-Metric 20 Aug 2009 image
03DIS03 drainage channel west of cap		355181	6801456	05/21/10	C	0 to 5 cm	<0.0002	Water-filled depression. 0 to 7.3 m N
03DIS03 drainage channel west of cap		355185	6801449	05/21/10	C	0 to 5 cm	0.0067	Water-filled depression. 0 to 9 m S
03DIS18		355210	6801429	05/28/03	C	0 to 5 cm	400	WP mortar fin. Two pools: east and west.
03DIS18East		355209	6801430	07/09/03	C	0 to 5 cm	240	
		355209	6801430	08/27/04	C	0 to 5 cm	0.002	
		355209	6801430	09/08/05	C	0 to 5 cm	0.08	
		355209	6801430	08/30/06	C	0 to 5 cm	0.007	Surface sediment from drainage channel.
		355209	6801430	05/29/07	C	0 to 5 cm	**0.69**	Surface sediment from water-filled drainage channel.
		355209	6801430	08/23/07	C	0 to 5 cm	0.0055	

Appendix Table III-2-A3 (cont.). WP concentrations (µg/g) detected at locations that were capped in March 2008 and February 2009.

Sample ID	Capped (Mon-Year)	Easting	Northing	Collection Date	Area	Depth	WP Conc. (µg/g)	Field Notes
03DIS18 cap perimeter	Mar-2009	355208	6801428	05/16/09	C	0 to 5 cm	0.0001, 0.0011	Center point UTM coordinates based on Aero-Metric 20 Aug 2009 image
03DIS18 drainage channel south of cap:		355207	6801425	05/21/10	C	0 to 5 cm	0.0001	0 to 5 m W, E, and S
04DIS068		355177	6801438	05/22/04	C	10 to 15cm	29.1	Approximately 1 m from 03DIS30 (toward pond 171 logger). Mortar Body 20 cm deep with smoke. Two samples: Surface 0 to 10 cm and Subsurface 10 to 15 cm deep.
		355177	6801438	05/22/04	C	0 to 10 cm	0.14	
		355177	6801438	05/29/07	C	0 to 5 cm	<0.0002	1.7-m x 1-m isolated crater. Metal detected 1 m SW of crater. Subsurface was frozen in May. Excavated in Aug and WP frag found.
1 m SW of 04DIS68		355176	6801437	05/29/07	C	0 to 5 cm	41	WP ordnance scrap.
04DIS68 cap perimeter	Mar-2009	355175	6801437	05/16/09		0 to 5 cm	0.0008, 0.001	Center point UTM coordinates based on Aero-Metric 20 Aug 2009 image
04DIS068 drainage channel south of cap		355173	6801434	05/21/10	C	0 to 5 cm	<0.0002	Water-filled depression.
04DIS125		355228	6801523	08/25/04	C	at UXO scrap	950	Location of WP fin found in May.
				09/12/05		5 cm	1.71	
04DIS125 Ditch Bottom		355226	6801523	05/23/06	C	5 cm	84	
04DIS125				08/30/06		5 cm	<0.0002	Intersection of cross-ditch and S ditch. Location was blasted to deepen ditch on 11 July 2006.
04DIS125 (cont.)				05/29/07	C	0 5cm	0.0058	In south cross-ditch. Surface sediment from walls and bottom of ditch east of datalogger sensors.

Appendix Table III-2-A3 (cont.). WP concentrations (µg/g) detected at locations that were capped in March 2008 and February 2009.

