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Cold Regions Research and Engineering Laboratory

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Engineer Research and Development Center

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

FY05 Data Report

Susan R. Bigl and Charles M. Collins, Report Editors

April 2006

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Prepared for

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I. EXECUTIVE SUMMARY

INTRODUCTION

This is the sixteenth annual contract report prepared by researchers from CRREL and other Federal agencies for U.S. Army Garrison Alaska, Public Works, describing results of research, remediation, and monitoring efforts addressing white phosphorus 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 is designated Operable Unit C (OU-C) under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

Over the five-year period 1999–2003, full-scale remediation was performed at Eagle River Flats using six remote-controlled pumps to temporarily drain contaminated ponds, allowing the sediments to dry and the white phosphorus to oxidize. This effort successfully remediated about 90% of the ponds. More recently, limited remediation using one or two pumps has been conducted to address the remaining few white-phosphorus-contaminated areas.

During the first year of the monitoring phase at Eagle River Flats, 2004, monthly flooding tides were predicted. Therefore, little remediation was performed as such. A single pump in Pond 146 was used to lower water levels in Area C, primarily to facilitate sampling and monitoring and to reduce its attractiveness to waterfowl. In 2004, several white phosphorus UXOs were detonated in the C-Marsh treatment area. After considering this event and analyzing the 2004 season mortality data, Remedial Action managers decided to expand treatment of the C-Marsh section of Area C during 2005 to better address the last known hot spots on the Flats. Therefore, this season, in addition to the Pond 146 pump, a second pump was utilized in a previously prepared sump in Northern C Marsh. White phosphorus (WP) remains in this area as identified in the monitoring study, and it contributed to a majority of the waterfowl mortality observed during the fall migration period. Two more seasons of limited pumping are projected to complete remediation of this area.

II-1. WATERBIRD UTILIZATION OF EAGLE RIVER FLATS FROM AERIAL SURVEYS, APRIL–OCTOBER 2005

William D. Eldridge

U.S. Fish and Wildlife Service conducted 30 aerial surveys to monitor waterfowl use within Eagle River Flats during the spring, summer, and fall of 2005. 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. Tundra and trumpeter swans used ERF only in small numbers during the spring of 2005 and increased in fall to a peak of 79 birds. Fall goose migration and duck species use of ERF in 2005 were similar to other years. The mean number of ducks observed in the fall (602) was lower than the mean of 836 during the 1988–1997 period, prior to the start of major pond pumping remediation. However, the general duck population in Upper Cook Inlet was also lower than recent years.

II-2. 2005 GROUND-BASED MORTALITY SURVEYS

Charles M. Collins, Marianne E. Walsh, Benjamin B. Steele, Leonard R. Reitsma, Jon E. Zufelt, and Ann Staples

Ground-based surveys to determine waterfowl mortality were conducted for a second consecutive year in 2005. A core group of transects, in areas with known remaining white phosphorus contamination and other areas most frequented by waterfowl, was surveyed at least twice weekly over the fall migration period (mid-August to late 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. The surveys located 49 waterfowl mortalities, as identified by carcasses, feather piles, and other body parts. Twenty-five mortalities, or 51% of the total, were along the Ditch Transect in Northern C Marsh, an area with known remaining white phosphorus contamination. All 17 gizzards recovered and analyzed for WP tested positive, indicating the deaths were due to WP poisoning.

III-1. EAGLE RIVER FLATS REMEDIATION PROJECT: LIMITED REMEDIATION OF NORTHERN C-MARSH

Michael R. Walsh, JoAnn Walls, Jon E. Zufelt, and Charles M. Collins

During the 2005 field season, the second year of the monitoring phase of the Eagle River Flats project, remediation was limited to known small areas of contamination that remain in the C Marsh area. This year’s tidal patterns, with no flooding tides from April through late July, provided a fairly good drying season that resulted in some remediation in Pond 155 and parts of C-Marsh.

Two pump units were deployed this year. A large, shore-based unit was reinstalled in the Pond 146 sump and operated from mid May to mid September, except during the July and August flooding cycles. Shortly after starting, the smaller of its two tandem pumps failed, so only the larger pump was used for the remainder of the season. The Flats experienced a dry spring this year, so this pump drained the surrounding area in C-Marsh after only a few hours.

The second unit was sited to allow draining from the Bomb Crater sump. To facilitate a shore-based unit at this site, a road was put through from the EOD pad to a clearing east of the northerly Bangalore ditch in C-Marsh and a gravel pad was installed in the clearing. The new road and pad allowed the genset to be towed into place and refueled on land, reducing helicopter time. The system used at this location ran from 26 May through 13 September, except during flooding tides, and provided limited redundancy, allowing us to lower the C-Marsh ditch system water level, improving drying conditions in this area of high mortality.

The normal midyear deployment was not done this season. A limited deployment was conducted to repair animal damage to a power cord. We advise that mid-season trips be resumed in the future.

This 2005 season was one of change, with all new contractors for logistics support, UXO clearing, and helicopter services. In addition, the CRREL –FRA office handled equipment operation and maintenance. Aging equipment and increased animal activity at the Flats resulted in more problems than usual. However, most were handled in a timely manner. Unanticipated heavy-lift helicopter support from the Army National Guard was required due to low spring water levels, a lack of sufficient equipment by the helicopter contractor, and the contractor’s failure to honor their contract in the fall. Fortunately, the Guard provided missions when we needed them and filled the gaps for us. Costs were minimized wherever possible, by sharing project personnel and reducing travel. Support from the Corps District Office was essential to completing the mission.

Known areas needing remediation remained unsaturated at the end of 2005. If an intense remediation plan is implemented next season, the areas should continue to improve. We recommend using a second pump in C-Marsh to further reduce water levels and provide redundancy in this critical area. Predicted tidal patterns indicate the 2006 and 2007 seasons should be excellent for remediation.

III-2. LONG-TERM MONITORING AND SAMPLING OF SEDIMENTS OF PONDS TREATED FOR WHITE PHOSPORUS

Marianne E. Walsh, Ronald N. Bailey, and Charles M. Collins

Summer 2005 was the second field season of long-term monitoring after five years of full-scale active remediation by pond pumping of white-phosphorus-contaminated ponds at Eagle River Flats (ERF). Monitoring includes the collection of multi-increment samples of the surface sediments of treated ponds and of discrete samples taken at locations that previously had high concentrations of white phosphorus. Monitoring also includes measuring sublimation/oxidation conditions at selected locations within contaminated or formerly contaminated ponds. Sublimation/ oxidation conditions were excellent in June and July 2005 in Area C Ponds 146 and 171, where reductions of white phosphorus in planted WP particles were 100% and 97%, respectively. Sublimation/oxidation conditions were marginal for Area C Pond 155 and the eastern side of Area BT, but some decontamination occurred based on the loss of planted particles and a decrease in WP concentrations at some locations. Two areas with continued lethal WP quantities are Area C Marsh, including several small pools and drainage ditch segments, and the southeast corner of Area BT.

III-3. 2005 WEATHER DATA FOR EAGLE RIVER FLATS

Charles M. Collins

Temperatures in Eagle River Flats were normal to slightly above normal throughout the summer remediation season from mid May through mid September. Although total cumulative precipitation for the season was about normal (205 mm), the portion accumulated during May and June was below normal; the portion from the last half of the season was normal to above normal. Normal temperatures and below normal precipitation in early summer provided good drying conditions during much of the season.

II-1. WATERBIRD UTILIZATION OF EAGLE RIVER FLATS FROM AERIAL SURVEYS, APRIL–OCTOBER, 2005

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 2005 were conducted by the U.S. Fish and Wildlife Service as part of the ongoing waterbird mortality and monitoring studies of ERF 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 salt marsh complex comprising 870 hectares (ha) on the south side of Knik Arm, approximately 10 kilometers (km) east of Anchorage (Fig. II-1-1). A detailed description of this area is presented in Racine and Cate, Eds. (1996).

METHODS

Aerial surveys of ERF were flown from April through October, 2005. Surveys were conducted more frequently during fall than in spring and summer. Surveys were flown using a fixed-wing aircraft at an airspeed of 100 to 120 km/hr and at an altitude of 70 to 75 meters (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 cassette tape recorder. Waterfowl numbers were classified by locations on ERF, using standardized study areas (Fig. II-1-1). When possible, birds were also recorded by individual ponds within each study area, using a standardized pond numbering system developed for the ERF database by the Cold Regions Research and Engineering Laboratory (CRREL). Areas (ha) of permanent and intermittent study ponds were obtained from digitized maps provided by CRREL and used to convert bird numbers to densities within the study areas.

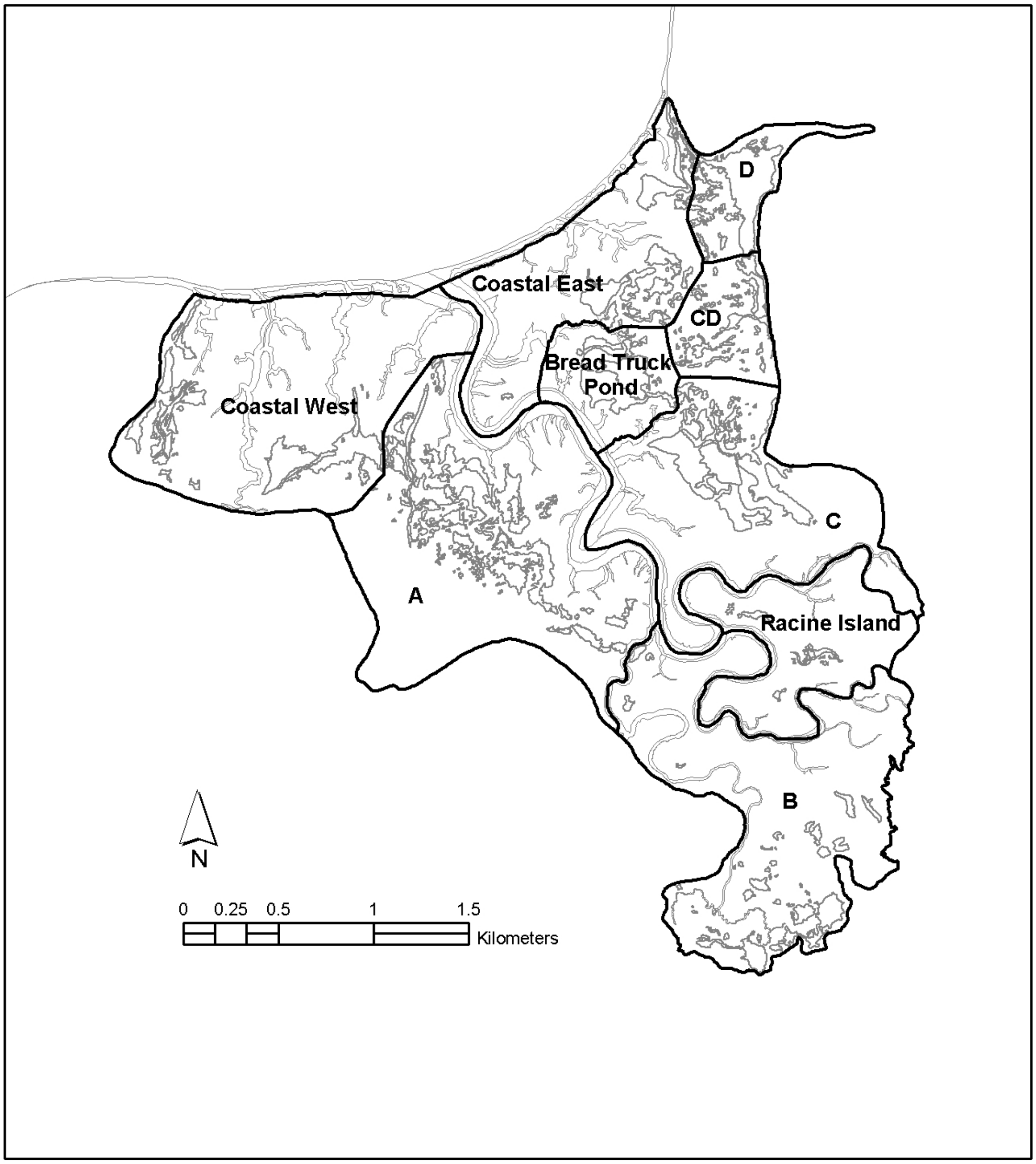

Figure II-1-1. Standardized ERF study areas surveyed for waterfowl.

RESULTS AND DISCUSSION

Moisture conditions

ERF experienced an earlier spring breakup in 2005 than in 2004. ERF was approximately 60 percent open by 23 April 2004 but completely open on 25 April 2005. Summer moisture conditions are explained in detail in other reports developed by CRREL in this publication, but in general conditions were very dry

(Collins, this volume, Section 111-3). Fall high tides flooded most of the ponds by late August. The ponds on ERF began freezing, with periods of thawing, in early October and were frozen for the winter by 25 October.

Abundance and distribution of waterbirds on ERF

Thirty aerial surveys were conducted in 2005. The number of fall surveys, used to evaluate mortality, was similar to recent years. Numbers of birds by species or species groups are listed by survey date in Table II-1-1 and Figure II-1-2. Utilization of ERF study areas by major waterfowl groups by season is presented in Tables II-1-2 and II-1-3. A discussion of utilization of ERF by species or species groups of waterbirds is presented below.

Swans

Tundra (*Cygnus columbianus*) and/or trumpeter swans (*C. buccinator*) utilized ERF in only small numbers during spring of 2005 (Table II-1-1).

In fall, swan numbers peaked in early October at 79 birds (Table II-1-1). Swans utilized Areas B, D and Coastal East most in fall (Table II-1-2, Fig. II-1-3). One dead swan was observed in western Area D on the 20 October survey.

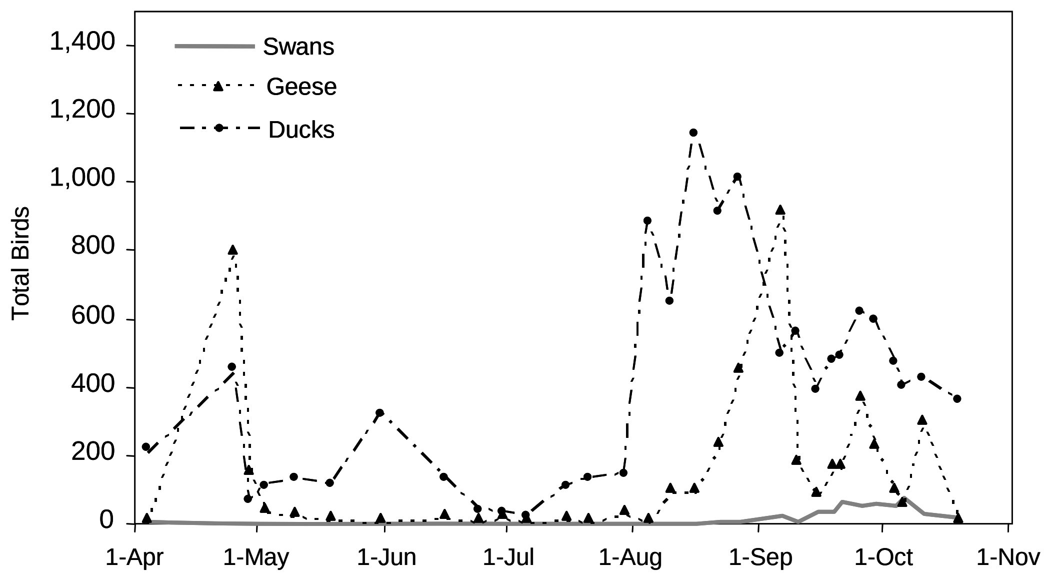

Figure II-1-2. Numbers of swans, geese, and ducks counted on ERF during aerial surveys in 2005.

Table II-1-1. Number of birds, by species or species group, observed during aerial surveys of ERF in 2005 (page 1 of 3).

	4/4	*4/25*	*4/29*	*5/3*	*5/10*	*5/19*	*5/31*	*6/16*	*6/24*	*6/30*
Swans	**6**	**1**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Geese										
White-fronted	0	93	32	0	2	2	0	0	0	0
Snow	0	650	0	0	1	0	0	0	0	0
Canada	0	41	110	30	15	3	0	14	0	14
Subtotal geese	**0**	**784**	**142**	**30**	**18**	**5**	**0**	**14**	**0**	**14**
Ducks										
Gadwall	4	6	0	0	0	0	0	0	0	0
American wigeon	0	35	4	39	0	35	58	55	2	4
Mallard	199	113	20	33	23	34	99	25	0	8
Northern shoveler	0	18	9	10	15	16	35	0	0	0
Northern pintail	0	238	21	7	60	14	115	39	0	6
Green-winged teal	0	27	0	6	11	0	0	0	0	0
Red-breasted merganser	0	0	0	0	6	1	0	0	0	0
Goldeneye	0	0	0	0	0	0	0	0	0	0
Unidentified duck	0	0	0	0	0	0	0	0	22	0
Subtotal ducks	**203**	**437**	**54**	**95**	**115**	**100**	**307**	**119**	**24**	**18**
Other birds										
Bald eagle	0	4	3	1	0	0	0	1	0	0
Harrier	0	0	0	0	0	0	0	0	0	0
Sandhill crane	0	0	37	37	7	0	7	0	6	5
Gulls	2	32	44	32	73	5	179	100	114	24
Yellowlegs	0	10	1	0	7	6	0	0	0	20
Shorebird	0	16	0	20	31	50	0	250	1310	117
Arctic tern	0	3	17	13	12	39	34	0	15	22
Common raven	0	0	0	0	0	0	0	0	0	0

Table II-1-1 (cont.). Number of birds, by species or species group, observed during aerial surveys of ERF in 2005 (page 2 of 3).

	7/6	*7/16*	*7/21*	*7/30*	*8/5*	*8/10*	*8/16*	*8/22*	*8/27*	*9/6*
Swans	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**6**	**26**
Geese										
White-fronted	0	0	0	0	0	20	66	135	14	15
Snow	0	0	0	0	0	0	0	0	0	0
Canada	0	8	0	22	0	70	20	90	425	885
Subtotal geese	**0**	**8**	**0**	**22**	**0**	**90**	**86**	**225**	**439**	**900**
Ducks										
Gadwall	0	0	0	0	0	0	0	0	0	0
American wigeon	0	41	58	40	249	207	220	315	163	59
Mallard	5	40	43	56	223	230	419	208	371	118
Northern shoveler	0	0	0	0	50	0	30	35	25	0
Northern pintail	0	6	0	6	150	126	170	81	263	60
Green-winged teal	0	0	15	26	156	70	244	146	161	97
Red-breasted merganser	0	0	0	0	0	0	0	0	0	0
Goldeneye	0	0	0	0	0	0	0	15	12	0
Unidentified duck	0	6	0	0	40	0	40	95	0	145
Subtotal ducks	**5**	**93**	**116**	**128**	**868**	**633**	**1123**	**895**	**995**	**479**
Other birds										
Bald eagle	0	0	0	1	1	0	0	0	0	1
Harrier	0	0	0	0	1	0	0	0	0	0
Sandhill crane	16	4	41	4	3	13	1	0	13	38
Gulls	68	16	20	6	4	0	8	1	0	0
Yellowlegs	30	0	250	0	12	6	15	0	0	6
Shorebird	500	200	25	172	175	150	70	0	0	0
Arctic tern	37	5	7	6	0	0	0	0	0	0
Common raven	0	0	0	0	12	0	0	0	1	0

Table II-1-1 (cont.). Number of birds, by species or species group, observed during aerial surveys of ERF in 2005 (page 3 of 3).