Sample ID	Capped (Mon-Year)	Easting	Northing	Collection Date	Area	Depth	WP Conc. (µg/g)	Field Notes
04DIS125 cap perimeter at jct. of the south and cross ditches	Feb-2008	355224	6801525	06/10/08		0 to 5 cm	<0.0002, <0.0002	
04DIS125 cap perimeter at jct. of the south and cross ditches		355224	6801523	05/16/09		0 to 5 cm	1.65	Center point UTM coordinates based on Aero-Metric 20 Aug 2009 image
South and Cross Ditch cap perimeter								
North side, 0 to 1 m from cap		355224	6801533	09/16/09		0 to 5 cm	0.022	
North side, 1 to 2 m from cap		355224	6801534	09/16/09		0 to 5 cm	0.012	
East side, 0 to 1 m from cap		355226	6801518	09/16/09		0 to 5 cm	<0.0002	
East side, 1 to 2 m from cap		355227	6801518	09/16/09		0 to 5 cm	<0.0002	
West side, 0 to 1 m from cap		355223	6801517	09/16/09		0 to 5 cm	<0.0002	
West side, 1 to 2 m from cap		355222	6801517	09/16/09		0 to 5 cm	1.3	
West side, 9 to 11 m from cap		355212	6801519	05/21/10		0 to 5 cm	<0.0002	0 to 9 m was marked for capping in March 2011
04DIS126		355167	6801527	08/25/04	C	at UXO scrap	2033	South ditch, west (in Segment 1). Thick metal fragment. WP odor in peat layer.
04DIS126 Ditch Bottom				05/19/06		5 cm	40	
04DIS126 High Wall		355167	6801529	05/19/06		5 cm	0.001	
04DIS126 Mid Wall		355167	6801528	05/19/06		5 cm	0.07	
04DIS126 South Wall				08/30/06		5 cm	14.4	
04DIS126				05/29/07		0 to 5 cm	**48**	Surface sediment from south wall of south ditch.
04DIS126 cap perimeter in south ditch, west side	Feb-2008	355166	6801523	06/10/08		0 to 5 cm	<0.0002, <0.0002	
04DIS126 cap perimeter	Expanded Mar-2009	355167	6801527	05/16/09		0 to 5 cm	0.0045	Center point UTM coordinates based on Aero-Metric 20 Aug 2009 image
East of Cap 0 to 5 m		355173	6801527	05/21/10		0 to 5 cm	<0.0002	

Appendix Table III-2-A3 (cont.). WP concentrations (µg/g) detected at locations that were capped in March 2008 and February 2009.

Sample ID	Capped (Mon-Year)	Easting	Northing	Collection Date	Area	Depth	WP Conc. (µg/g)	Field Notes
East of Cap 5 to 10 m		355178	6801525	05/21/10		0 to 5 cm	<0.0002	
West of Cap 0 to 5 m		355156	6801535	05/21/10		0 to 5 cm	<0.0002	
West of Cap 5 to 10 m		355161	6801532	05/21/10		0 to 5 cm	<0.0002	
BIP 11		355169	6801590	06/01/05	C	5 cm	511	
				08/31/06		5 cm	31	Crater 1.6-m to 2-m across. Depth in center is 67 cm.
				05/29/07		0 to 5 cm	0.019	Surface sediment inside rim.
BIP 11 cap perimeter	Feb-2008	355166	6801586	06/10/08		0 to 5 cm	<0.0002	
	Expanded Mar-2009	355167	6801588	05/16/09		0 to 5 cm	0.018	Center point UTM coordinates based on Aero-Metric 20 Aug 2009 image
BIP_11 and nearby craters		355167	6801588	05/21/10	C	0 to 5 cm	<0.0002	
Edge of C Marsh Pond 23 (E of Line 2.5 120m S)		355292	6801535	08/24/02	C	5 cm	0.161	
				05/30/07		0 to 5 cm	**1.3**	Surface sediment from walls and bottom of pool. UXO tech found 105-mm UXO. EOD removed projectile, which they identified as a practice round.
	Feb-2008	355290	6801531	06/10/08		0 to 5 cm	0.0011, 0.0006	Center point UTM coordinates based on Aero-Metric 20 Aug 2009 image
		355290	6801532	05/16/09		0 to 5 cm	0.051, 0.0003	
		355290	6801532	05/21/10		0 to 5 cm	0.0026	Sampled depressions with standing water.

Appendix Table III-2-A4. Multi-increment sieved samples (>0.59 µm)

Area	Location	Position	Easting	Northing	Date Collected	Sample Mass (kg)	WP Mass (µg)
A	Pond 226	10-m radius around center	353,681	6,801,015	09/21/10	0.077	0.036
			353681	6801015	09/21/10	0.17	0.036
			353681	6801015	09/21/10	0.19	0.077
	Pond 258	10-m radius around center	354009	6800667	09/21/10	0.194	0.068
			354009	6800667	09/21/10	0.144	0.049
			354009	6800667	09/21/10	0.264	0.035

Appendix Table III-2-A5. Discrete samples.

Area	Position	Easting	Northing	Date Collected	WP Conc. (µg/g)	Comments
BT	Pond 730 May_Anomaly 1	354790	6801814	05/17/10	0.0001	surface
		354790	6801814	05/17/10	33.4	subsurface
	Pond 730 May_Anomaly 2	354792	6801812	05/17/10	0.069	surface
		354790	6801814	05/17/10	1,826	subsurface
	Pond 730 Sept_Anomaly_01	354820	6801792	09/22/10	<0.0002	Looks like a doorknob
	Pond730 Sept_Anomaly_02	354826	6801797	09/22/10	<0.0002	Looks like a meteorite
	Pond 730 Sept_Anomaly_03 Surface Sediment	354819	6801798	09/22/10	<0.0002	Deep. Thin-walled ordnance scrap.
	Co-located with metal	354819	6801798	09/22/10	<0.0002	
	Under metal	354819	6801798	09/22/10	<0.0002	
C	CMarsh Anomaly 4.2" mortar projectile 01DIS01	355145	6801497	05/21/10	<0.0002	
Racine Island	Inside 10RI_DU05	355421	6800517	09/22/10	0.079	Rectangular plate. Looks like WP ordnance scrap
Coastal East	Crater from 12 May 2010 UXO detonation	353902	6802188	05/15/10	0.34	In gully. Inside crater
		353902	6802188	05/15/10	4.47	In gully. Within 1 m of crater edge
		353902	6802188	09/18/10	103	Subsurface sediment.

III-3. 2010 WEATHER DATA FOR EAGLE RIVER FLATS

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INTRODUCTION

During the full-scale pumping remediation in Eagle River Flats (ERF), conducted from 1997 through 2003, and the limited pumping remediation after that, the success of the remediation was greatly dependent on the weather conditions during the summer remediation season. Shallow ponds and marsh areas contaminated with white phosphorus were remediated by temporarily draining the water from the treatment area with large pumps and allowing the contaminated sediment to dry. This in turn allows the white phosphorus to sublime and oxidize into non-toxic phosphate compounds. Because of the importance of weather in the success of the remediation effort, we have monitored meteorological conditions in Eagle River Flats every summer since a meteorological data station was first installed at the edge of the EOD pad in May 1994 (Haugen 1995). Even though the active remediation has now been completed, we continue to maintain the meteorological station at Eagle River Flats as part of the long-term monitoring program. Each summer a standard suite of meteorological data including air temperature, wind speed and direction, radiation, precipitation, and evaporation are collected. Meteorological data are posted periodically on the Eagle River Flats web page linked to the CRREL public web site, allowing interested personnel to check on-site conditions from off site (www.crrel.usace.army.mil/erf).

METEOROLOGICAL STATION

The Eagle River Flats meteorological station (Fig. III-3-1) is located off the edge of the EOD pad on a small gravel pad extending into the salt marsh of Area C. Atop the 4-m guyed tower is a wind anemometer that records wind direction and speed. This location is high enough to be above any effects caused by the edge of the nearby EOD pad. Air temperature and relative humidity sensors within standard shields are located at 2- and 0.5-m heights on the tower. At the 2-m height, a side arm holds two Epply radiation sensors that measure incoming and reflected short wave radiation (0.3 to 3 µm). A white fiberglass enclosure mounted on the tower contains the Campbell Scientific CR10 datalogger system and data storage module. All meteorological data collected for the season are stored on the storage module. Also mounted in the enclosure is a radio modem that communicates between the met station and the Ethernet RF modem base station at Route Bravo Bridge. The antenna for the radio is attached to the top of the tower. From the base station, the data is transmitted by phone line to a server at the Hanover site. A pair of tipping bucket precipitation gages are located 5 m east of the tower. A standard 1.22-m (48-in) diameter evaporation pan is located 2 m west of the tower. A Druck pressure transducer at the bottom of the evaporation pan measures water depth. The station is powered with a 12-V battery, charged by a solar panel mounted on the tower. Table III-3-1 summarizes the instruments and parameters measured at the ERF meteorological station.

Figure III-3-1. Eagle River Flats meteorological station located along the edge of the OB/OD pad in Area C. The 4-m tower is located in the right center, the 1.22-m-diameter evaporation pan is located to the right, and the shielded rain gage is located to the left.