	9/10	*9/15*	*9/19*	*9/21*	*9/26*	*9/29*	*10/4*	*10/6*	*10/11*	*10/20*
Swans	**8**	**38**	**36**	**64**	**54**	**60**	**53**	**79**	**31**	**19**
Geese										
White-fronted	24	0	0	0	0	0	0	0	0	0
Snow	0	0	0	0	0	0	0	0	0	0
Canada	147	75	161	160	360	219	90	45	290	0
Subtotal geese	**171**	**75**	**161**	**160**	**360**	**219**	**90**	**45**	**290**	**0**
Ducks										
Gadwall	0	0	0	0	0	0	0	0	0	0
American wigeon	31	26	75	33	37	80	14	0	12	0
Mallard	143	271	249	339	351	319	228	207	371	344
Northern shoveler	0	0	0	0	0	0	0	0	0	0
Northern pintail	297	21	8	23	104	76	28	20	0	0
Green-winged teal	30	57	118	63	71	79	102	42	28	0
Red-breasted merganser	0	0	0	0	0	0	0	0	0	0
Goldeneye	0	0	10	15	0	0	0	0	0	0
Unidentified duck	45	0	0	0	40	28	87	120	0	0
Subtotal ducks	**546**	**375**	**460**	**473**	**603**	**582**	**459**	**389**	**411**	**344**
Other birds										
Bald eagle	2	0	0	2	0	0	3	1	0	1
Harrier	0	0	0	0	0	0	0	0	0	0
Sandhill crane	30	0	2	0	0	0	0	0	0	0
Gulls	0	0	0	0	0	0	0	0	0	0
Yellowlegs	0	0	0	0	10	0	0	0	0	0
Shorebird	0	0	0	0	0	0	0	0	0	0
Arctic tern	0	0	0	0	0	0	0	0	0	0
Common raven	0	0	0	0	0	0	0	0	0	0

Table II-1-2. Mean numbers of waterfowl groups in 2005 by season. The number of complete surveys used to classify observations by area for spring and fall were 7 and 16, respectively.

	Coastal West	A	B	Racine Island	C	CD	Bread Truck	Coastal East	D
Spring									
Swans	0.0	0.9	0.1	0.0	0.3	0.0	0.0	0.0	0.0
Geese	4.3	103.9	1.7	4.6	19.7	0.3	4.7	0.7	0.0
White - fronted	0.0	3.1	0.9	0.3	13.1	0.3	0.4	0.3	0.0
Snow	0.0	92.9	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Canada	4.3	7.9	0.9	4.3	6.4	0.0	4.3	0.4	0.0
Ducks	9.3	83.9	11.4	4.0	19.4	4.7	10.1	39.9	4.6
Fall									
Swans	0.0	1.3	5.2	0.0	0.6	2.9	0.0	5.7	14.2
Geese	34.4	61.6	11.3	1.8	44.6	0.0	3.8	49.6	0.0
White - fronted	2.2	6.2	4.6	0.8	1.2	0.0	0.0	2.2	0.0
Canada	32.2	55.4	6.8	0.9	43.4	0.0	3.8	47.4	0.0
Ducks	10.7	145.8	65.7	1.9	103.9	106.4	11.7	32.6	123.6

Table II-1-3. Percent duck use of major habitat types by season on ERF in 2005.

	(n)	Ponds	Knik Shoreline	Eagle River	Tidal Sloughs
Spring	(362)	100.0	0.0	0.0	0.0
Summer	(373)	80.7	0.0	19.3	0.0
Fall	(7,869)	96.7	<1	3.0	<1

Geese

Peak counts of geese in spring occurred on 25 April (Table II-1-1, Fig. II-1-4). Snow geese (*Chen caerulescens caerulescens*) comprised 66 percent of the total geese counted in spring, followed by Canada geese (*Branta canadensis*) and tule white-fronted geese (*Anser albifrons frontalis*). Geese utilized Areas A and C most in spring (Fig. II-1-4).

A small number of Canada geese usually use ERF during summer for nesting or brood-rearing (Table II-1-1).

Fall goose migration was similar to other years. Peak use occurred in early September with a lesser peak in mid October. Heaviest utilization by geese occurred in Areas A, C, Coastal West, and Coastal East (Table II-1-2, Fig. II-1-4). Tule white-fronted geese were observed in small numbers in fall. Snow geese were not observed but generally do not migrate through Cook Inlet in fall.

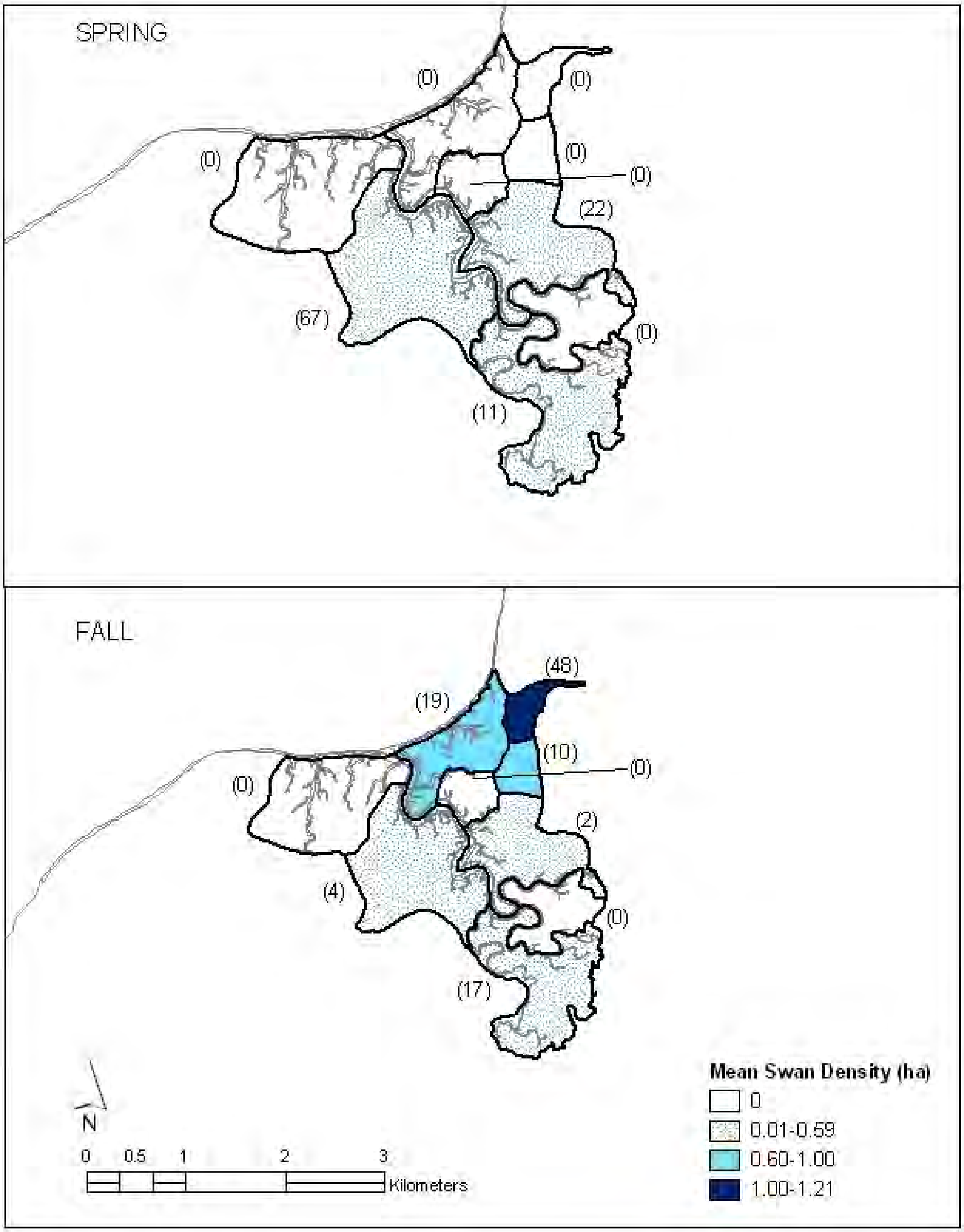

Figure II-1-3. Mean densities of swans on ERF study areas in spring and fall 2005. Numbers in parentheses are the percent of total swans observed in each area. The area (ha) of permanent and intermittent ponds in each area was used to calculate densities.

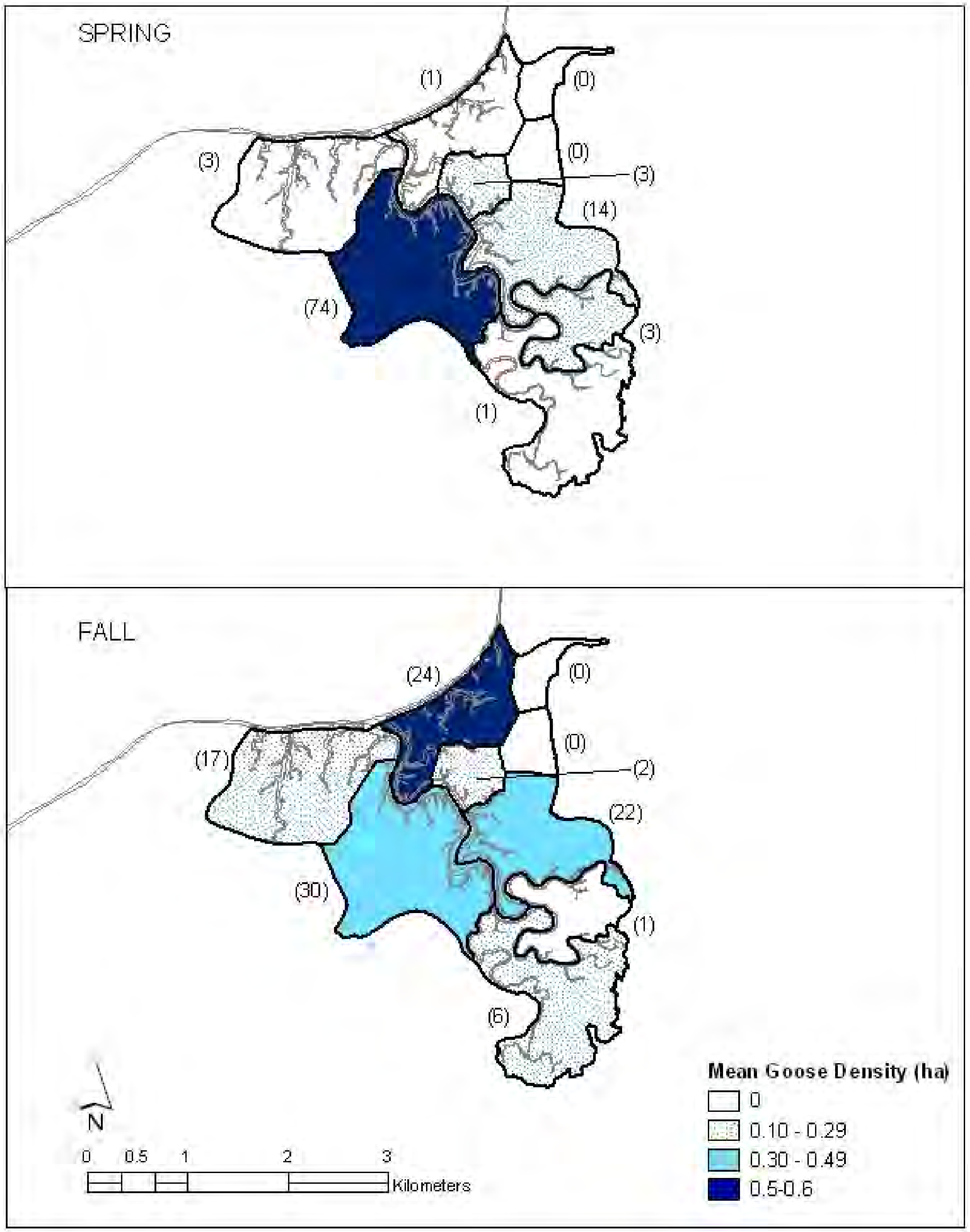

Figure II-1-4. Mean densities of geese on ERF study areas in spring and fall 2005. Numbers in parentheses are the percent of total geese observed in each area. The area (ha) of permanent and intermittent ponds in each area was used to calculate densities.

Ducks

Duck species utilizing ERF in 2004 were similar to other years (Table II-1-1). Dabbling ducks comprised 99 percent of the ducks counted through the season. Mallards (*Anas platyrhynchos*), American wigeon (*A. americana*), green-winged teal (*A. crecca*), and northern pintail (*A. acuta*) were the most common species observed. Of the four major habitat types used to classify duck locations, ponds were the most important (Table II-1-3). Numbers of all species of ducks combined are presented for 1991-2004 and 2005 in Figure II-1-5. Generally ERF supported fewer ducks in 2005 than earlier years.

In spring the number of ducks peaked on 25 April (Table II-1-1, Fig. II-1-5), and duck use of ERF was generally light during May. Ducks utilized Areas A and Coastal East most in spring, and density was highest in Coastal East (Fig. II-1-6).

Migration phenology for ducks during fall 2005 was earlier than recent years, with peak numbers occurring in late August with a smaller peak in early October (Table II-1-1, Fig. II-1-2). The mean number of ducks observed in the fall, 602, was lower than the 1988-1997 mean of 836. Extremely dry summer conditions and the effects of previous years' pumping and draining on both the amount of habitat available and food resources may be influencing duck utilization of ERF. However, the general population of ducks in Upper Cook Inlet also was less than in previous recent years, which means reduced numbers on ERF may also be a function of fewer migrating birds in 2005. Distribution of

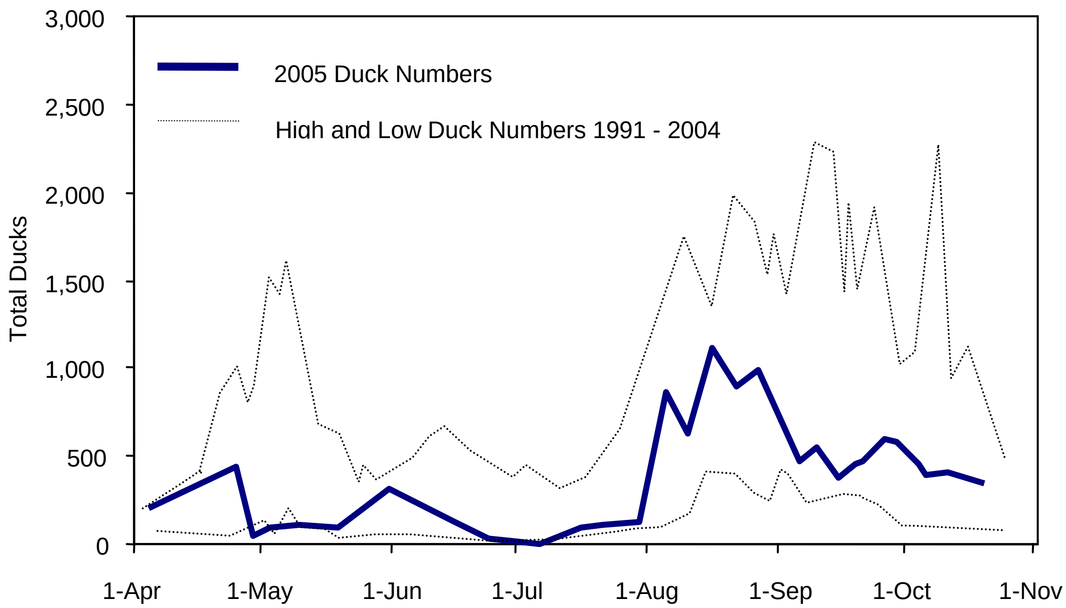

Figure II-1-5. Numbers of ducks observed during aerial surveys of ERF in 2005, compared to the low and high numbers of ducks observed from 1991 through 2004.

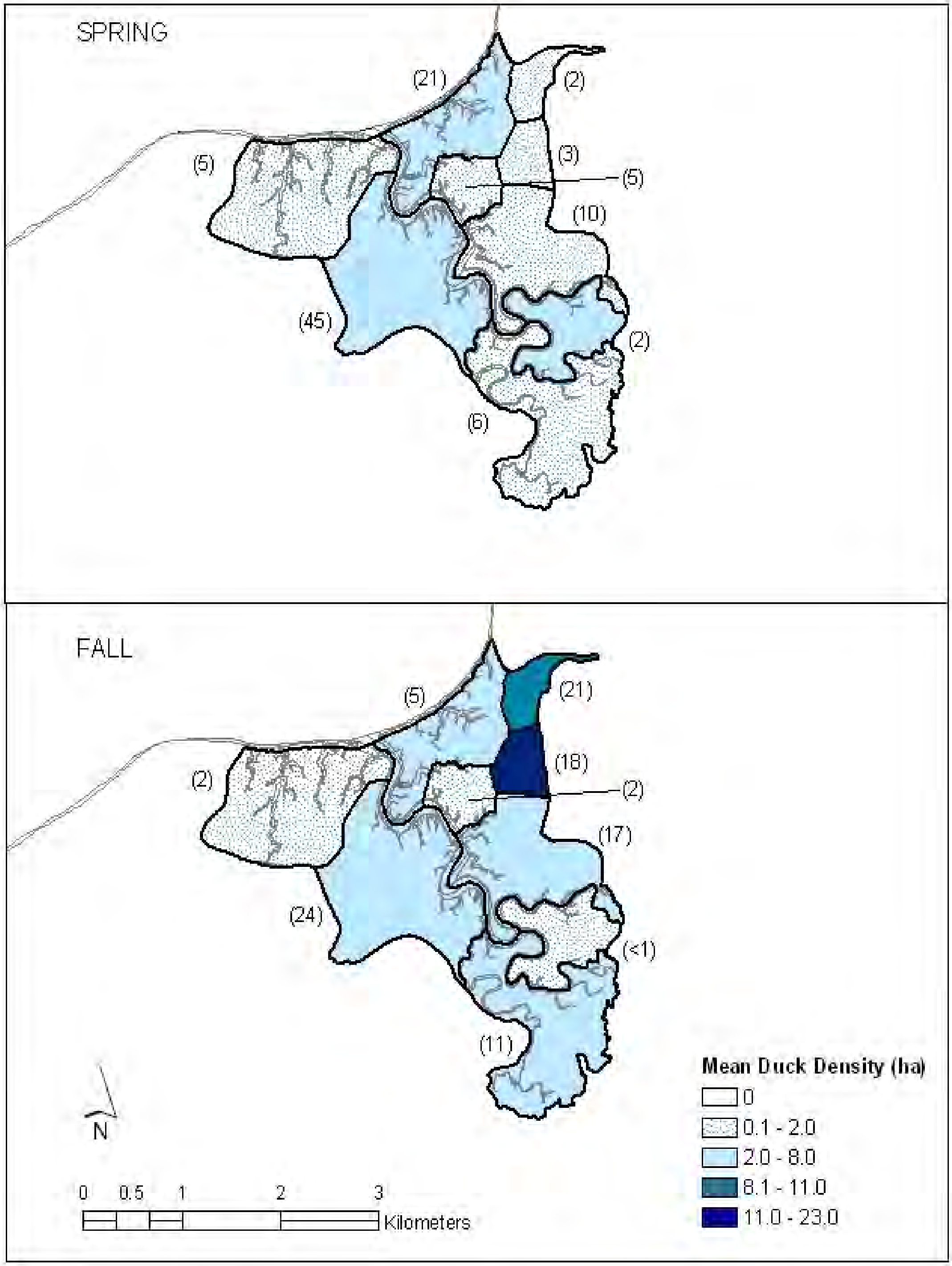

Figure II-1-6. Mean densities of ducks on ERF study areas in spring and fall 2005. Numbers in parentheses are the percent of total ducks observed in each area. The area (ha) of permanent and intermittent ponds in each area was used to calculate densities.

ducks in fall saw highest use in Areas A and D. Highest densities occurred in Areas C/D and D (Fig. II-1-6). Observations of ducks were also recorded by individual pond when possible. While it was not possible to separate small ponds in complex systems, use of important, distinguishable ponds was recorded (Fig. II-1-7). The large permanent and intermittent ponds of Areas D, C/D, and C were important.

Changes in Fall Pond Use by Ducks

Because of the ongoing treatability studies and attempts to reduce exposure of ducks to white phosphorus, duck utilization of the standard study areas of ERF from 1997 through 2005 is compared in Table II-1-4. Use of areas A, C, C/D, and D was highest. Use of Area B ponds decreased considerably to the lowest level in recent years.

Bald Eagles

Numbers of bald eagles (*Haliaeetus leucocephalus*) were low in 2005 (Table II-1-1), similar to recent years. While specific shoreline surveys for eagles were not conducted, concentrations similar to earlier years of 50 or more eagles would have been noticed. Lower numbers of eagles in recent years may be due to decreased mortality of waterbirds on ERF.

Shorebirds

Numbers of shorebirds were combined for all species since individual species were not identified from the airplane (Table II-1-1). Numbers of shorebirds were lower than other recent years. Common species on ERF include least sandpipers (*Calidris minutilla*), semipalmated sandpipers *(C. pusilla*), western sandpiper (*C. mauri*), dowitchers (*Limnodromus spp.*), and greater and lesser yellowlegs (*Tringa spp.*).

Gulls and Terns

Gull species were combined for aerial surveys (Table II-1-1). They include mew gulls (*Larus canus*), glaucous-winged gulls (*L. glaucescens*), and herring gulls (*L. argentatus*). Arctic terns (*Sterna paradisaea*) were common into July. The mew gull colony formerly in Area D now consists of just a few pairs.

Sandhill Cranes

Sandhill cranes (*Grus canadensis*) were observed on ERF in small numbers sporadically from spring to mid September (Table II-1-1).

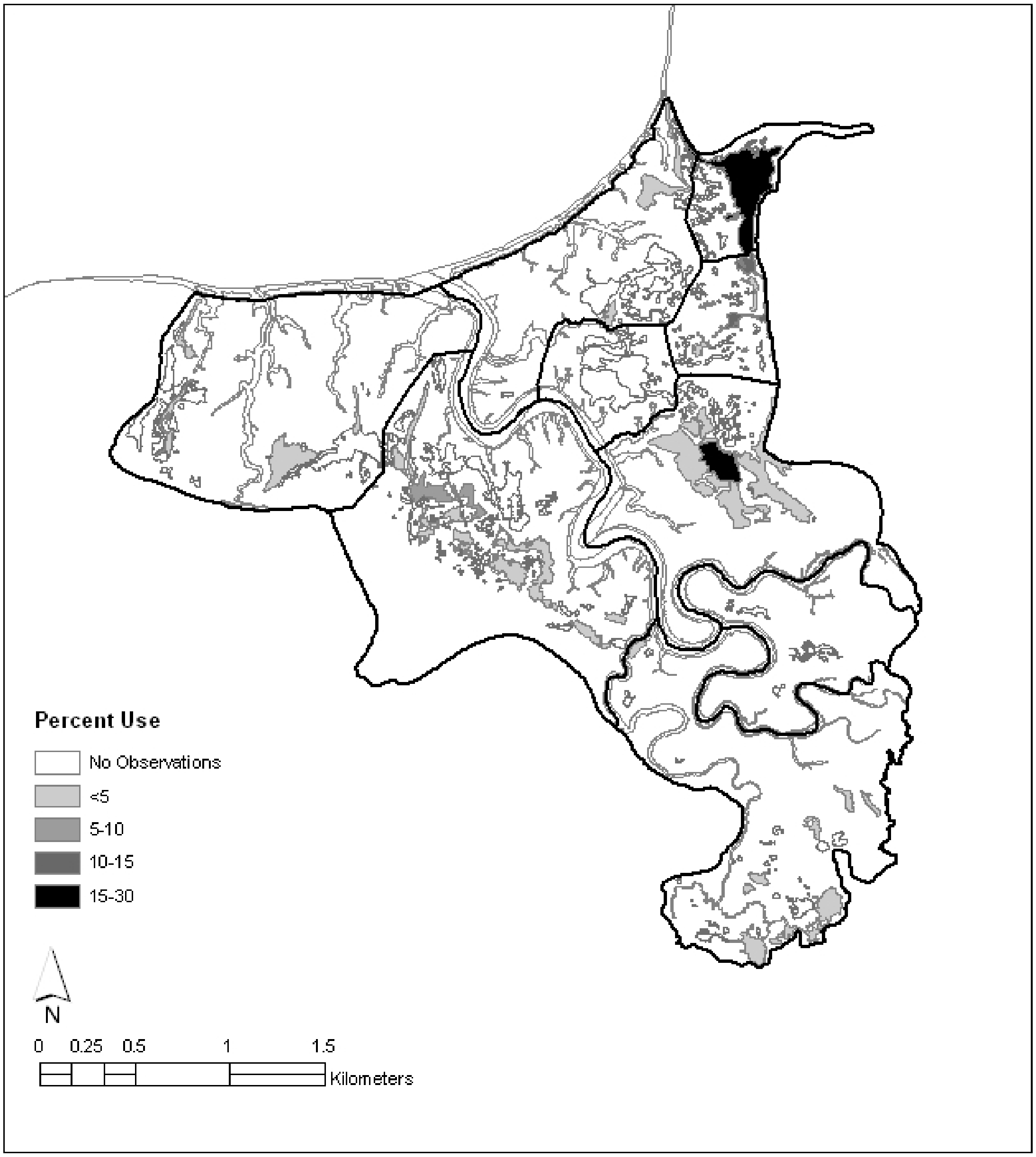

Figure II-1-7. Percent use of ponds by ducks classified to ponds during aerial surveys in fall 2005.

Table II-1-4. Percent use of ERF study areas and major habitat types by ducks in fall 1997-2005. Habitat types within study areas used by ≤ 1% of ducks are not listed.

	Percent Use								
Area/Habitat	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Coastal West	**9.9**	**17.6**	**18.8**	**7.9**	**6**	**3.4**	**7.2**	**4.7**	**5.6**
Ponds	5.6	9.1	10.9	5.8	5.4	1.9	1.1	1.7	1.4
Knik Shoreline	4.3	7.6	6.6	1.8	0.2	<0.1	0.7	0	0.1
Area A	**14.6**	**5.6**	**14.9**	**23.5**	**18.7**	**16.9**	**10.3**	**18.2**	**24.6**
Ponds	14.5	5	11.5	16.7	9.8	7.6	5	7.8	11.9
Eagle River	0	0	0	0	0	0	0	0	1.3
Area B	**25**	**19.2**	**20.1**	**19**	**10.5**	**21.4**	**33**	**19.3**	**9.8**
Ponds	19.2	18.2	16.1	17.8	9.7	17.6	25.3	10.2	7
Eagle River	5.8	1	1.4	1.2	0.2	1.3	0.4	0	0.1
Racine Island	**0.6**	**1.1**	**1.5**	**0.7**	**0.2**	**0.1**	**0.6**	**1**	**0.4**
Area C	**17.9**	**4.8**	**4.8**	**10**	**25.4**	**21.1**	**15.1**	**13**	**17.2**
Ponds	2.4	4.7	1	4.6	23.3	15.5	13.6	4.1	10.2
Eagle River	15.5	0.1	1	4.8	0.3	0.1	0	0.1	1.9
Area C/D	**11.4**	**15.3**	**8.5**	**9**	**12.5**	**17.5**	**17.4**	**14**	**13**
Ponds	11.4	15.3	3.7	5.7	8.1	12.8	10.6	6.3	8.8
Bread Truck	**1.3**	**1.9**	**2.3**	**3.7**	**0**	**0.1**	**0.3**	**3.5**	**2**
Ponds	1.3	1.9	1.1	1.5	0	0	0	0.9	0.2
Coastal East	**9.1**	**21.1**	**9.1**	**6.6**	**3.6**	**0.7**	**4.4**	**7.2**	**11.6**
Ponds	2.8	9.3	5	4.5	5.4	0.4	0	3.3	5.8
Knik Shoreline	6.3	11.7	0.9	1.4	0.2	0	0	0.2	0.2
Area D	**10.7**	**13.4**	**20**	**19.7**	**23.1**	**19**	**11.8**	**19**	**15.7**
Ponds	10.7	13.4	13.3	19.6	23.1	18.9	10.3	16.7	15.7

REFERENCE

Racine, C.H., and D.W. Cate (Eds.) (1996) Interagency expanded site investigation: Evaluation of white phosphorus contamination and potential treatability at Eagle River Flats, Alaska. FY 95 Final Report. CRREL. Contract Report to U.S. Army, Alaska Directorate of Public Works, Ft. Richardson, Eagle River.

II-2. 2005 GROUND-BASED WATERFOWL MORTALITY SURVEYS

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INTRODUCTION

Mortality rate of dabbling ducks in Eagle River Flats was chosen as the short- and long-term method of determining the effectiveness of remediation of 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.
>
> 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 ROD also stated that monitoring at Eagle River Flats would be conducted to verify that RAOs are achieved. The goals of monitoring were (CH2M Hill 1998):

> "To verify that an exposure pathway does not exist between waterfowl and white phosphorus-contaminated sediment,
>
> To determine the number of waterfowl using ERF,
>
> To determine the number of waterfowl dying as a result of feeding in white phosphorus-contaminated sediment, and
>
> To determine whether remedial action is effective or needs modification."

Beginning in 1994, dabbling duck mortality was estimated using radio-collared mallards (NWRC 2004). Studies were conducted through 2002, except in 2000, when helicopter non-availability prevented the study. Each year a number of wild mallards (ranging from 68-138) were captured over a two-week period in August using net guns from a helicopter. The mallards were fitted with radio collars and released. This subset of the wild mallard population was monitored twice a day until October 15 (or freeze-up) to determine its movement within Eagle River Flats, the rate at which the mallards leave Eagle River Flats (the turnover rate), and the mortality rate of the radio-collared mallards. These data were combined with the data from periodic aerial census surveys conducted by U.S. Fish and Wildlife Service and extrapolated in a model to estimate mortality for the entire population of waterfowl using Eagle River Flats. Using this method involved making a number of assumptions, including that the radio-collared mallards represented dabbling ducks in general, the turnover rate for the subset of radio-collared mallards represented the turnover rate for the entire dabbling duck population, the mortality of the radio-collared mallards was not related to stress associated with handling and fitting of radio-telemetry equipment, and mortality of radio-collared mallards is representative of the mortality of the entire population.

By 2002, mortality rate estimated by the model indicated that the short-term RAO of a 50% reduction of mortality had been met; however, the model lacks the sensitivity to estimate the more stringent long-term RAO of 1% mortality of the population. Because of the lack of sensitivity of the model and the expenses and uncertainty involved with radio telemetry, especially the use of helicopters to capture the mallards, continued future use and effectiveness of this method was problematic.

In a CLOSES draft memo, CH2M Hill (2004) suggested a weight-of-evidence approach be used to estimate overall mortality rates at ERF. After discussing the situation, the Remedial Project Managers decided to use this approach, which integrates sediment sampling for white phosphorus, aerial surveys of dabbling duck populations, and ground transects to assess dabbling duck mortality attributable to white phosphorus contamination (including confirmation that the ducks ingested white phosphorus).

Mortality studies using ground transects had been successfully conducted from 1991-1995, including two years of ground-based mortality surveys in 1994 and 1995 that overlapped with the telemetry mortality studies (Racine et al. 1992, Racine et al. 1993; Reitsma and Steele 1994, 1995; Steele and Reitsma 1996.) Transects used for those studies included edge transects that covered the perimeters of the major contaminated ponds, grid transects in the C/D area traversing a variety of salt marsh habitats, and forest-edge transects to count feather piles from the many carcasses removed by eagles from Eagle River Flats to the forest edge.

In contrast to the 1991-1995 period, major waterfowl feeding ponds that were contaminated with white phosphorus have now been either decontaminated by pond pumping or are no longer viable waterfowl habitat due to drainage by ditching. However, small areas of white phosphorus contamination still remain in the marsh of northern Area C, in the eastern part of Area BT, and on Racine Island.

During the early 1990s, large numbers of sick and dying waterfowl were predated or scavenged by bald eagles, resulting in large numbers of feather piles in the forest edge adjacent to Eagle River Flats. Much of this predation occurred in the spring migration period when other food sources for eagles in Upper Cook Inlet were scarce. The current numbers of eagles present in Eagle River Flats in the spring are greatly reduced from the early 1990s, reflecting the reduced waterfowl mortality from white phosphorus. Fewer than four and generally one or none were seen on aerial survey flights in the spring of 2005 (Eldridge, this volume, Section II-1) versus the fifty or more seen each spring during 1991-1994.

During 2004, ground-based mortality transects were successfully established and surveys carried out to determine waterfowl mortality. A core group of transects was surveyed at least twice a week over a 6-week fall migration period from mid-August to the end of September. The transects covered the marshes of northern Area C and eastern BT Area and the major waterfowl feeding ponds in Area C that have been remediated. We had designed and located mortality transects based on our knowledge of known remaining areas of white phosphorus contamination and long-term observations of waterfowl usage in Eagle River Flats. We counted 111 waterfowl mortalities during the 2004 ground-based surveys (Collins et al. 2005).

METHODS

During the 2005 season, three types of ground-based mortality survey transects were conducted. The first type was a core group of transects covering areas with known remaining white phosphorus contamination and areas most highly used by waterfowl. This core group was surveyed at least twice a week, except during periods of flooding tides, over the fall migration period from mid-August to near the end of October. The transects covered the marshes of northern Area C and eastern BT Area and the major remediated waterfowl feeding ponds in Area C.

The second survey type involved transects in areas used by waterfowl that have been remediated or have no known contamination. These transects were monitored less frequently than the core transects, generally weekly or bi-weekly. This type included transects in Area A that cover ponds that have undergone remediation, a canoe transect of Pond 40 in the C/D area, and a grid transect covering much of the remaining area of C/D.

A third survey type, conducted only once during the fall, consisted of forest-edge transect surveys to the east of Eagle River Flats. These transects were checked for feather piles from carcasses carried into the woods by predators and scavengers, mainly eagles.

Transect Survey Procedure

Ground-based transect lines for the core group of surveys were the same as in 2004 (Fig. II-2-1). The Ditch transect covers small pools in the Northern C marsh where two large interconnected drainage ditches were excavated for pumping remediation. The Duck Pond transect covers the small ponds (the Duck Ponds) in the eastern BT area. These were drained with a small ditch system excavated in July 2004. Transects were also laid out around the perimeter of the large waterfowl feeding ponds that have been previously treated by pumping – Pond 183 in Area C and Pond 730 in western C/D Area. The four transects included in the core survey group include:

1. Northern C Marsh Ditch Transect ....1,040 m total transect length
2. Pond 183 Transect..900 m
3. Pond 730, and 4. Duck Pond Transects..........2,360 m combined length

Total length of the four transects was approximately 4,300 m; this allowed a pair of observers to walk the entire distance in 4 to 5 hours.

Transect locations were surveyed with a Trimble Pathfinder Pro XR Global Positioning System. The centerline of the 10-m wide lanes was marked with 5-ft-high orange fiberglass markers with the tops spray-painted fluorescent lime-green. Past experience with these fiberglass markers in Eagle River Flats shows that they are highly visible from great distance. They also survive winter ice conditions well and can be expected to last for a number of years, thus facilitating re-establishment of the transect lanes each year. The lane’s widths were delineated with pairs of 4-ft wood lath with lime-green painted tops. The laths were spaced 10-m apart and placed every 50 or 100 meters along the survey lanes. These wooden laths generally do not survive the winter ice conditions and the lane widths have to be remarked each summer with new 4-ft lath. During the installation and marking of the 10-m wide lanes, the lanes width between pairs of lath was swept by the UXO technician and marked for UXO avoidance. This allowed the survey team to subsequently walk the lane periodically to conduct the mortality surveys without an UXO technician escort.

The second (remediated areas) transect type, done weekly or bi-weekly, consisted of:

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

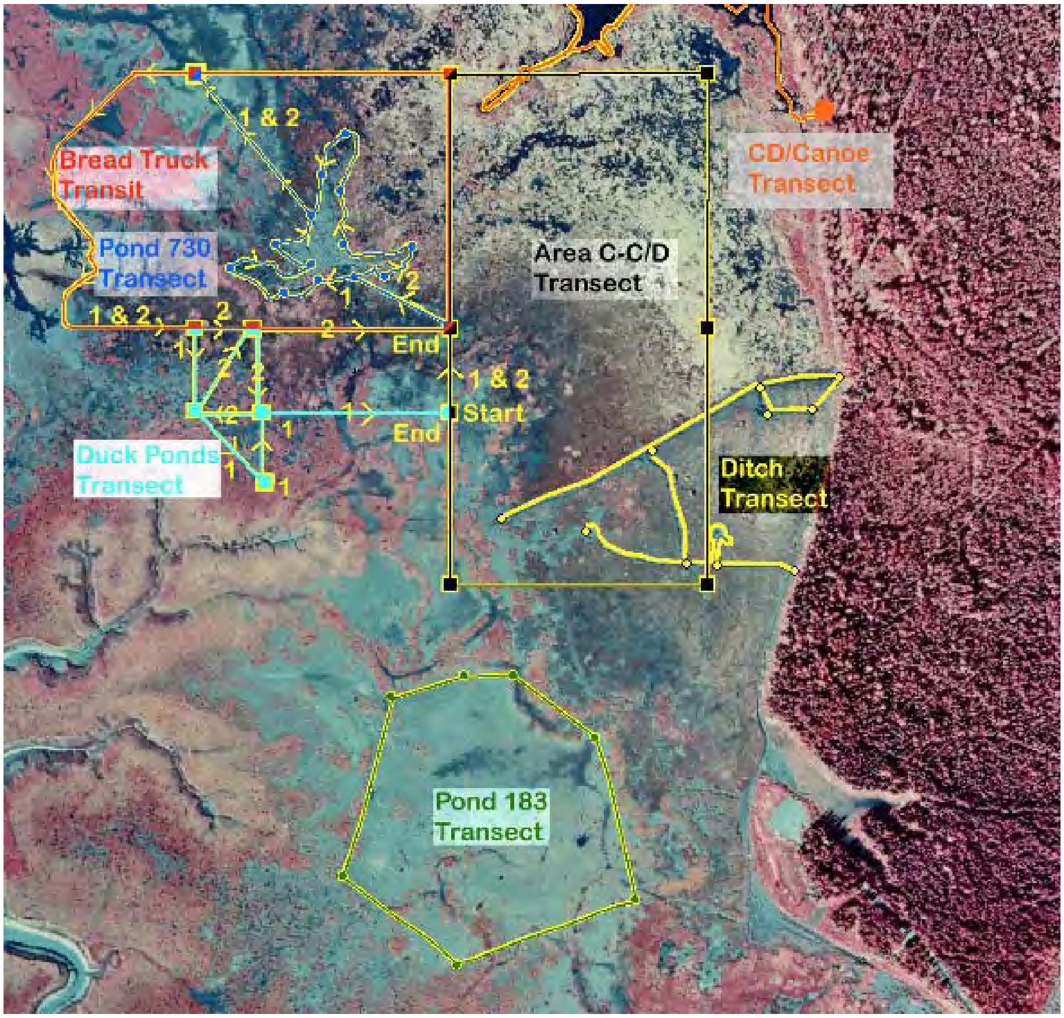

Figure II-2-1. Mortality transects in Areas C and C/D.