RESULTS

On 20 May the full suite of instruments including precipitation and evaporation pan measurements was restarted for the 2010 summer season. On 19 September, the precipitation and evaporation pan measurements were discontinued for the winter, while temperature, relative humidity, and radiation measurements were continued.

Table III-3-2 summarizes the available Eagle River Flats 2010 weather data from mid May through mid September of 2010. Also included is the Anchorage NWS data for May through September along with the normal monthly temperatures for Anchorage. The Anchorage NWS data are included because we have no long-term average data for the Eagle River Flats site. Table III-3-2 also presents the monthly total rainfall for Eagle River Flats and for Anchorage, along with the Anchorage normal monthly rainfall. Temperatures in Eagle River Flats were normal for June and below normal for July and August. Precipitation was above normal for June and July and normal for August.

Table III-3-1. Summary of meteorological station instruments and the parameters measured.

Instrument	Parameter Measured
R.M. Young wind anemometer, 4-m height	Average wind speed (m/s) Average wind direction (m/s) Peak wind speed (m/s) Time of peak wind speed
(2) Air temperature sensors, 2-m and 0.5 -m heights	Average 2-m temperature (°C) Maximum 2-m temperature (°C) Minimum 2-m temperature (°C) Average 0.5-m temperature (°C) Maximum 0.5-m temperature (°C) Minimum 0.5-m temperature (°C)
(2) Relative Humidity sensors, 2 m-and 0.5-m heights	Average 2-m relative humidity (%) Maximum 2-m relative humidity (%) Minimum 2-m relative humidity (%) Average 0.5-m relative humidity (%) Maximum 0.5-m relative humidity (%) Minimum 0.5-m relative humidity (%)
(2) Epply radiation (0.3–3 µm) sensors, incident and reflected	Average shortwave incident radiation (W/m^2) Average shortwave reflected radiation (W/m^2)
Tipping bucket rain gage (2)	Tipping bucket 15-min precipitation (mm) Tipping bucket total daily precipitation (mm)
Druck 357/D pressure transducer	Evaporation pan water level 15-min sample

Figure III-3-2 plots the maximum, minimum, and average air temperatures for the summer. Average temperatures for summer season were below normal. The highest temperature (26.3°C) of the 2010 summer occurred before the summer really started, on 27 May. There were only 25 days all summer where maximum temperatures reached 20°C or more: seven days in May, four days in June, five days in July, seven days in August, and two days in September. This compares to at least 41 days in 2009 when maximum temperatures reached 20°C or more. During the period of full-scale and limited pumping remediation (2000 – 2007) each of the seasons had between 37 and 67 days with maximum temperatures reaching 20°C or more. All of them were good drying years (Collins 2001–2008).

Table III-3-2. Monthly summary of temperatures and precipitation for ERF and Anchorage (ANC), showing the 2010 monthly (or partial monthly) average temperatures for both sites, normal monthly average temperatures for Anchorage, monthly or partial monthly total measured precipitation for ERF, and monthly total and normal average precipitation for Anchorage.

	Average Temperature (°C)			Rainfall (mm)		
Month	**ANC normal**	**ANC 2010**	**ERF 2010**	**ANC normal**	**ANC 2010**	**ERF 2010**
May	8.3	9.7	—	17.8	5.1	—
20-31 May			12.3			2
June	12.6	12.4	12.5	26.9	30.7	39
July	14.7	13.6	13.4	43.2	83.1	65
August	13.6	13.6	12.5	74.4	84.8	67
1-19 Sept			10.1			18
Sept	9.0	9.8	—	72.9	23.6	—