Area A transect took approximately 5 hours to conduct, including the walking time to access the area from Lower Cole Point. An access trail was marked and cleared from Lower Cole Point, the nearest point where a vehicle can be driven, along Otter Creek and the western edge of Eagle River Flats to the start of the transect at the south end of Pond 290 (Fig. II-2-2). The transect followed the east side of Pond 290, then along the east side of the Northern A pond complex and back, returning along the west side of Pond 290.

The Canoe Transect started along the east shore of C/D. The starting point was accessed by walking north approximately 1,200 m along the trail from the EOD pad and then along a short path down the bluff to the edge of the marsh, where a canoe was stored. The canoe was used to follow along the entire edge of Pond 140. The C/D grid transect followed a 250- x 500-m grid laid out through the C/D marsh (Fig. II-2-1). The two transects together took about six hours to complete.

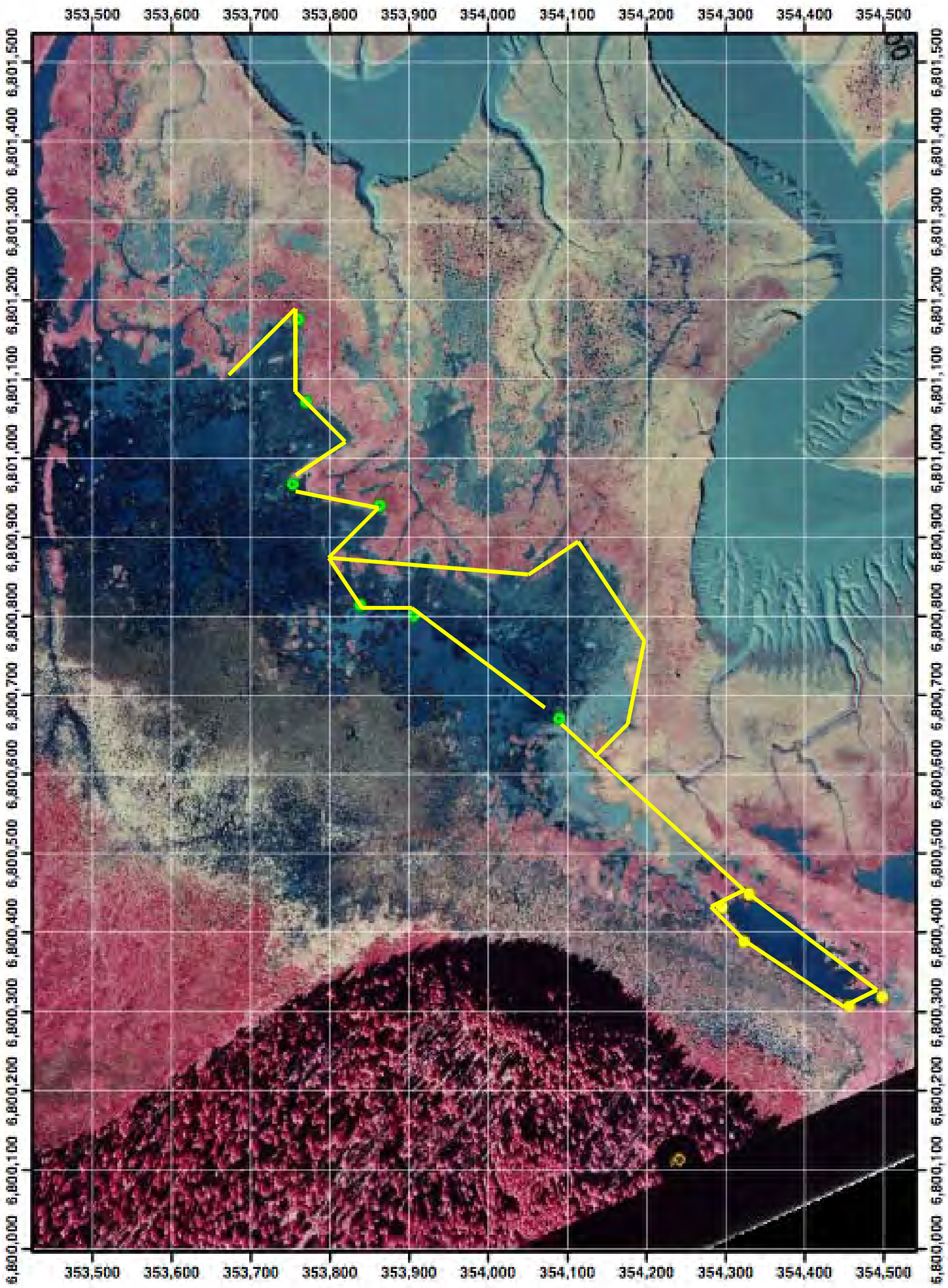

Figure II-2-2. Mortality transect in Area A.

All transects were surveyed similarly. The 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. 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 freshness of the carcass. A unique sequential sample identification number was assigned (e.g. MORT 001, MORT 002, etc.) to all carcasses and feather piles. If the carcass was in good shape, it was collected and the gizzard removed for later white phosphorus analysis. The carcass was then disposed of off-site. Carcass-handling procedure is discussed below. The location where the carcass or feather pile was found was marked with a PVC pin flag with the identification number and date.

If a feather pile was located rather than a carcass, similar information was recorded, including date, location, identification number, and species if it could be determined from the feathers. The feather pile location was marked with a PVC pin flag with an identification number and date. This prevented the feather pile from being recounted on future surveys.

Woodland transects consisted of four 400-m long transects running into the forest from the salt marsh boundary on the eastern side of Eagle River Flats. Additionally, one 50- by 200-m quadrat was located along the forest edge east of Northern C Marsh. The quadrat and all four transects were surveyed once in the fall to search for feather piles.

Waterfowl Carcass Handling Procedure

The survey team carried a collection kit consisting of latex exam gloves, single-edge razor blades, zip-lock sample bags, and a small cooler. When a carcass was collected, it was returned to the EOD pad where the gizzard was removed. A razor blade was used to cut a 2-in slit in the carcass just below the breastbone. Reaching into the slit and up behind the breastbone, the gizzard was pulled out and removed from the carcass. The gizzard was placed in a sample bag, and date, carcass number, and location information was recorded on the bag and in the field book. The bagged gizzard was then placed in the small cooler. At the end of each day, the labeled sample bags with gizzards were refrigerated. Every few days the gizzards were dissected, the gizzard contents were removed and placed in glass vials. Approximately every week the gizzard content samples were shipped to CRREL-Hanover for laboratory analysis. At the CRREL-Hanover laboratory the contents were analyzed for white phosphorus on a gas chromatograph using EPA Method 7580 (U.S. EPA 1995).

Period of Observations

The mortality surveys were conducted during the fall migration period from mid-August to October 20. The core mortality transects were surveyed at least twice a week (generally Tuesday and Friday) over the 9-week period except during times of high flooding tides. The second type of transects were surveyed on Wednesdays, alternating each week between the Area A transect and the Canoe and C/D transects. During early September, the time of peak fall migration, the Core transects and the additional transects were surveyed more often, depending on availability of personnel and availability of access to the range. Several separate survey teams participated, using the same procedures. Over 100 individual transect surveys were conducted over the 9-week period.

RESULTS

Mortality Data

Between mid-August and the third week of October, the surveys identified 49 waterfowl mortalities along transects in Eagle River Flats, consisting of carcasses, feather piles and partial skeletal remains (Table II-2-1). Table II-2-2 summarizes the seasonal waterfowl mortality totals by transect. Twenty-five mortalities, or 51% of the total, were found along the Ditch Transect in Northern C Marsh, an area of known remaining white phosphorus contamination. Based on sediment sampling this is the largest remaining area of contamination.

Pond 730 transect had seven mortalities or 14% of the total. Pond 730 was previously remediated by pond pumping and, based on sediment sampling, was felt to be clean. Because of the initial observation of mortalities in this area in 2004, additional sediment sampling was conducted (Walsh et al. 2005). Several small ponds just west of Pond 730 were found to be contaminated with white phosphorus. These are the likely contamination source causing waterfowl deaths in the vicinity of Pond 730. This result reemphasizes the importance of having an integrated monitoring program that includes both mortality observations and sediment sampling.

Three mortalities were found along the C/D transect; all were near the southern end of the transect lines near the Ditch Transect. It is likely that the contamination in Northern C Marsh also caused these mortalities. At the BT Transect, further north and west, no mortalities were observed. The two mortalities in “other Area C” were found in areas adjacent to the Ditch Transect and were most likely associated with waterfowl feeding in Northern C Marsh.

Four mortalities were observed on the Canoe Transect around the perimeter of Pond 40. The source poisoning waterfowl here is unclear. This large, deep pond is a major resting and loafing area for ducks. Pond 40 is too deep to allow effective feeding by ducks over much of its area and past sampling has shown no contamination. Ducks often feed in other adjacent areas and return to this large pond to rest and loaf in its relatively safe waters. It is possible that waterfowl

Table II-2-1. Waterfowl mortality data by transect and date.

		Carcasses Found										
Day	**Date**	**Ditch** Transect	**183** Transect	Duck Pond Transect	**730** Transect	**BT** Transect	**C/D** Transect	**Canoe** Transect	**Area A** Transect	**Other Area C**	**Forest** Transects	TOTAL
Mon	8/15/05	2	0	0	1							3
Tue	8/16/05		0			0	0				0	0
Wed	8/17/05	0					0	2			0	2
Thu	8/18/05								4			4
Fri	8/19/05	2	0	0	3	0	0					5
Tue	8/23/05	0	0	0	0							0
Fri	8/26/05	0	0	0	0	0						0
Tue	8/30/05	3	0	0	0	0						3
Wed	8/31/05							1				1
Fri	9/2/05	5	0	1	0	0	1					7
Tue	9/6/05	2	0	0	0	0						2
Wed	9/7/05	0							0			0
Thu	9/8/05	0										0
Fri	9/9/05	0	1	0	1	0						2
Sat	9/10/05	0										0
Mon	9/12/05	0										0
Tue	9/13/05	0	0	1	0	0						1
Wed	9/14/05	0						0				0
Thu	9/15/05	0										0
Fri	9/16/05	0	0	1	1							2
Tue	9/20/05	2	0	0	0					1		3
Wed	9/21/05								0			0
Fri	9/23/05	3	0	0	0							3
Tue	9/27/05	3	0	0	0							3
Wed	9/28/05							1				1
Tue	10/4/05	0	0	0	1							1
Fri	10/14/05	3	0	0	0					1		4
Tue	10/18/05	0	0									0
Fri	10/21/05	0					2					2
	TOTAL	**25**	**1**	**3**	**7**	**0**	**3**	**4**	**4**	**2**	**0**	**49**

Table II-2-2. Summary of waterfowl mortality counts by transect.

Transect	Number
Ditch Transect	25
Pond 730 Transect	7
Pond 183 Transect	1
Duck Pond Transect	3
BT Transect	0
C/D Transect	3
Canoe (Pond 40) Transect	4
Other Area C	2
Forest Transects	0
Area A Transect	4
Total	**49**

fed in the contaminated areas of the Northern C Marsh and the small ponds west of Pond 730 before returning to this area for the evening.

The Duck Pond Transect had three mortalities. The drainage ditches installed in July 2004 were successful in draining the majority of the small contaminated ponds in this area and removing them as waterfowl feeding habits where waterfowl could potentially pick up particles of white phosphorus and be poisoned. The mortalities may have occurred in a partially drained contaminated area or in the nearby small contaminated ponds just to the west of Pond 730.

At the beginning of the monitoring period, three carcasses and one feather pile were found in vicinity of Pond 290 in Area A. This pond was pumped and treated during the treatability study in 1997. Sediment sampling for white phosphorus since then has been negative. It is possible that an isolated hot spot of white phosphorus contamination remains in Pond 290 and a group of ducks found it while feeding. The ducks may also have fed in a different contaminated area then moved to Pond 290 where they died. During the rest of the fall monitoring period, no additional mortalities were found in Pond 290 or anywhere else in Area A. Additional sediment sampling will be conducted in Pond 290 next year in an attempt to identify any remaining contamination hot spot that may have caused these four duck deaths.

No feather piles were found in the woodland transects.

Of the 49 mortalities, 19 were carcasses, 29 were feather piles, and one just a partial skeletal remains. Seventeen gizzards were recovered and analyzed for white phosphorus; all 17 tested positive (Table II-2-3). The 100% positive confirmation on the gizzard analyses gives us reasonable assurance that all the mortalities observed are due to white phosphorus poisoning. Detailed data about each mortality, including date, species, collector, and location (UTM coordinates) are given in Appendix Table II-2-A1.

Table II-2-3. Waterfowl mortality confirmations.	
Type	**Number**
Carcasses	19
Feather piles	29
Other evidence of mortality	1
Number of gizzards recovered	17
Gizzards with white phosphorus	100%

Estimates of Waterfowl Population and Mortality Rate

Calculation of mortality rate involves estimating the total population of ducks that use Eagle River Flats from the weekly aerial censuses collected over the summer and fall by the U.S. Fish and Wildlife Service (Eldridge, this volume, Section II-1) and estimating the total number of ducks that die from white phosphorus. It is difficult to estimate total population from periodic aerial censuses because it is not known how many ducks seen on one census were the same ones present at the previous census. However, the six years of radio tracking data collected in 1996-2002 enabled us to estimate the number of ducks that leave ERF between censuses, or the turnover rate. In previous years, NWRC used 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]). Since we do not have measured turnover rate for 2005, we estimated it by using an average turnover rate of 0.83 that was based on the long-term average turnover rate for the entire length of the telemetry studies from 1996 through 2002.

The population estimate model developed by NWRC (NWRC 2004) and employed in our mortality study last year (Collins et al. 2005) used a composite of the total dabbling duck aerial census data for each census period to calculate the total estimated fall population. The total populations for each duck species, which were counted separately during the aerial census flights, were first summed together to give a total number of dabbling ducks for that census period. Then the total number of dabbling ducks for each census period was adjusted using the average NWRC turnover rate of 0.83 to give a total population estimate. If there was a positive change in population between a census period and the previous period, the difference was the increase in population for that census period. If there was no change or a negative change in population between a period and the previous period then Zero was assumed as the change in population for the census period. The model is a conservative estimate of the total dabbling duck population, and most likely underestimated the total population. We have noticed over a number of years of observations in Eagle River Flats that numbers of an individual species may fluctuate widely from one census period to another, often greatly increasing, while total numbers of dabbling ducks for that census period may actually decrease. We know from those observations that new duck individuals were feeding and potentially being exposed to white phosphorus in Eagle River Flats. In those instances, the model would underestimate the number of dabbling ducks using Eagle River Flats. In turn, using the results of the model would overestimate the mortality rate of dabbling ducks. We reran the original model with the 2005 data (Table II-2-4) to give us a conservative or lower end estimate of the total fall 2005 dabbling duck population in Eagle River Flats. Using the original model, the total fall 2005 dabbling duck population was calculated to be 2,130 birds. The observed mortality was 49, giving a minimum mortality rate of the fall 2005 dabbling duck population in Eagle River Flats of 2.3%.

Table II-2-4. Estimate of fall dabbling duck population using original NWRC population model. (See explanation below)

Observation Date	Aerial Count	Unknown Dabblers	Total Dabblers	Adjusted for Turnover	Total Population Change
7/30/05	128	0	128	154	154
8/5/05	828	40	868	1046	892
8/10/05	633	0	633	763	0
8/16/05	1083	40	1123	1353	590
8/22/05	785	95	880	1060	0
8/27/05	983	0	983	1184	124
9/6/05	334	145	479	577	0
9/10/05	501	45	546	658	81
9/15/05	375	0	375	452	0
9/19/05	450	0	450	542	90
9/21/05	458	0	458	552	10
9/26/05	553	40	593	714	163
9/29/05	542	28	570	687	0
10/4/05	372	87	459	553	0
10/6/05	269	120	389	469	0
10/11/05	411	0	411	495	27
10/20/05	344	0	344	414	0
		Total Fall Dabbling Duck Population			**2,130**

The model uses the total dabbling duck population for each census period. Total dabbling duck numbers for each census period are adjusted using the average NWRC turnover rate of 0.83. If there is a positive change in population between period and the previous period, the difference is the increase in population for the census period. If there is no change or a negative change in population between a period and the previous period then Zero is assumed as the change in population for the census period.

In order to refine the fall dabbling duck population estimate, we revised the population estimate model. The model now uses the aerial census data for each of the individual dabbling duck species counted for each census period rather than just the total number of dabbling ducks for each census period. In the revised model, (Table II-2-5) total counted numbers for each dabbling duck species for each census period was adjusted for turnover by dividing by the average NWRC turnover rate of 0.83. The total increase in population for each duck species 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 species population for that period. If the current period's population was lower than the previous period, then there was no net increase in the species population for that period. The increases in each of the duck species populations were then summed to give the total estimated increase in population of dabbling ducks for that census period. The totals for each census period were summed to give the total estimated dabbling duck population for the season. Using the revise model, the total fall 2005 dabbling duck population was calculated to be 3,882 birds. The observed mortality was 49, giving a minimum mortality rate of the fall 2005 dabbling duck population in Eagle River Flats of 1.3%.

Table II-2-5. Revised population model to calculate Fall 2005 dabbling duck population based on aerial census data for each dabbling duck species. (See explanation below)

Observe Date	American Wigeon	Adjusted for Turnover	Mallard	Adjusted for Turnover	Northern Shoveler	Adjusted for Turnover	Northern Pintail	Adjusted for Turnover	Green-winged Teal	Adjusted for Turnover	Unknown Dabblers	Adjusted for Turnover	Total population increase
7/30/05	40	**48**	56	**67**	0	**0**	6	**7**	26	**31**	0	**0**	154
8/5/05	249	**300**	223	**269**	50	**60**	150	**181**	156	**188**	40	**48**	892
8/10/05	207	*249*	230	**277**	0	*0*	126	*152*	70	*84*	0	*0*	8
8/16/05	220	**265**	419	**505**	30	**36**	170	**205**	244	**294**	40	**48**	590
8/22/05	315	**380**	208	*251*	35	**42**	81	*98*	146	*176*	95	**114**	187
8/27/05	163	*196*	371	**447**	25	30	263	**317**	161	**194**	0	0	434
9/6/05	59	*71*	118	*142*	0	*0*	60	*72*	97	*117*	145	175	175
9/10/05	31	*37*	143	**172**	0	*0*	297	**358**	30	*36*	45	*54*	316
9/15/05	26	*31*	271	**327**	0	*0*	21	25	57	**69**	0	*0*	187
9/19/05	75	**90**	249	*300*	0	*0*	8	10	118	**142**	0	*0*	133
9/21/05	33	*40*	339	**408**	0	*0*	23	**28**	63	76	0	*0*	127
9/26/05	37	**45**	351	**423**	0	*0*	104	**125**	71	**86**	40	**48**	175
9/29/05	80	**96**	319	*384*	0	*0*	76	*92*	79	**95**	28	*34*	61
10/4/05	14	*17*	228	*275*	0	*0*	28	*34*	102	**123**	87	**105**	99
10/6/05	0	*0*	207	*249*	0	*0*	20	*24*	42	*51*	120	**145**	40
10/11/05	12	**14**	371	**447**	0	*0*	0	*0*	120	**145**	0	*0*	306
10/20/05	0	*0*	344	*414*	0	*0*	0	*0*	0	*0*	0	*0*	0
													3,882

Total numbers for each species for each census period is adjusted using the average NWRC turnover rate of 0.83. Blue (bold) indicates a positive change in species population between that period and the previous period. Red (italic) indicates no change or a negative change in population between that period and the previous period. Zero is then assumed for change in population for that period. The positive differences for each species are then summed for the census period to arrive at total increase in population for census period. These total increases for each census period are then summed to estimate fall population of 3,882.

DISCUSSION

A number of uncertainties are included when determining a mortality rate:

- Errors in counting waterfowl numbers from the air during the aerial census flights.
- Periodicity of aerial flights, which might miss peaks of waterfowl population.
- Errors in applying an average turnover rate.
- Errors in counting actual carcasses 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.

We applied conservative estimates of these uncertainties to the results of each of the two population models in turn. We conservatively estimate that the actual total fall population of dabbling ducks may be plus or minus 20% of the calculated population from each of the two models.

Using an average turnover ratio, which was originally developed using mallards, yet applied to all species of dabbling ducks, is problematic. However, it is the only turnover data available. In analyzing the 2004 mortality data last year (Collins et al. 2005), we evaluated the average turnover method for calculating total population of ducks by reviewing data from previous years for which there was actual turnover rate from telemetry data available. We compared estimates using the average turnover rate method to estimates made using the actual turnover rate data. The population estimates were similar for both methods. We also tried to determine a week-to-week average turnover rate base on the telemetry data. Again, results were similar to just using an average turnover rate for the season.

Based on field observations, and experience and knowledge of Eagle River Flats, we estimate that the dabbling duck mortality may be as much as 50% higher than the 49 actually counted in 2005 but not any higher than that. Following remediation, most contaminated ponds are either now clean or are no longer accessible to waterfowl. Other areas of open water where waterfowl concentrate, Area B and D for example, were never found to be contaminated with white phosphorous (Racine et al. 1992).

For the original population model, combining our estimated error for carcass counts and population estimates (Table II-2-6) gave us a mortality rate of between 1.9% and 4.3% of the estimated fall 2005 dabbling duck population, with the median estimate being 3.1%. For the revised population model using the each species population counts, combining our estimated error for carcass counts and population estimates (Table II-2-6) gave us a mortality rate of between 1.1% and 2.4% of the estimated fall 2005 dabbling duck population, with the median estimate being 1.8%.

The original population model gives a more conservative estimate of population and thus mortality, while the revised model better reflects the species dynamics of Eagle River Flats. Both estimated mortality rates are well below the short-term RAO, but still above the long-term RAO of 1% mortality rate of the fall dabbling duck population.

Mortality data from the survey transects also indicated that a majority of the mortality was occurring in two areas with known remaining white phosphorus contamination – the area of Northern C Marsh where the ditches were excavated for pond pumping and the small ponds adjacent to Pond 730. These two areas accounted for over 70% of the mortality. If these remaining areas can be effectively remediated over the next two years, the long-term remediation goal should be met. Given the possible errors in estimating actual mortality described above, several years of mortality estimates below 1% might be needed to defend a conclusion that the long-term goal has been met. In any case, the data on mortality, in conjunction with the other data from sediment sampling and aerial surveys, will provide a weight-of-evidence approach to evaluating the effectiveness of the remediation effort in Eagle River Flats.

Table II-2-6. Tabular summation of the estimate range of the Fall Dabbling Duck Population and duck mortalities, taking into account the estimated error ranges. Combining these ranges of estimates gives an estimated mortality rate for 2005.

Parameter	Original Model	Revised Model
Fall Dabbling Duck Population Estimate	2,130	3,882
Range in Estimate of Fall Dabbling Duck Population (± 20% of model's estimate)	1, 704 — 2,556	3,106 — 4,658
Range in Mortalities (+ 50% of counted mortalities)	49 — 74	49 — 74
Range in Estimated Mortality Rate	1.9% — 4.3%	1.1% — 2.4%
Median Estimated Mortality Rate	3.1%	1.8%

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Appendix Table II-2-A1. Waterfowl mortality detailed data.

MORT ID No.	Date	Carcass or Feather Pile	Species	Gizzard Collected	Easting (NAD 27)	Northing (NAD 27)
1	8/15/05	Feather Pile	GW Teal	No	355195	6801632
2	8/15/05	Feather Pile	Mallard	No	355265	6801555
3	8/15/05	Carcass	Mallard	Yes	354908	6801818
4	8/17/05	Carcass	Mallard	Yes	355112	6802067
5	8/17/05	Carcass	Mallard	No	355194	6802376
6	8/18/05	Feather Pile	Mallard	No	354363	6800363
7	8/18/05	Carcass	Pintail	Yes	354357	6800439
8	8/18/05	Carcass	Mallard	No	354413	6800406
9	8/18/05	Carcass	Pintail	Yes	354413	6800406
10	8/19/05	Feather Pile		No	355171	6801615
11	8/19/05	Carcass	Mallard	Yes	355244	6801665
12	8/19/05	Carcass	Mallard	Yes	354783	6801820
13	8/19/05	Carcass	GW Teal	Yes	354868	6801848
14	8/19/05	Feather Pile	Wigeon	No	354893	6801850
15	8/30/05	Feather Pile	Mallard	No	355160	6801620
16	8/30/05	Feather Pile	Mallard	No	355300	6801680
17	8/30/05	Feather Pile	GW Teal	No	355260	6801560
18	8/31/05	Partial carcass	Mallard	No	355210	6802075
19	9/2/05	Carcass	Mallard	Yes	355220	6801540
20	9/2/05	Carcass	Mallard	Yes	355190	6801625
21	9/2/05	Carcass	Mallard	Yes	355120	6801600
22	9/2/05	Carcass	Mallard	Yes	355120	6801600
23	9/2/05	Carcass	Pintail	Yes	355070	6801575
24	9/2/05	Feather Pile	Mallard	No	355000	6801655
25	9/2/05	Feather Pile	Mallard	No	354965	6801555
26	9/6/05	Feather Pile	GW Teal	No	355205	6801620
27	9/6/05	Feather Pile	Mallard	No	355195	6801615
28	9/9/05	Breast bone	?	No	354826	6801821
29	9/9/05	Feather Pile	Mallard	No	355132	6801374

Appendix Table II-2-A1 (cont.). Waterfowl mortality detailed data.

MORT ID No.	Nearest Landmark	Area Assignment	Found By
1	North drainage ditch.	Ditch Transect	B. Steele, E. Stamm
2	By south sump.	Ditch Transect	B. Steele, E. Stamm
3	Pond 730	730 Transect	B. Steele, E. Stamm
4	C/D Pond, Canoe transect	Canoe Transect	B. Steele, E. Stamm
5	C/D Pond, Canoe transect, towards D.	Canoe Transect	B. Steele, E. Stamm
6	West and E side of Pond 290.	Area A transect	B. Steele, E. Stamm
7	Pond 290, E side.	Area A transect	B. Steele, E. Stamm
8	Pond 290, W side	Area A transect	B. Steele, E. Stamm
9	Pond 290	Area A transect	B. Steele, E. Stamm
10	West end of ditch.	Ditch Transect	B. Steele, E. Stamm
11	East end of N ditch.	Ditch Transect	B. Steele, E. Stamm
12	West end of Pond 730	730 Transect	B. Steele, E. Stamm
13	Center of Pond 730	730 Transect	B. Steele, E. Stamm
14	Center of Pond 730	730 Transect	B. Steele, E. Stamm
15	North ditch at T.	Ditch Transect	A. Staples
16	North sump at T.	Ditch Transect	A. Staples
17	Head of south sump.	Ditch Transect	J. Zufelt
18	Canoe Transect, middle of E/W channel.	Canoe Transect	A. Staples, J. Zufelt
19	South ditch at T.	Ditch Transect	J. Zufelt
20	ditches, N sump.	Ditch Transect	J. Zufelt
21	~1/2 way to W end of N ditch.	Ditch Transect	J. Zufelt
22	~1/2 way to W end of N ditch.	Ditch Transect	J. Zufelt
23	East end of N ditch.	Ditch Transect	J. Zufelt
24	Duck Pond transect, E end stake.	Duck Pond Transect	A. Staples
25	Southeast stake of CD transect.	C/D Transect	J. Zufelt
26	Near sump at N cross ditch, E side of ditch.	Ditch Transect	J. Zufelt
27	Near sump at N cross ditch, W side of ditch.	Ditch Transect	J. Zufelt
28	Pond 730, W side	730 Transect	M+M Walsh
29	183 transect, N end.	183 Transect	Charlie Collins

Appendix Table II-2-A1 (cont.). Waterfowl mortality detailed data.

MORT ID No.	Date	Carcass or Feather Pile	Species	Gizzard Collected	Easting (NAD 27)	Northing (NAD 27)
30	9/13/05	Feather pile	?	No	354941	6801667
31	9/16/05	Carcass	Mallard	Yes	354924	6801800
32	9/16/05	Feather Pile	Mallard	No	354852	6801700
33	9/20/05	Feather Pile	Mallard	No	354908	6801515
34	9/20/05	Feather Pile	?	No	355166	6801602
35	9/20/05	Carcass	Mallard	Yes	355300	6801695
36	9/23/05	Feather Pile	GW Teal	No	355110	6801590
37	9/23/05	Partial carcass	Mallard	Yes	355125	6801635
38	9/23/05	Feather Pile	Mallard	No	355190	6801620
39	9/27/05	Carcass	Mallard	Yes	355200	6801570
40	9/27/05	Feather Pile	?	No	355175	6801540
41	9/27/05	Feather Pile	Mallard	No	355145	6801540
42	9/28/05	Carcass	Mallard	Yes	355130	6802070
43	10/4/05	Feather Pile	Mallard	No	354860	6801780
44	10/14/05	Feather Pile	GW Teal	No	355177	6801345
45	10/14/05	Feather Pile	?	No	355100	6801380
46	10/14/05	Feather Pile	GW Teal	No	355210	6801675
47	10/14/05	Feather Pile	GW Teal	No	355140	6801550
48	10/21/05	Feather Pile	?	No	355290	6801810
49	10/21/05	Feather Pile	Mallard	No	355200	6801930

Appendix Table II-2-A1 (cont.). Waterfowl mortality detailed data.

MORT ID No.	Nearest Landmark	Area Assignment	Found By
30	Duck Pond to CD segment.	Duck Pond Transect	A. Staples, K. Bjella
31	Pond 730, S side.	730 Transect	M+M Walsh
32	Duck Pond south.	Duck Pond Transect	A. Staples, Jim Hug
33	~1/2 way between Pond 183 and Duck Pond transects.	Other Area C	M+M Walsh
34	North ditch,~ 30M from T on S side.	Ditch Transect	M+M Walsh
35	North ditch, N side, ~ 40M from E end of ditch.	Ditch Transect	M+M Walsh
36	N ditch, 1/3 way from W end to T, on N side	Ditch Transect	J. Zufelt, A. Staples
37	North ditch, N side, ~ 10 M to T on cross ditch.	Ditch Transect	J. Zufelt, A. Staples
38	North ditch at T sump on S side.	Ditch Transect	J. Zufelt, A. Staples
39	~ 10M W of cross ditch, ~1/2 way up on W side.	Ditch Transect	J. Zufelt
40	1/2 way between S ditch sump and cross ditch on N side of S ditch.	Ditch Transect	J. Zufelt
41	~20M from W end sump on S side of S ditch.	Ditch Transect	J. Zufelt
42	Canoe transect, south pond, floating.	Canoe Transect	A. Staples, K. Dearborne
43	Floating in small pond off S end of Pond 730.	730 Transect	A. Staples, K. Dearborne
44	~ 30M's from edge of Pond 183, E side of transect.	Other Area C	A. Staples, J. Zufelt
45	Two piles on either side N ditch, ~50 M's from W sump.	Ditch Transect	A. Staples, J. Zufelt
46	North side of north ditch by tripod.	Ditch Transect	A. Staples, J. Zufelt
47	North side of W sump on S ditch.	Ditch Transect	A. Staples, J. Zufelt
48	East of east border CD transect.	C/D Transect	A. Staples, K. Dearborne
49	~ 60 M's S of NE corner CD transect.	C/D Transect	A. Staples, K. Dearborne

III-1. EAGLE RIVER FLATS REMEDIATION PROJECT: LIMITED REMEDIATION OPERATIONS UNDER SECOND YEAR OF MONITORING PHASE

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INTRODUCTION

The Eagle River Flats Record of Decision (RoD), signed in October 1998, indicated that the 2005 field season would be the second year of the remediation project's monitoring phase. However, recent detonations of several white phosphorus (WP) rounds have deposited new residue in Northern C-Marsh and WP-related mortalities continue to occur there. To mitigate this known remaining contamination and to fulfill the obligation of the RoD, we conducted limited remediation operations in the Northern C-Marsh area during both 2004 and 2005.

As specified in the RoD, the active remediation method we utilized entailed pumping of contaminated areas to remove overlying water, allowing the contaminated sediments to desaturate and the WP to sublimate. The pumping in Northern C-marsh was conducted within drainage systems established during previous remediation seasons. An added benefit of using this method is that the drying allowed the sampling team to move safely and to sample more effectively, thus better defining continued areas of concern.

The 2005 season was one of change, with a new pump deployment strategy and all new contractors for logistics support, UXO clearing, and helicopter services. Every year brings new challenges. Through the efforts of many contributors, we overcame many to make this a successful remediation season.

DEPLOYMENTS

The initial 2005 deployment of pump systems took place in mid May. This year, the number of pump systems deployed at the Flats was increased to two. System 3, reinstalled in Pond 146, has a set of tandem pumps with a capacity of 189 L/s (3000 gpm). The system, through a complex of interconnecting ditches, is capable of addressing most areas known to remain contaminated: C-Marsh Ponds 155 and 171, and the less-contaminated Ponds 183 and 146 (Fig. III-1-1). System 5, installed in the Bomb Crater (BC) sump in the northeast section of the C-Marsh area, also pumped water (primarily incoming groundwater from the eastern edge of the Flats) to a drainage gully leading to the Eagle River.

The mid-season deployment, normally in July, was cut back as a cost-saving measure. The only mid-season issue that required an on-site solution occurred when a beaver chewed through a pump system power cord. Alaska personnel replaced the power cord when they were at the Flats in August for mortality transect set-up. In mid-September, during the final field deployment, equipment was pulled from the field. The following subsections detail tasks addressed during these deployments.

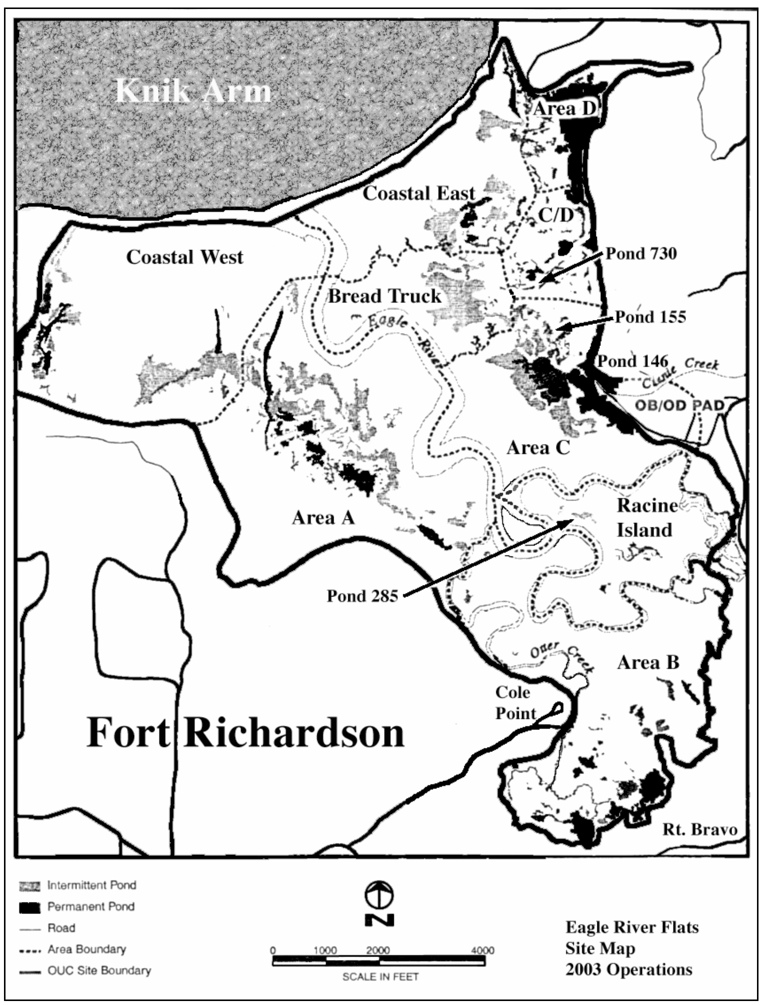

Figure III-1-1. Map of Eagle River Flats showing areas and pond identification numbers.

Duck Road

At the end of the 2004 season, the Remedial Project Managers agreed to add at least one more pump to the C-Marsh area to address contamination within the major drainage ditch system. In the past, this required the placement of pumps and gensets with at least a medium-lift-capable helicopter provided by the military. With the ongoing wars in Iraq and Afghanistan, the Army CH-47 helicopters were not available for the 2005 season and availability of the National Guard UH-60s was uncertain. Therefore, construction of a road into an area adjacent to northern C-Marsh was planned for the beginning of the field season to reduce dependency on these aircraft.

An access route to the C-Marsh area was cleared of UXO in early May. The route follows a jeep trail behind the EOD Pad, veering off through an overgrown clearing to an area east of the northern Bangalore ditch in C-Marsh (Fig. III-1-2). The jeep trail was cleared of vegetation, widened, and a limited amount of gravel placed in wet areas. A new road (Duck Road) was constructed between the jeep trail and the edge of the Flats using geotextile and unsorted gravel from the EOD Pad. A gravel pad (BC Pad) was constructed at the end of the new road. This new route will allow gensets to be trailered within operational distance of the C-Marsh sumps and refueling operations to be conducted without the using a helicopter. From this location, a power and instrumentation cord can be run from the shore-based gensets to sumps located at the Bomb Crater, Northern C, or Southern C sumps.

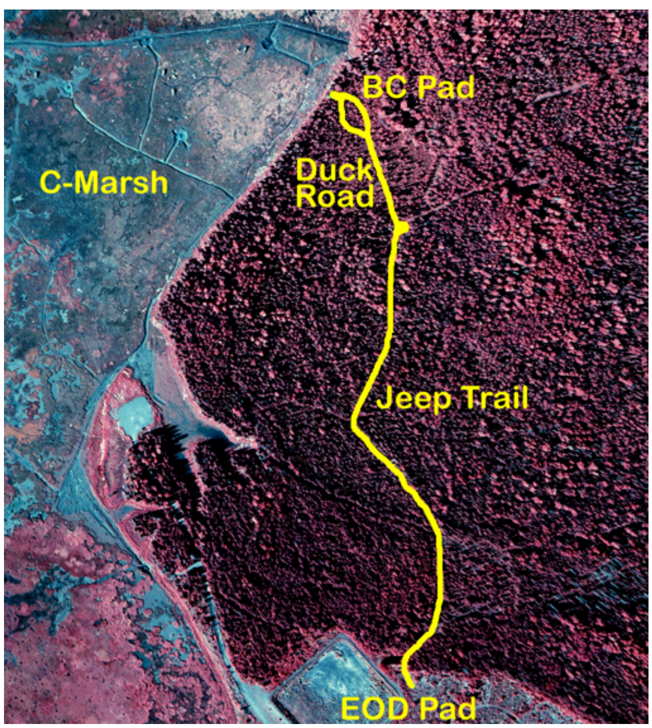

Figure III-1-2. New access route to northern C-Marsh.

Equipment Deployment

The tidal pattern for the 2005 season favored a mid-May deployment. To prepare for this, both Systems 3 and 5 were serviced earlier in the spring by Rotating Equipment of Anchorage. The equipment was delivered to the EOD Pad on 16 May. By 19 May, everything required for operation was on the EOD Pad and ready for deployment. By the end of the next week, both systems were up and running as detailed below. On 31 May, the equipment was turned over to the CRREL FRA office for operation and maintenance.