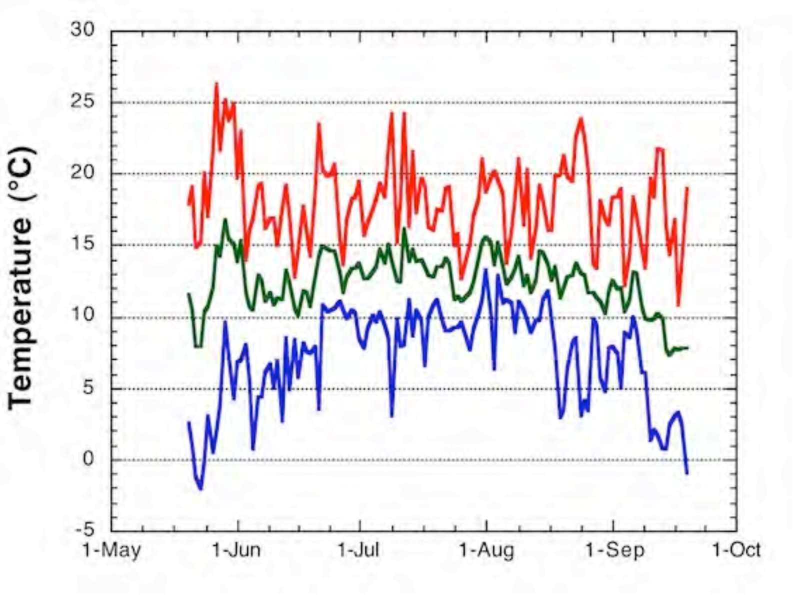

Figure III-3-2. Maximum, minimum, and average air temperatures for the Eagle River Flats meteorological station from mid May through mid September 2010 shown in red, blue, and green, respectively. Only 25 days reached 20°C or warmer.

Precipitation in Anchorage area and in Eagle River Flats was above normal in June and July, normal in August, and below normal for September. A plot of both precipitation and cumulative evaporation (Fig. III-3-3) illustrates the distribution of rain throughout most of the summer. In addition a plot of incident radiation, an inverse proxy for cloudiness, and cumulative evaporation (Fig. III-3-4) shows that there were just a few periods of clear skies longer than just a day or two throughout the summer. Clear skies occurred in late May, during a couple five-day periods in June, and an eight-day period in late August. As might be expected, maximum evaporation correlates with the periods of maximum incident radiation. Luckily, we were not dependent this year on warm dry weather for drying and remediation of white phosphorus-contaminated sediments.

Daily meteorological data for the summer season are summarized in Table III-3-3. If needed, more detailed data, including all available 15-min observations and additional measured parameters, are available from CRREL in spreadsheet format.

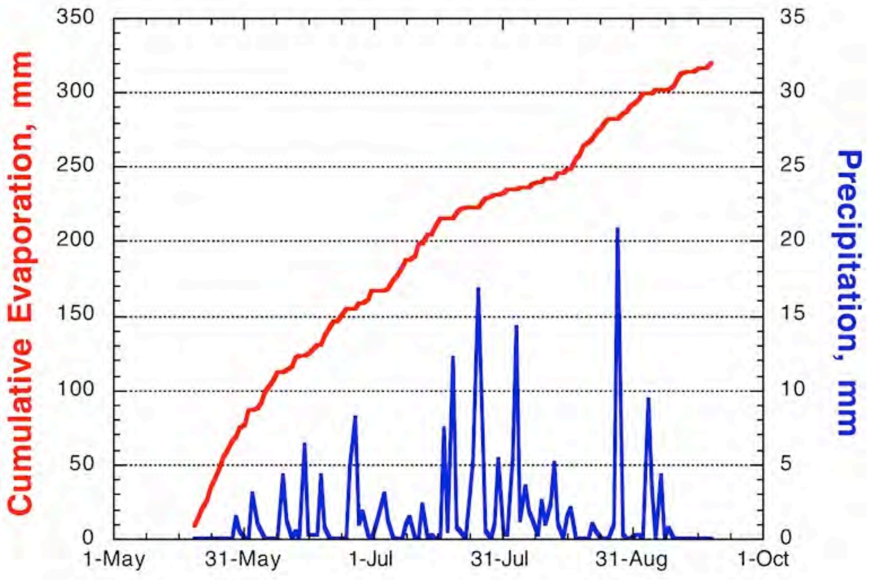

Figure III-3-3. Net cumulative evaporation for the season and precipitation data showing the wetter than normal precipitation conditions throughout June and July. Precipitation was near normal for August and below normal for the first half of September.