On 27 May, the fuel situation was checked and all tanks were near full. The determination was made to recheck the tanks in July following the flooding tides to assess the need for additional fuel.

System 3

System 3 was to be installed in the sump formed at the end of the old dredge channel in Pond 146. Normally, helicopter support is not required when this pump and discharge line are installed. This year, however, record-low water levels prevented us from floating the pump into position from around Clunie Pad. We were able to place the genset and associated cables in their intended position on 19 May. In addition to the 1900-L mobile fuel tank that is part of the system, two 1900-L stationary double-walled fuel tanks were co-located with the genset. On 20 May, a Guard UH-60L helicopter airlifted the pumps for System 3 into place and they were later hooked up and test-fired.

On 21 May, System 3 was brought on line briefly. However, problems with the 63 L/s pump forced a quick shutdown. Further investigation indicated that this pump had a bad lower bearing on the pump shaft. The system was then switched to utilize only the 126 L/s pump and restarted. We soon discovered a hole in the discharge line hose near the river that had not been there during installation a few hours earlier. A porcupine had been in the line during the initial startup and escaped by chewing its way out through the hose. The line was then repaired and the system restarted. Within a few hours, the water level in the area was drawn down and the pump was cycling. Another minor problem – excess smoke from Genset 3 – was fixed by reconfiguring the crankcase recirculating system using a larger vacuum line.

The remaining field equipment was prepared for airlift, and on 25 May the discharge line, data loggers, video towers, and other peripheral equipment were airlifted into the field using an Evergreen A-Star helicopter. Although the helicopter was almost an hour late arriving, we were able to transfer all the equipment needed for field operations in one day.

System 5

On 20 May, the System 5 pump was also airlifted to the BC sump in C-Marsh by the Guard UH-60L helicopter. The System 5 genset was towed to the

BC Pad. The next day, new power and switch cables were made up for the system and the generator was leveled. Also, an 1100-L double-walled fuel tank was placed near the generator. On 25 May, the discharge line for System 5 was airlifted into place; later that day, the system was assembled and test-fired. An over-temperature fault, normally a sign of a bad sensor in the radiator, shut the system down but it restarted after being reset. This was serviced later by Rotating Equipment. The smoke problem with System 3 also occurred with this unit and was also addressed by Rotating Equipment.

Mid-Year Assessment

Due to funding considerations, the normal mid-year deployment to the Flats for equipment maintenance and check-up was cancelled. We planned to address equipment problems as they occurred by phone communications between the Hanover and Ft. Richardson offices. It was decided that blasting missions would not be necessary and that we should evaluate the effectiveness of the current drainage system for a year in its current configuration to determine if any more ditch work is required.

One major operational problem required on-site action. Following the July flooding tide, the System 5 generator would start, warm up, then lug down and quit when the pump was to kick in. The FRA O&M crew was given a list of items to check and they discovered the power cable had been chewed into, likely by a beaver. Charlie Collins was down from the Ft. Wainwright office to assist in the mortality transect initiation and checked out the situation. Inspection of the cable revealed two of the leads had been chewed, exposing the wire to the salt water. The wires had arced, vaporizing several centimeters of the conductors and grounding out the line. This caused the generator to lug and quit. When he replaced the damaged cable with a new one, the system ran without a problem.

The fuel situation this season was a bit of a mystery. When the gensets were ready to refuel, it was discovered that the auxiliary fuel tanks were almost empty. Tanks were subsequently partially filled but the fuel once again disappeared. Fuel theft is suspected. At Genset 3, a porcupine bit into the supply line from the portable fuel tank to the genset. An unknown amount of fuel was spilled before the damaged line was discovered and repaired. After refilling the tank, it was discovered that at least five gallons of water were in the 1100-L mobile fuel tank.

Retrograde

The retrograde mission was scheduled for mid-September prior to flooding tides beginning on 17 September. The date was set in consideration of future remediation work in 2006 and 2007. By stretching the season to mid-September, we are able to keep the treatment area from rehydrating to the point of thorough sediment deconsolidation. Some deconsolidation will occur over the winter because of freeze / thaw, but it will be limited because of these actions.

Shortly after arrival (12 September), the commercial helicopter contractor backed out of both its commitments – the medium lift mission on September 14^{th}

and the utility mission on the 16^{th}. Both missions were combined into one and the National Guard once again pulled through for us, agreeing to supply a UH-60 for the day of the 14^{th}.

System 5 (BC Pad) was shut down on 13 September and the pipe broken down and stacked in the field. On the morning of 14 September, System 3 was shut down and the pump disconnected. After resolving a last-minute paperwork requirement, the aircraft arrived at the Flats. All pumps, pipe, and towers were pulled between 0940 hrs and 1325 hrs, with a refueling run in between. The discharge line was secured on the EOD pad on the 15^{th} and all equipment hauled to the temporary Environmental yard that afternoon. The equipment was serviced on the 16^{th} (oil and filters), concluding the remediation season for 2005.

IMPLEMENTATION

The 2005 season was predicted to be a fairly good one for drying due to the absence of early season (May – June) flooding tides (Table III-1-1). Weather conditions during this period are generally favorable, with summer rains normally holding off until early July. Moderately high flooding tides in late July would terminate the contiguous dry spell, and very high flooding tides in mid-August were predicted to finish off the season. Knowing that 2006 and 2007 were predicted to be ideal with respect to tides, we decided to stretch the season to as long as practical to preserve as much sediment consolidation in the treatment area as possible. Therefore, we set the installation date to mid-May and the pull-out date to 16 September, prior to a second cycle of very high tides.

The early season pump-down of the area was relegated to System 3, which normally has a capacity of 189 L/s. However, because one of the tandem pumps failed, it operated at 126 L/s for virtually the whole season. Fortunately, the Flats were quite dry this year (Pond 183 was almost fully exposed). After the initial pump-down, System 5 was engaged. Following the July and August flooding tides, both systems were used to pump down the treatment area and saw a lot of duty over the season. System 3 addressed a larger area, but System 5 was exposed to more flow from the area north of C-Marsh.

Bread Truck Ditch control structure performed well over the season, although sheet flooding from the south prevented it from being fully effective. The structure survived both the winter and field season without any visible damage. Areas near and on the structure are now fairly heavily vegetated, which should further protect it from erosion. The structure's effect on gully advancement is unknown at this time, because no aerial photographs were taken in either 2004 or 2005. The structure was inspected at the end of the season. The hinges on the flapper door at the end of the drain pipe have failed and need to be replaced prior to next season.

Table III-1-1. Predicted flooding tides for 2005 season.				
Day	**Time**	**Height (m)**	**Time**	**Height (m)**
May				
25	0905	9.45	–	–
June				
24	0955	9.45	–	–
July				
22	0847	**9.60**	2153	9.05
23	0937	**9.66**	2233	9.27
24	1027	**9.57**	2314	9.48
25	1116	9.30	2357	9.51
August				
19	0747	9.54	2053	9.24
20	0838	**9.82**	2128	**9.48**
21	0927	**9.94**	2203	**9.69**
22	1014	**9.85**	2240	**9.82**
23	1101	**9.57**	2318	**9.75**
September				
17	0741	**9.66**	2023	**9.60**

Notes: Pre-season tidal predictions.
>9.48-m tides are normally flooding tides.
Actual flooding tides in **RED**.

Although a pump was installed in the Bomb Crater sump, some water remained in most of the major ditches over the summer (Fig. III-1-3). No additional drainage in Area C was created this season, although some tinkering of the existing system (hand shoveling to address high spots and restricted flows) inevitably occurred. The drainage ditches installed in the Duck Ponds proved effective in partially draining that area to the point where some drying occurred in these ponds (Fig. III-1-4). Some shovel work was done at a high point near the drainage gully in the spring, and a tide gate was installed in late May.

Although the July flooding tides interrupted remediation in the drained areas, this was a good season. A long, contiguous non-flooding period extended from startup on 21 May to 22 July, a total of 63 days. Over the summer, Ponds 146, 171, 155, and 183 dried (Fig. III-1-5). The mostly dry weather prevalent through the third week of July, combined with mild temperatures, created good remediation conditions. In areas that did not dry sufficiently for remediation to occur, the ground remained firm enough to resume drying quickly when remediation is conducted next season.

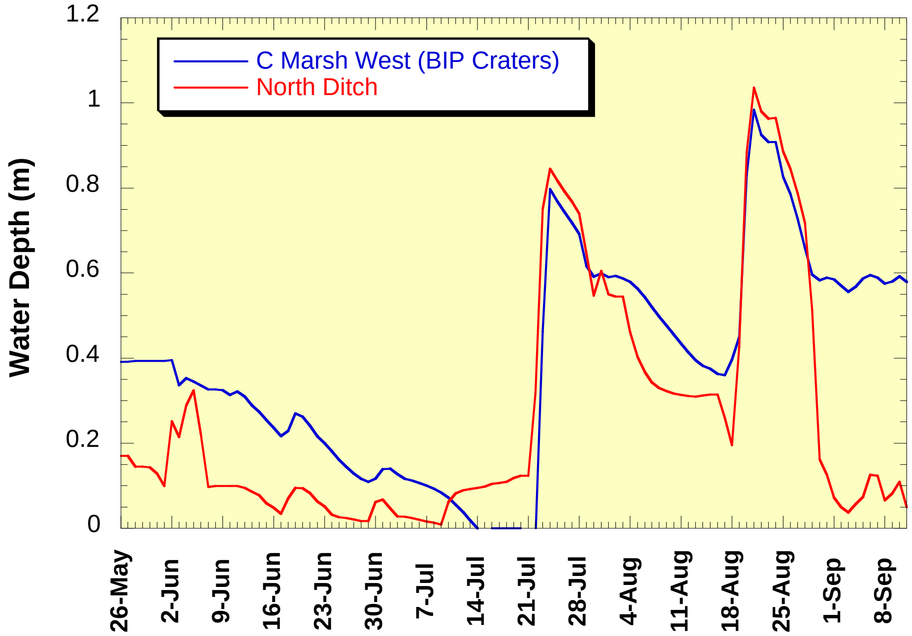

Figure III-1-3: Water levels in north Bangalore ditch and the Blow-in-Place WP craters.

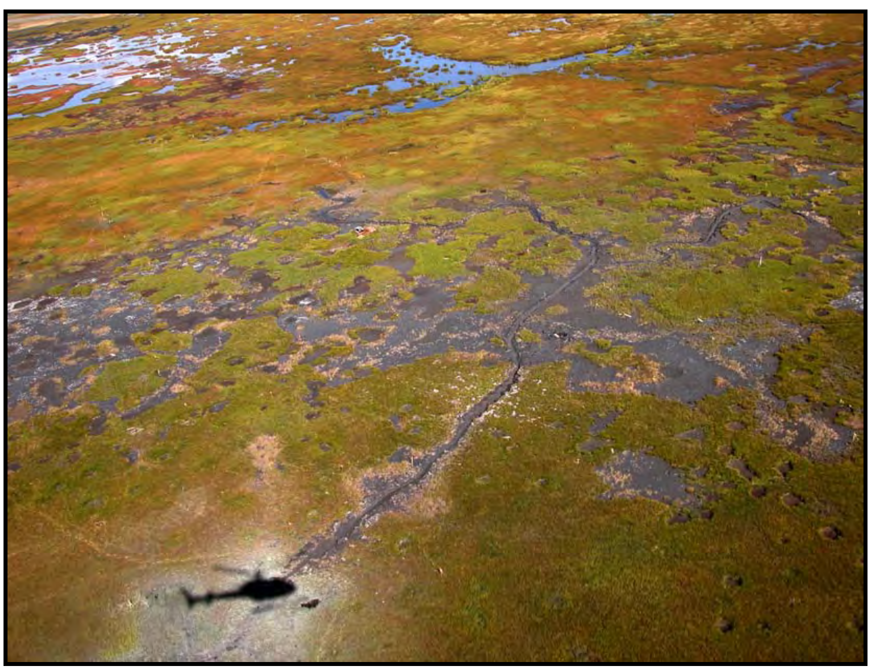

Figure III-I-4. Duck Ponds ditch system, August 2005.

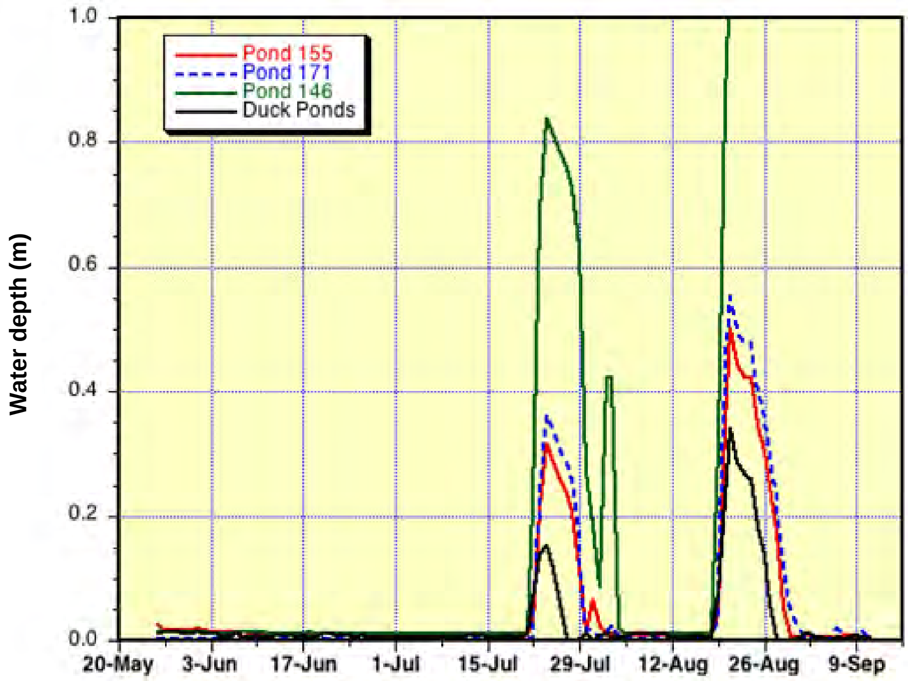

Figure III-1-5. Water levels in treated ponds.

PERFORMANCE EVALUATION

The pump systems are starting to show their age. The loss of the bearing on the 63 L/s pump on System 3 degraded that system for most of the season. Also, Genset 5 was intermittently plagued by a sensor fault for the first few weeks of remediation. Pipe clamps are failing and we are having problems with some of the discharge hose. Overall, the equipment is still capable of accomplishing the mission; however, closer monitoring of the units may be required in the future.

Three fuel spills occurred near the gensets over the summer. The fuel line to Genset 3 had been gnawed around 10 August and fixed the following day, and two spills occurred on 12 September during the final refueling just prior to retrograde. These were reported to DPW on 13 September and addressed following retrograde. The fuel line spill required the most excavation, probably because it infiltrated the pad and soil along with the water leaking from a nearby section of discharge line hose from System 3.

Significant drying in Ponds 155 and 171 occurred this season. The combination of low initial water levels in the spring, no flooding from startup in May to late July, and effective drainage of these ponds through this period resulted in very good drying conditions. However, both discrete sampling and UXO clearance indicate that C-Marsh remains contaminated. Once again, a significant proportion of mortalities were recorded in this area, specifically near the major ditches.

Table III-1-2 lists statistics for pump use during the 2005 season. Figure III-1-6 shows the cumulative use of the pumping systems (hours and cycles), along with the timing the two flooding tide events. The initial dry condition of the Flats is reflected by the lack of an initial spike in run time normally seen at the beginning of the season. The steady climb in System 5 pump cycles prior to the first flooding tide resulted from flow into the north Bangalore ditch from the area north of C-Marsh. The spike in pump hours following the flooding tides indicates the initial drawdown of the treatment area following restarting of the pumps. Following the second flooding tide, a delay in the startup of System 5 resulted from the partially severed power cord to the pump. The effect of the heavy rains in late August and early September is reflected in the continuing high pump usage following the drawdown after the second flooding event.

Adding a second pump in the ditch system this year went a long way towards draining that system, but significant sections of water remained, especially in the southern portion of the complex. In addition, the constant flux of water towards and along the north rim of the north Bangalore ditch kept most of that side of the ditch from drying throughout the summer. Additional work in this area will be needed to rectify this situation.

A detailed chronology of general events through the 2005 season is given in Appendix III-1-A. Appendix III-1-B provides information related to operation and maintenance of the units in 2005. Lastly, Appendix III-1-C includes an abbreviated chronology of the pumping project over the multiple seasons of operation.

Table III-1-2. Pump operation statistics for the 2005 season.

System	Start date	Stop date	Span (days)	Genset hours	Pump hours*	Pump cycles
3	21 May	14 Sep	117	396	314 (1)	635 (1)
					1.4 (2)	7 (2)
5	26 May	13 Sep	111	383	282.1	572

* Note: System 3 has two pumps, 126-L/s (1) and 63-L/s (2).

THE 2006 SEASON AND BEYOND

Tidal predictions for 2006 indicate a very good year for remediation, with no flooding tides predicted from May until 10 August (Table III-1-3). Following the August tides, the period from 16 August to 7 September will not flood. Over the last several seasons, the rainfall trend has been little precipitation through July and sometimes through early August. If this trend continues, 2006 should have an excellent remediation season. If weather conditions hold, significant remediation should occur with three systems deployed to Area C. However,

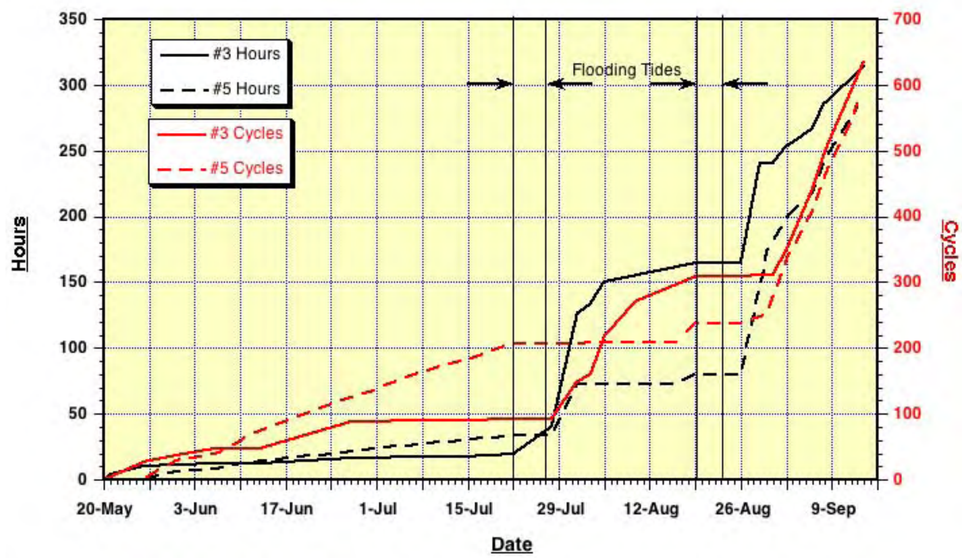

Figure III-1-6. Pump operation over the course of the 2005 season.

creation of additional drainage in the C-Marsh area may be required to facilitate drying along the northern ditches. The outlook for 2007 is even better, with no flooding tides from mid-May through the end of August (Table III-1-4). We anticipate this will be the last remediation season, because 2007 is followed by two years of frequent flooding tides. In both 2008 and 2009, flooding tides occur the first week of June and marginally flooding tides continue through to the middle of September. It is likely that the capping of hotspots will occur the winter following the 2007 season, although this decision has not been finalized at the time of this report.

REFERENCES

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

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* (C.M. Collins and D.W. Cate, ed.). CRREL Contract Report to U.S Army, Alaska, Directorate of Public Works. FY 2002 Final Report, p.23–43.

Table III-1-3. Predicted flooding tides for 2006 season (May–September).

Day		Time	Height (m)	Time	Height (m)
May	–	–	–	–	–
June	–	–	–	–	–
July	–	–	–	–	–
August	10	0855	**9.66**	–	–
	11	0941	**9.75**	2222	9.51
	12	1027	**9.69**	2259	**9.75**
	13	–	–	2339	**9.82**
	14	–	–	–	–
	15	0022	**9.60**	–	–
September	7	0753	**9.72**	2038	9.48

Notes: Pre-season tidal predictions.
ERF tidal classifications:
9.48- to 9.54-m tides: Minor / May be preventable
9.55- to 9.71-m tides: Substantial / Likely to flood
>9.71-m tides: Major / Unpreventable
Bold tides are likely flooding tides.

Table III-1-4. Predicted flooding tides for 2007 season (May–August).

Day		Time	Height (m)	Time	Height (m)
May	18	0906	**9.82**	–	–
June	–	–	–	–	–
July	–	–	–	–	–
August	29	0859	**9.63**	2132	9.51
	30	0942	**9.66**	2206	**9.75**
	31	1026	**9.54**	2241	**9.91**

Notes: See Table III-1-3

APPENDIX III-1-A. CHRONOLOGY OF EVENTS FOR THE 2005 SEASON

The following is a chronology of the pond pumping project for the 2005 season from January through December.

Date	Event
January	Develop pumping and sampling master schedules
May	Construction of new road and pad to access northern C-Marsh 9 May: BSE and CRREL mark and start clearing road of UXOs. 10 May: Clearing operation finished. Start clearing brush for Duck road and opening up jeep trail. 11 May: Start grading jeep trail and clearing vegetation on Duck Road. 13 May: Start laying gravel on Duck Road. 18 May: Finished Duck Road and BC Pad. Laid gravel on some jeep trail soft spots. 19 May: Did some repair work on Goose Road. Equipment returned.
May	Pump system installation 16 May: Equipment delivered to EOD Pad (except pipe). 19 May: Pipe brought down to EOD Pad. 20 May: Airlifted pumps to field. Hooked up / fired up System 3. System 5 towed into place. 21 May: System 3 operational. Failure of pump 2 (63 L/s). Smoke problem with genset. 25 May: Discharge line airlifted to field. System 5 assembled and test fired. 26 May: System 5 operational. Temperature fault and excess smoke problems. 27 May: Smoke problem fixed (crankcase vent undersized). Radiator switch for #5 ordered to address over temperature fault. 31 May: Gave Jon an outline of tasks. Turned O&M over to CRREL / FRA.
July	Flooding tides: System off 22 – 28 July. Drained by 31 July.
August	Both systems ran out of fuel in early August. Auxiliary fuels tanks almost empty. Fuel run. Power cord to Pump #5 partially severed 3 August. Fixed 16 August. Fuel line to Genset #3 chewed and leaking. Discovered 10 Aug. Fixed 11 Aug. Flooding tides: System off 19 –26 . Drained by 29 August.
September	Retrograde operation 10 Sep: Inspected equipment. Running fine but needs fuel. BT Tide gate door off. 12 Sep: Fuel delivery to System #5 and #3. Arrange for helicopter support. 13 Sep: Shut down System #5. Prep for airlift. Fuel spill from refueling op reported 14 Sep: Shut down / break down System #3. Airlift of all equipment. 15 Sep: Pipe secured on EOD Pad. Equipment transported to yard on post. 16 Sep: Oil and filters changed out on all gensets. End of field season.
September	Flooding tides: September 16 – 21. CRREL / FRA assumes winter maintenance responsibilities.
October	Data analysis. Rough draft of report. Presentation preparation for end of year meeting.
November	7 – 8: Year-end wrap-up and planning meeting, Seattle, WA.
December	Prepare draft report for 2006 season. Start planning process for next season.

APPENDIX III-1-B. O&M LOG FOR THE 2005 SEASON

The following table (Table III-1-B1) constitutes the operation and maintenance (O&M) log for units fielded at Eagle River Flats during the 2005 season. Problems occurred throughout the season with the equipment, although external factors were involved in several of the incidents. Three significant problems occurred. The first was the failure of pump 2 (63 L/s) on System #3 that occurred shortly after start-up. This pump was out of commission the remainder of the season. The second problem was a partially severed power cord between the pump and genset on System #5. This caused a grounding of the genset and shutdown of the system. Because we had cancelled the mid-July service run, it took two weeks to address this problem. The third problem was a damaged fuel line between the fuel tank and genset for System #3. This had been chewed by an animal and resulted in a significant fuel spill. We ran out of fuel once and had to refuel twice, the second time for a minor amount of fuel to get us through the last few days of the season. Fuel track will need to be better applied next season. As both systems were shore-based this year, O&M required only one person, and no helicopter-assisted refueling operations were conducted. Both factors saved the project a significant amount of money.

In addition to servicing the fielded equipment, CRREL also maintained the stored equipment. Five generators were started once a month in the storage yard by the POL Lab building. We are still experiencing some starting difficulties, even with the shut-off switches to the batteries. We have worked around this problem for the time being.

Prior to the start of the season, Gensets 3 and 5 had bearing seals replaced, and the radiator was replaced on #3 by Rotating Equipment. Crankcase vent exhaust recirculating systems were installed on these systems and, after resizing the air lines, are working well. CRREL recommends that the bearings, impellers, and couplings be replaced on Pumps 1, 2, 4, and 6. Pump 4 should be done this year. The others can wait.

Table III-1-B1. O&M log for 2005.

Date	System 3			System 5			Notes
	Genset (hr)	Pump (hr)	Pump (cyc)	Genset (hr)	Pump 1 (hr)	Pump 2 (cyc.)	
21 May	3352.9	2109.7	7636	—	—	—	System 3 started. 63 L/s pump vibrating. Shut down.
22 May	3358	2114.3	7641	—	—	—	Genset smoking.
25 May	3366.2	2119.9	7661	—	—	—	Crankcase vent fixed. No smoke.
26 May				2533.2	1693.8	5698	System 5 started.
31 May	3369.4	2121.1	7672	2543.1	1700	5727	Placed pads under Genset #3.
6 June	3371.9	2122.1	7683	2546.1	1702	5737	Sys 5: Temperature switch faulty.
13 June	3372.1	2122.2	7684	2566.6	1708	5772	Sys. 5: Temperature switch fixed.
22 July	3385	2129.2	7728	2594.7	1727.4	5904	Systems shut down – Flood tide.
27 July	-	—	—	—	—	—	Started System 3
28 July	3405.9	2150.4	7729	2596	1728.1	5905	Started System 5. Stuck float switch.
1 Aug	3498	2237	7785	2663.9	1766.3	5905	System 5 out of fuel. No Aux fuel.
3 Aug	3502	2238.8	7797	2664.3	1766.3	5905	Both systems down. Refueled and restarted. Sys 5 won't pump.
10 Aug	3543.3	2265.4	7908	—	—	—	#5 down. #3 fuel line leaking.
11 Aug	—	—	—	—	—	—	Fuel line repaired.
16 Aug	—	—	—	—	—	—	System 5 power cable repaired.
19 Aug	3557.7	2275	7945	2679	1774.1	5935	Systems shut down – Flood tide.
26 Aug	—	—	—	—	—	—	Turned systems back on.
29 Aug	3632	2350.2	7947	—	—	—	Refilled #3. Wouldn't start. Water in fuel.
30 Aug	—	—	—	2774	1867.6	5949	Sys. 3: Drained 20 L water from fuel tank. Still wouldn't start.
31 Aug	—	—	—	—	—	—	Cleaned fuel system for #3. Started
2 Sept	3651	2363.5	7986	2808.2	1893.2	6033	Both systems running fine.
6 Sept	3676.7	2377.2	8077	2834.2	1911.7	6105	Discharge hose strap failure near Genset #3. Fixed.
12 Sept	3730	2418	8224	2906.5	1969.5	6243	Partial refueling of systems.
13 Sept	—	—	—	2915.9	1975.9	6270	System #5 shut down for season. Refueling spills reported.
14 Sept	3749	2424	8271	—	—	—	System #3 shut down for season.
16 Sept	—	—	—	—	—	—	Filters replaced on gensets. Oil changed on all gensets.

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

Appendix C 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-C1. 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	
	23-Jun	27-Aug	256	0.39	66	System 4: 126 L/s		in Area	
	28-May	27-Aug	290	0.91	92	System 5: 126 L/s		A)	
	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-C1 (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 Support
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	

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

III-2. LONG-TERM MONITORING AND SAMPLING OF SEDIMENTS OF PONDS TREATED FOR WHITE PHOSPORUS

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INTRODUCTION

Summer 2005 was the second field season of long-term-monitoring after five years of full-scale active remediation by pond pumping of white phosphorus-contaminated ponds at Eagle River Flats (ERF). By the end of the active remediation in 2003, surface sediments of the major waterfowl feeding ponds (Area C Ponds 183, 146; Bread Truck Pond 109; Area A Ponds 226, 258 and 290) did not have detectable concentrations of white phosphorus (Fig. III-2-1). Residual white phosphorus remained in small pools within the marsh of the northeast section of Area C, in several small ponds in the eastern part of Area BT, and in drained ponds on Racine Island. Several of these areas continued to be addressed with limited remediation (Walsh, M.R. et al., this volume, Section III-1).

In 2004, a long-term monitoring program commenced with the objective to periodically confirm that 1) white phosphorus particles are not within the surface sediments, where they could be ingested by dabbling ducks, and 2) the ponds that have been decontaminated by pond pumping or drainage by ditching remain uncontaminated. Surface sediments of the ponds should remain uncontaminated unless white phosphorus is reintroduced. Potential mechanisms for reintroduction of white phosphorus are migration of buried white phosphorus to the surface, disturbance of the surface sediments by detonations during training that exposes underlying contaminated sediments, removal of overlying sediments by ice rafting, or detonation of WP-filled unexploded ordnance.

Monitoring involves collecting multi-increment samples of surface sediments in treated ponds and discrete samples at locations where high concentrations of white phosphorus were previously observed. Sublimation/ oxidation conditions are measured at selected locations within contaminated or formerly contaminated ponds. Monitoring also includes a ground-based waterfowl mortality survey and a meteorological station; results of these studies are described elsewhere in this volume (Collins et al., Section II-2; Collins, Section II-3).

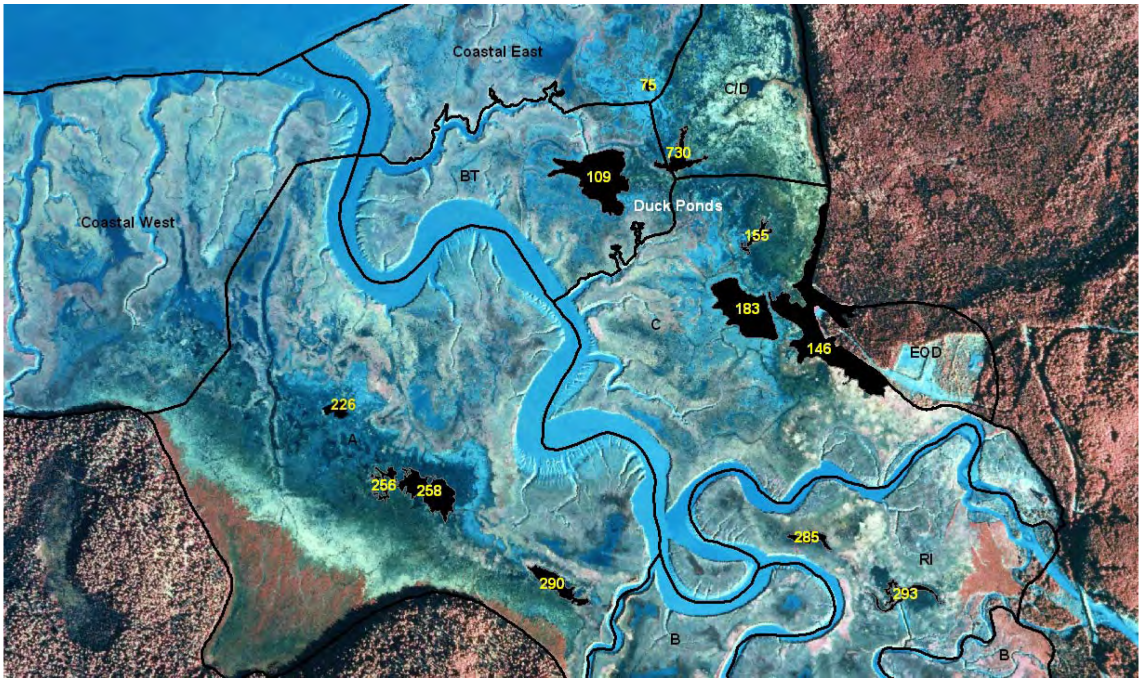


Figure III-2-1. Aerial photo (Aeromap 2001) of Eagle River Flats showing identification numbers for treated ponds.

METHODS

Sampling

Discrete Samples

In May 2003, we located several small pools with very high white phosphorus concentrations (Table III-2-1, Walsh et al. 2004). These pools were within the marsh in the northeast sector of Area C (Fig. III-2-2). In July and August 2003, we located additional pools with high white phosphorus concentrations and found that each of these pools contained metallic remnants of detonated WP ordnance items. In total, we found twelve pools with WP mortar fins (tail assemblies and partial bodies filled with white phosphorus), five pools with mortar fragments (as identified by our unexploded ordnance (UXO) technician), and one pool that contained numerous breached 57-mm recoilless rifle projectiles. Because of these findings, in 2004 we performed a systematic magnetometer survey of the Area C Marsh and the southeast section of Area BT (Duck Ponds). This revealed 55 additional locations with metallic WP ordnance scrap and WP residue in the co-located sediment (Walsh, M.E. et al. 2005). In 2004 and 2005, we re-established the locations of 24 contaminated pools for resampling. We navigated with a Trimble GPS Pathfinder Pro XR system to the selected UTM coordinates and used the site markers that remained from previous sampling. At each location, at least 20 increments of surface sediment were collected within 2 m of the center point to fill a 250-mL container.

Another result of the magnetometer survey was the discovery of 21 UXOs (not including the 57-mm recoilless rifle projectiles). About 13 of these items were unexploded 105-mm projectiles; the exact identification of each projectile was uncertain due to corrosion and that the projectiles were not exhumed from the mud (Fig. III-2-3). The projectiles resided under the vegetated mat of C Marsh at approximately 30 cm depth. A cluster of five 105-mm projectiles was found 40 m east of Pond 155 (Fig. III-2-4). These projectiles were initially thought to all contain high explosives, and following the established protocol, were blown in place. However, the detonation produced the thick white cloud characteristic of WP-containing ordnance. On June 1 and September 2005, we sampled nine craters produced from the BIP (blow-in-place) operation of August 2004 (Table III-2-2). In May we used a small pump to help dewater these craters to facilitate remediation and sampling. At each crater, at least 20 increments of surface sediment were collected to fill a 250-mL container (Fig. III-2-5).

Multi-increment Samples

Multi-increment sampling mimics the way dabbling ducks feed in shallow ponds and increments are collected from a much larger area than for discrete samples. This sampling method is more likely to reveal the presence of hotspots (locations with high white phosphorus concentrations) than discrete sampling because each multi-increment sample is composed of many subsamples over the area we wish to represent. We focused the multi-increment sampling on the drainage ditches in C Marsh where the majority of waterfowl carcasses were found during the ground-based mortality monitoring in the fall of 2004 (Fig. III-2-6). In August 2004, we sampled some of these ditches, but high water levels limited our ability to thoroughly sample the sediment. In 2005, a pump installed in C Marsh removed most of the water from these ditches, allowing us to sample the sediments on the sides and bottoms of the ditches where ducks can dabble.

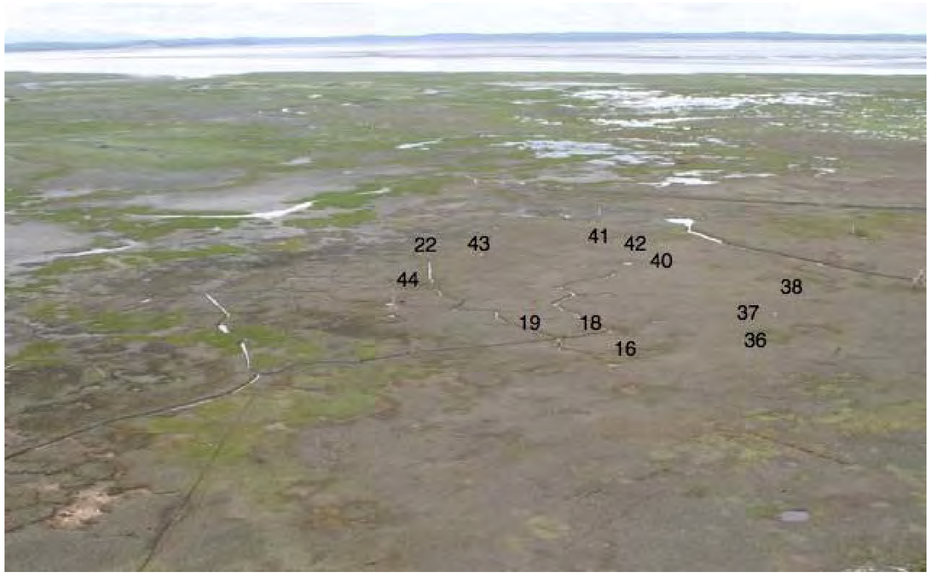
During the May 2005 sampling effort, we subdivided the ditches into segments averaging 40 m in length (Fig. III-2-7) and collected surface sediment by traversing each ditch segment, stopping every two meters to scoop a 30-40 mL aliquot of surface sediment from the sides and bottom of the ditch into a plastic bag. These sediment samples weighed between 2 and 5 kg, depending on the length of ditch segment, and contained at least 60 increments of sediment. In September 2005, we collected two types of multi-increment samples from each ditch segment. One sampler collected surface sediment using the same procedure as in May 2005. The second sampler collected only the sediment size fraction that would have lethal-sized particles of white phosphorus (Walsh et al. 1997) by using a long-handled spoon to collect approximately 50-mL aliquots of sediment every few meters and placing each aliquot in a sieve bucket (0.59 mm mesh). The sediment was stirred under water to remove the fine grain sediment. The material remaining on the mesh was composed mostly of organic matter. The mesh was sufficiently fine to also retain the ecologically relevant white phosphorus particles that, if present, would pose significant hazard to waterfowl.

Table III-2-1. White phosphorus concentrations in discrete samples collected from locations in Area C marsh that had high concentrations when first sampled in 2003 or 2004 and were resampled in September 2005. Coordinates are UTM NAD 27.