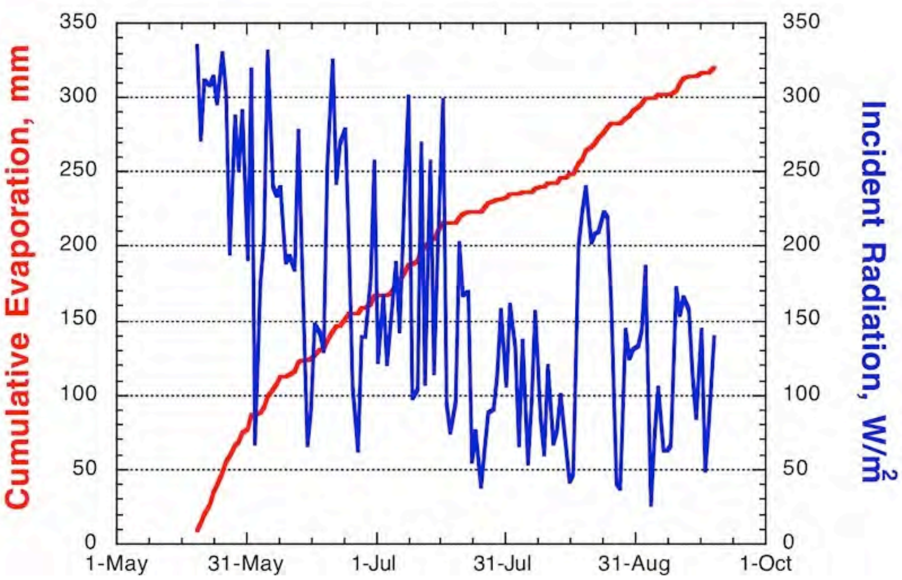

Figure III-3-4. Net cumulative evaporation for the season and incident radiation data showing the mostly cloudy conditions and lower evaporation rate throughout most of the summer other than in late May and a week long period in mid to late August.

Table III-3-3. Daily climatic data for Eagle River Flats meteorological station from mid May through mid September 2010 (pg. 1 of 3).

Date	Air Temperature °C			Precip (mm)	Ave Radiation (W/m^2)	
	Max	Min	Ave		Incident	Reflected
5/20/10	17.8	11.5	2.5	0	334	39
5/21/10	19.1	10.4	0.9	0	271	32
5/22/10	14.8	7.9	-1.2	0	311	38
5/23/10	15.2	7.9	-2.1	0	307	37
5/24/10	20	10.3	-0.2	0	313	39
5/25/10	17	10.7	3	0	295	36
5/26/10	21.7	12	0.5	0	330	40
5/27/10	26.2	14.9	1.9	0	303	37
5/28/10	21.7	14.2	3.8	0	194	23
5/29/10	25.1	16.7	9.6	0	287	36
5/30/10	23.7	15.4	7.2	1.5	250	31
5/31/10	25	15	4.2	0.5	291	36
6/1/10	19.7	13.8	6.8	0	191	23
6/2/10	23	15.4	6.9	0	318	41
6/3/10	14	11.7	8	3	67	7
6/4/10	16	10.6	5.6	1	175	21

Table III-3-3. Daily climatic data for Eagle River Flats meteorological station from mid May through mid September 2010 (pg. 1 of 3).

Date	Air Temperature °C			Precip (mm)	Ave Radiation (W/m^2)	
	Max	Min	Ave		Incident	Reflected
6/5/10	16.9	10.5	0.8	0.5	205	27
6/6/10	19.1	12.8	4.4	0	331	44
6/7/10	19.3	12.4	4.3	0	239	31
6/8/10	16.1	11	6.1	0	233	31
6/9/10	16.8	11.6	6.7	0	240	33
6/10/10	16.9	10.8	5	4.3	188	25
6/11/10	14.9	11.2	6.9	1.3	193	25
6/12/10	17.6	11.2	2.6	0	183	23
6/13/10	19.2	13.2	8.5	0.5	277	39
6/14/10	17.1	12.4	4.8	0	191	26
6/15/10	12.7	10.6	8.3	6.3	66	8
6/16/10	14.6	10.1	5.7	0.3	90	11
6/17/10	17.7	11.8	8.2	0.3	147	19
6/18/10	15.9	11.7	7.5	0.3	141	19
6/19/10	14.2	10.7	7.4	4.3	129	17
6/20/10	19	12.9	7.9	0.8	254	36
6/21/10	23.4	14.2	3.6	0	324	44
6/22/10	20.3	15	10.7	0	242	34
6/23/10	19.9	14.7	10.3	0	269	40
6/24/10	19.9	14.6	10.4	0	278	39
6/25/10	20.6	14.6	10.6	0	198	28
6/26/10	15.6	13.1	11.1	4.8	104	14
6/27/10	13.6	11.7	10.5	8.1	62	7
6/28/10	16.8	12.7	9.8	1	139	20
6/29/10	18.2	13.4	10.5	1.8	139	18
6/30/10	18.4	13.3	10.1	0.3	178	25
7/1/10	19.4	13.7	8.5	0	256	37
7/2/10	15.7	12.7	7.7	0.8	121	16
7/3/10	16.6	12.6	9.1	2	167	22
7/4/10	17.5	13.1	10.1	3	120	15
7/5/10	18.2	13.5	9.6	1.3	147	21
7/6/10	19.3	14.6	10.3	0	188	26
7/7/10	18.3	13.7	9.3	0	142	19
7/8/10	21.7	15.1	8.5	0	245	35
7/9/10	24.2	13.9	3	1	300	44
7/10/10	15.2	12.5	9.9	1.5	97	13
7/11/10	18.1	12.4	7.9	0	103	13

Table III-3-3. Daily climatic data for Eagle River Flats meteorological station from mid May through mid September 2010 (pg. 1 of 3).

Date	Air Temperature °C			Precip (mm)	Ave Radiation (W/m^2)	
	Max	Min	Ave		Incident	Reflected
7/12/10	24.1	16.1	8	0	269	38
7/13/10	16.3	13.8	11.2	2.3	107	14
7/14/10	21.5	14.7	8.7	0	257	36
7/15/10	17.2	13.8	10.5	0.3	114	15
7/16/10	19.7	14	9.7	0	194	29
7/17/10	19.2	13.5	6.5	0	298	45
7/18/10	16.3	12.8	9.9	7.4	94	11
7/19/10	16	12.8	10.7	0.5	74	9
7/20/10	17.4	13.5	11.2	12.2	95	12
7/21/10	17.3	13.5	9.7	0.8	202	28
7/22/10	19	14.1	8.9	0.5	166	23
7/23/10	19	13.7	9	0	169	23
7/24/10	15	11.2	9.3	2.5	55	7
7/25/10	15.8	11.5	9.3	5.1	75	9
7/26/10	12.6	11	9.5	16.8	38	4
7/28/10	15.1	11.7	7.7	0.5	88	11
7/29/10	17	12.4	9.1	0	90	11
7/30/10	18.2	14.1	10.1	1	113	14
7/31/10	21.1	15.1	11.1	5.3	157	20
8/1/10	18.6	15.5	13.3	0.3	106	13
8/2/10	19.7	15.2	10.3	0.3	161	22
8/3/10	20.1	13.6	6.3	5.3	131	17
8/4/10	19.6	15.2	12.9	14.2	66	8
8/5/10	18.6	13.4	10.9	1.3	136	19
8/6/10	13.7	12.3	11.1	3.6	54	6
8/7/10	16	12.7	10.9	1.8	95	11
8/8/10	18.3	13.3	8.9	1.3	156	20
8/9/10	21	14.2	11.1	0.3	84	11
8/10/10	16.4	12.1	10.4	2.5	59	7
8/11/10	20.3	12.9	9.7	1	119	14
8/12/10	14.1	11.7	8.8	2.3	67	7
8/13/10	16.2	12.5	9.7	5.1	76	8
8/14/10	19.2	14.6	9.7	1	100	11
8/15/10	18	14.4	11.2	0	64	7
8/16/10	16	13.6	11.8	1.5	41	4
8/17/10	16	12.5	9.7	2	46	4
8/18/10	19.8	13.4	7.8	0	201	28

Table III-3-3. Daily climatic data for Eagle River Flats meteorological station from mid May through mid September 2010 (pg. 1 of 3).

Date	Air Temperature °C			Precip (mm)	Ave Radiation (W/m^2)	
	Max	Min	Ave		Incident	Reflected
8/19/10	19.9	11.3	2.9	0	222	31
8/20/10	21.3	12	3.6	0	239	34
8/21/10	19.9	12.8	6.3	0	202	28
8/22/10	19.5	12.9	8.1	1	208	29
8/23/10	22.6	13.7	8.5	0.5	209	30
8/24/10	23.8	13	3	0	223	32
8/25/10	22.5	12.9	4.1	0	219	31
8/26/10	20.3	11.6	3.4	0	162	22
8/27/10	13.7	11.6	9.8	1	40	4
8/28/10	13.4	11.3	9.4	20.8	36	3
8/29/10	18	11	5.6	0.3	143	21
8/30/10	16.8	10.2	4.7	0	124	17
8/31/10	16.4	11.7	7.7	0	130	16
9/1/10	18.3	12.5	7.9	0.3	133	18
9/2/10	18.3	11.9	7.4	0.3	144	21
9/3/10	19	12	5	0	186	27
9/4/10	12.2	10.4	8.8	9.4	25	2
9/5/10	14.3	11.2	8.5	3.3	72	7
9/6/10	18.4	13.1	10	0	105	13
9/7/10	17	13.1	9	4.3	62	7
9/8/10	14.8	10.7	6.1	0	62	7
9/9/10	13.4	9.9	6.1	0.8	66	6
9/10/10	19.7	9.6	1.3	0	171	23
9/11/10	18.4	9.9	2.1	0	153	21
9/12/10	21.8	10.2	1.7	0	165	22
9/13/10	21.7	9.8	0.7	0	157	22
9/14/10	16.2	7.7	0.7	0	113	15
9/15/10	14.3	7.3	2.4	0	84	10
9/16/10	16.7	7.8	3	0	143	18
9/17/10	10.8	7.7	3.3	0	49	5
9/18/10	13.7	7.8	2.4	0	80	10
9/19/10	18.9	7.7	-1	0	139	17

REFERENCES

Collins, C.M. (2001) 2000 weather data for Eagle River Flats. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY00 Final Report. Collins, C.M. and D.W. Cate, Eds. Contract Report to U.S. Army, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 71–78.

Collins, C.M. (2002) 2001 weather data for Eagle River Flats. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska Collins, C.M. and D.W. Cate, Eds. FY01 Final Report. Contract Report to U.S. Army, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 121–130.

Collins, C.M. (2003) 2002 weather data for Eagle River Flats. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska Collins, C.M. and D.W. Cate, Eds. FY02 Final Report. Contract Report to U.S. Army, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 119–129.

Collins, C.M. (2004) 2003 weather data for Eagle River Flats. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY03 Final Report. Collins, C.M. and D.W. Cate, Eds. Contract Report to U.S. Army, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 111–122.

Collins, C.M. (2005) 2004 weather data for Eagle River Flats. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY04 Data Report. Collins, C.M. and D.W. Cate, Eds. Contract Report to U.S. Army, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 97–109.

Collins, C.M. (2006) 2005 weather data for Eagle River Flats. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY05 Data Report. Bigl, S.R. and C.M. Collins, Eds. Contract Report to U.S. Army, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. pp. 83–95.

Collins, C.M. (2007) 2006 weather data for Eagle River Flats. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska. FY06 Data Report. Bigl, S.R. and C.M. Collins, Eds. ERDC/CRREL LR-07-1. Contract Report to U.S. Army, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. p. 113–124.

Collins, C.M., C. Williams, and T. Hall (2008) 2007 weather data for Eagle River Flats. In Remediating and Monitoring White Phosphorus Contamination at Eagle River Flats (Operable Unit C), Fort Richardson, Alaska: FY07 Data Report Bigl, S.R. and C.M. Collins, Eds. ERDC/CRREL LR-08-04. Contract Report to U.S. Army, Alaska, Directorate of Public Works and the U.S. Army Engineer District, Alaska. U.S. Army Engineer Research and Development Center, Hanover, NH. p. 115–124.

Haugen, R.K. (1995) Climate and tides. In Interagency Expanded Site Investigation: Evaluation of White Phosphorus Contamination and Potential Treatability at Eagle River Flats, Alaska. FY94 Final Report. C.H. Racine and D.W. Cate, Eds. CRREL Contract Report to U.S. Army, Alaska, Directorate of Public Works, May 1995. pp. 187–200.