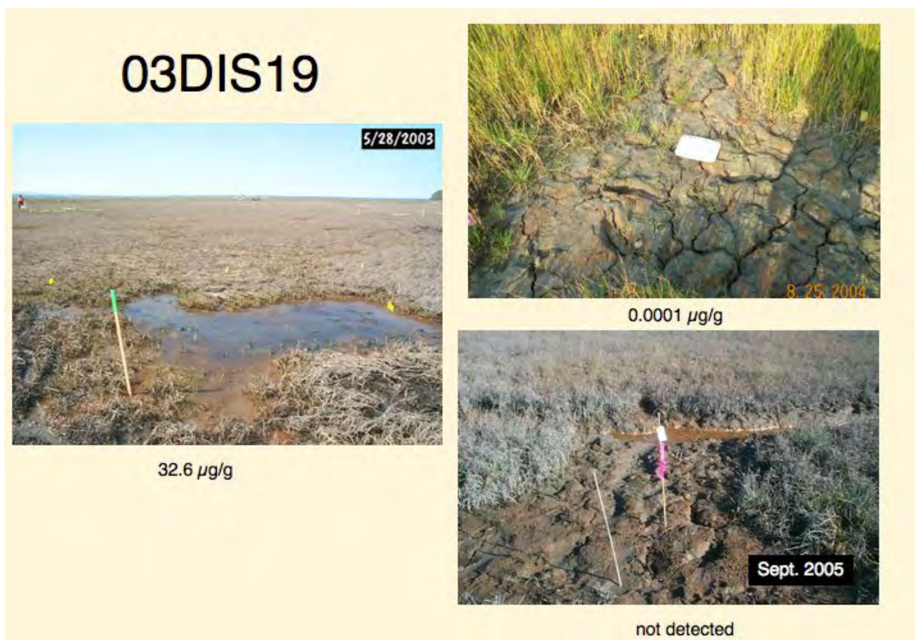
	Location			White Phosphorus Concentration (µg/g)		
Sample ID	**East (m)**	**North (m)**	**Area**	**May-03**	**27-Aug-04**	**Sept-05**
03DIS16 *****	355,226	6,801,423	C	460	1.7	90
03DIS18 *****	355,209	6,801,430	C	400	0.002	0.08
03DIS19 *****	355,195	6,801,428	C	32.6	0.0001	Not Detected
03DIS22	355,126	6,801,461	C	47	95	3.8
				Sep-03		
03DIS36	355,233	6,801,449	C	450	6.5	24
03DIS37	355,220	6,801,465	C	66	19	(0.04/15.7 ******)
03DIS38	355,217	6,801,490	C	4,300	2.1	1,160
03DIS40	355,168	6,801,505	C	38	355	75
03DIS41	355,137	6,801,515	C	1,300	11	1.9
03DIS42	355,144	6,801,509	C	204	11	99
03DIS43	355,138	6,801,473	C	150	110	15
03DIS44	355,143	6,801,438	C	1,750	0.37	0.068

	Location			White Phosphorus Concentration (µg/g)	
Sample ID	**East (m)**	**North (m)**	**Area**	**May-04**	**Sept-05**
04DIS66	355,161	6,801,418	C	60.5 (subsurface)	Not Detected (surface)
04DIS73	355,119	6,801,449	C	5,600	0.75
04DIS082	355,247	6,801,461	C	1,605	32
04DIS084	355,249	6,801,443	C	3,678	209
04DIS085	355,222	6,801,425	C	91.1	7.7
04DIS086	354,857	6,801,626	BT	11.6	2.3
04DIS090	354,827	6,801,651	BT	5,284	0.66
04DIS093	354,823	6,801,706	BT	3,444	311
04DIS097	354,780	6,801,724	BT	2,767	2.5
04DIS103	354,788	6,801,661	BT	8.76	0.007
04DIS114	354,788	6,801,615	BT	0.52	Not Detected
04DIS125	355,228	6,801,523	C	950	1.7

* Drained by ditches that were installed August 2003.
** (surface/ subsurface)



a. Aerial oblique photograph taken in May 2005.



b. The pool corresponding to sample 03DIS19 contained a mortar fin filled with WP. The pool was drained in August 2003.

Figure III-2-2. Photographs showing a) the locations of discrete samples with high WP concentrations in 2003 that were resampled in 2004 and 2005 and b) ground views of one of the discrete samples. The two-digit numbers in (a) are the sample identification numbers that replace XX in 03DISXX in Table III-2-1.

Figure III-2-3. 105-mm WP projectile found in Area C in August 2004.

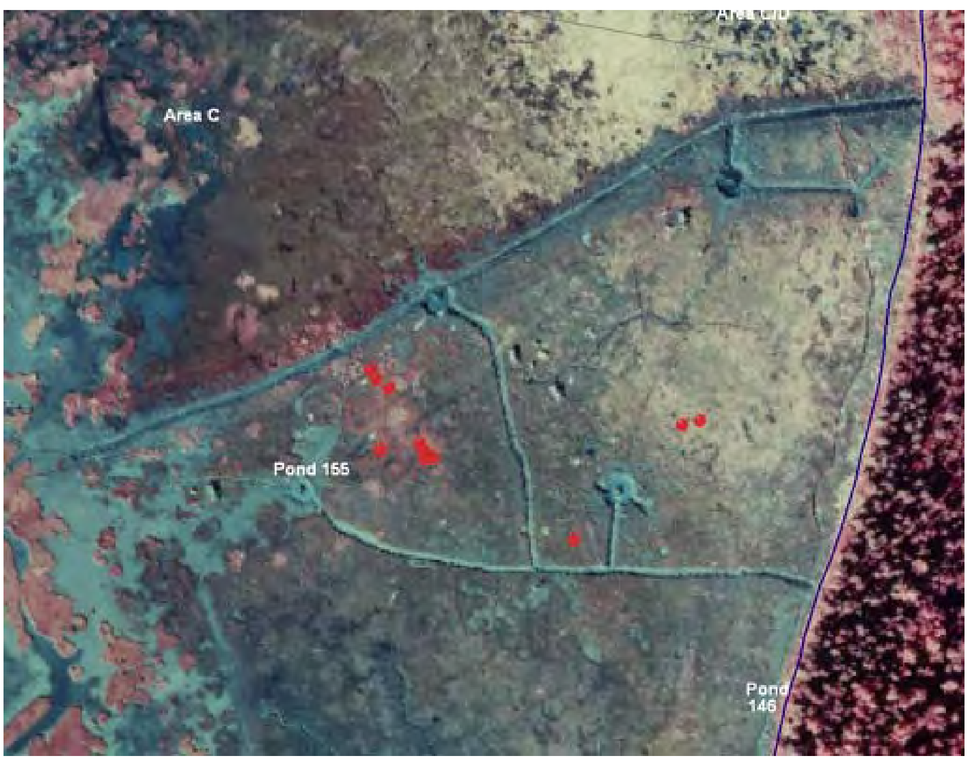


Figure III-2-4. Locations of unexploded ordnance found in August 2004.

Figure III-2-5. June 2005 sampling of BIP craters in C Marsh. The craters were drained in May 2005 using a small gasoline-powered pump to facilitate remediation and sampling.

Table III-2-2. White phosphorus concentrations in discrete samples collected from craters produced by BIP (blow-in-place) detonations of ordnance found in August 2004. Coordinates are UTM NAD 27.

	Location		WP Concentration (μg/g)	
Sample ID	**East (m)**	**North (m)**	**1-June-05**	**12-Sept-05**
BIP 5	355,188	6,801,563	8.24	1.31
BIP 6	355,184	6,801,562	72	0.012
BIP 7	355,185	6,801,565	53	0.83
BIP 8	355,184	6,801,567	29	2.89
BIP 9	355,182	6,801,570	1,330	0.68
BIP 10	355,167	6,801,567	1,160	0.62
BIP 11	355,169	6,801,590	511	not detected
BIP 12	355,165	6,801,595	not detected	not detected
BIP 13	355,164	6,801,598	not detected	not detected
C Marsh Pond 15	355,187	6,801,558	8.3	2.0
Rims of BIPS 5 to 9			1.2	not sampled
Rims of BIPS 11 to 13			0.065	not sampled

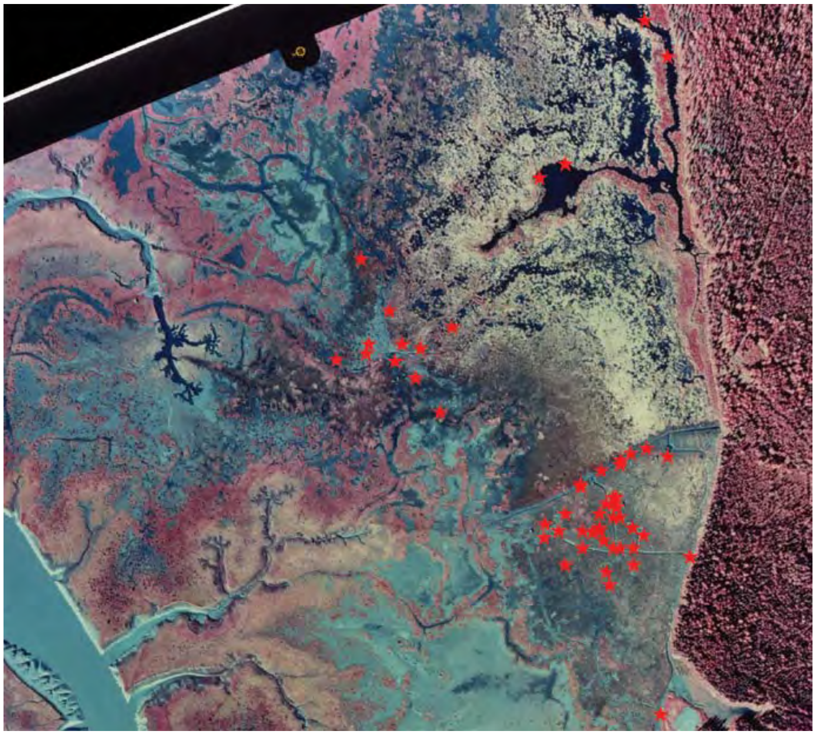


Figure III-2-6. Location of duck carcasses found in fall 2004. White phosphorus was detected in the gizzard contents of each duck.

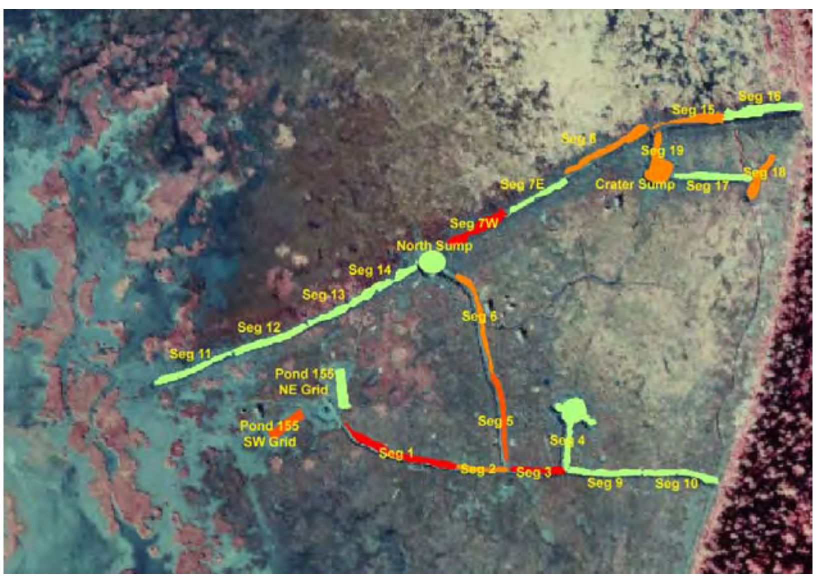


Figure III-2-7. Locations of multi-increment samples collected in C Marsh ditches in 2005. Red and orange indicate white phosphorus was detected. Green indicates that white phosphorus was not detectable in the samples.

We also resampled Pond 155. In 1998 we sampled two 5.46 m X 20 m areas within Pond 155 by combining 48 subsamples from the nodes of a 1.82-m square grid. The spacing of the subsamples was designed to detect 2-m diameter hotspots. The northeast section of the pond did not have detectable white phosphorus, but the southwest section of the pond did have significant concentrations (Fig. III-2-7). We have collected samples from the southwest grid several times over the years and continue to detect white phosphorus. Because of the proximity of Pond 155 to the detonation of the 105-mm WP projectiles in August 2004, recontamination of this pond was a possibility. In May 2005, we resampled both gridded areas and, in August 2005, we resampled the southwest grid only.

Laboratory Analysis of Sediments for White Phosphorus Residues

Samples were analyzed for white phosphorus by EPA SW-846 Method 7580 (USEPA 1995). First, all samples were screened for the presence of white phosphorus using headspace Solid Phase Micro-extraction, then estimates of white phosphorus concentration were obtained using solvent extraction and gas chromatography. For multi-increment sediment samples, a 200-g subsample was formed from at least 30 increments of the field sample and extracted with 100 mL of isooctane. For multi-increment sieved samples, the entire sample was extracted with isooctane. Discrete samples were subsampled by taking a 40-g portion and extracting the white phosphorus with 20 mL of isooctane. White phosphorus was determined using a nitrogen-phosphorus detector.

Sublimation/Oxidation Conditions

This year, sensors and dataloggers monitored sediment temperature and moisture conditions at eight locations (Table III-2-3, Fig. III-2-8) using the same configuration we have used since 1997 (Walsh et al. 2003). The sensors were Campbell Scientific (Logan, UT) Model 107B soil/water thermistor probes for temperature, Campbell Scientific Model 257 (Watermark 200) soil moisture sensors, SoilMoisture® (SoilMoisture Equipment Corp., Santa Barbara, CA) Series 2725 tensiometers for sediment moisture, and Druck (New Fairfield, CT) pressure transducers (PDCR 1830) for water level. At two locations (Area C Piezo and Pond 155 Piezo), the Druck was placed within a piezometer well to measure groundwater elevation. At the remaining stations, the Drucks were at the sediment surface to measure water depth in each pond during tidal flood events and subsequent draining.

After the water is pumped from the ponds and ditches, weather, tides, and local hydrology determine if the sediments actually desaturate. Sublimation/oxidation conditions are favorable if the sediments dry below water saturation and warm to at least 15°C. The sediments are deemed unsaturated when tensiometers read at least 10 cbars. The tensiometers maximum is about 70 cbars.

At six datalogger stations, five white phosphorus particles of known mass (5.6±0.5 mg) were planted in the sediment in May and removed in September to determine if the WP mass decreased. Each white phosphorus particle was placed in a plug of clean sediment and then the sediment placed in a nylon fine-mesh bag. The five replicate sediment plugs were buried at 5 cm depth at each datalogger station. To determine if the white phosphorus particles had decreased in mass, the sediment plugs containing particles were recovered on 12 September 2005 and placed into isooctane to extract white phosphorus residue prior to analysis by gas chromatography.

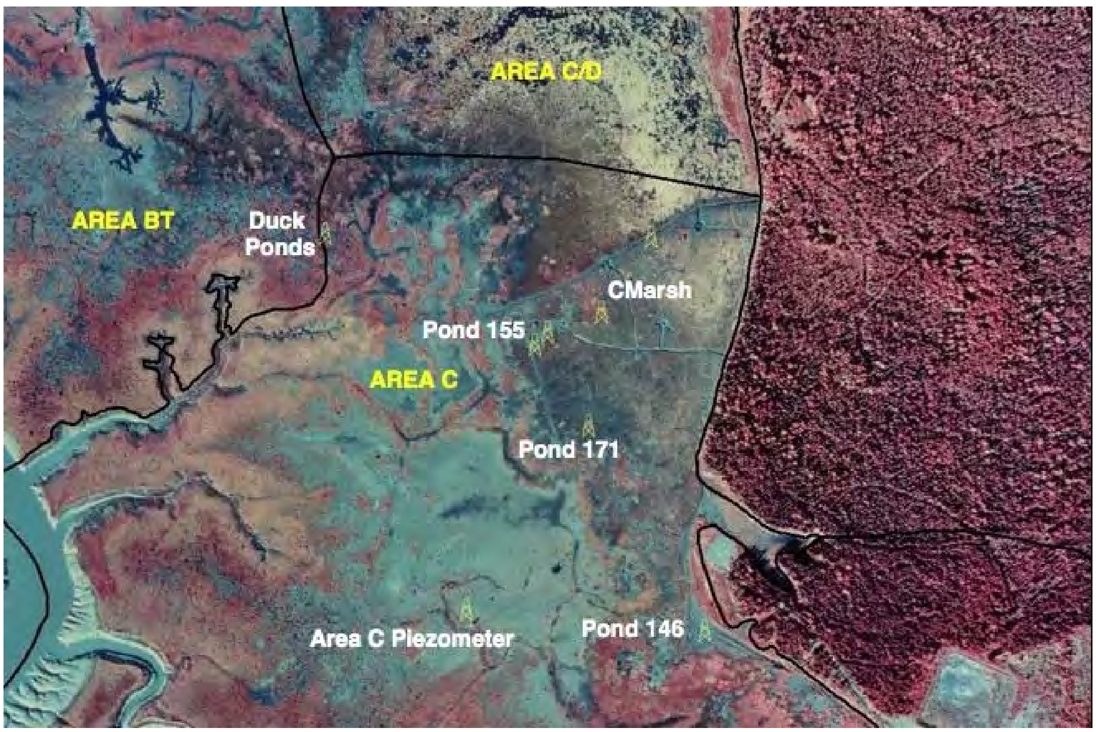


Figure III-2-8. Aerial photo (Aeromap 2003) of Area C of Eagle River Flats showing datalogger locations used to monitor sublimation/oxidation conditions in 2005.

Table III-2-3. UTM coordinates (NAD 27) of dataloggers.

Area	Datalogger Site	East (m)	North (m)
Area C	C Marsh North (Ditch)	355,244	6,801,658
	C Marsh West (BIP Craters)	355,183	6,801,565
		355,310	6,801,172
	Pond 155	355,116	6,801,540
	Pond 155 Piezometer	355,101	6,801,524
	Pond 171	355166	6801426
	C ('94 piezo site) (Pond 164)	355,016	6,801,199
Area BT	Duck Pond	354,841	680,1662

RESULTS AND DISCUSSION

Two conditions are needed to decontaminate the surface sediments. Water must be removed so that sediments will desaturate and the sediment temperatures must warm sufficiently to vaporize the white phosphorus particles. At ERF, pumps remove the surface water and then the weather, local hydrology, and tidal cycles control if the surface sediments will actually dry. Surface water was removed from Area C by one pump located in Pond 146 and a second pump in the crater sump located in the northeast corner of Area C. Groundwater levels were monitored at two locations in Area C (Area C Piezo and Pond 155 Piezo). The groundwater level at both locations was falling in May when we installed the dataloggers, and dropped approximately 0.8 m below the sediment surface just prior to a flooding tide on July 22 (Fig. III-2-9). This drop in groundwater level was sufficient to desaturate the surface sediments for several weeks at each location.

Sublimation/oxidation conditions were monitored in the surface sediment of previously monitored locations in Ponds 146, 171, and 155. As a response to the known white phosphorus contamination and accumulation of waterfowl carcasses around the large drainage ditches and BIP craters in C Marsh, we installed monitoring stations with sensors in the north drainage ditch and in the cluster of BIP craters east of Pond 155. We also monitored the surface sediment in the southwest part of Area BT (Duck Ponds), which was drained by shallow ditches excavated in 2004.

Pond 146 is a permanent pond located adjacent to the EOD pad and Clunie Inlet. This pond was heavily contaminated prior to treatment by dredging and pumping. In 2005, during the 47 days when the surface sediments were unsaturated at the Pond 146 datalogger (Fig. III-2-10a), the mean sediment temperature at 5-cm depth was 19.0°C. The maximum mid-day hourly average temperature was 25.4°C on July 9. High temperature spikes (up to 34.4°C) were recorded nightly at the Pond 146 sensors in the early morning hours over a two-week period from late June to mid July. These readings are considered anomalous because they are not consistent with the weather conditions or the peak temperatures at other monitoring sites. The most likely explanation is a wolf marking (urinating) on the sensor, not an uncommon occurrence in Eagle River Flats. In any case, sublimation/oxidation conditions were excellent until the 22 July 2005 flooding tide; particles planted in Pond 146 declined in mass by100% (Table III-2-4). The surface sediments of Pond 146 should be considered remediated. Periodic multi-increment sampling in the formerly contaminated parts of this pond should be conducted every few years; however, there is no compelling reason to install a monitoring station in this pond in future years unless recontamination is detected by sampling or duck carcasses accumulate here.

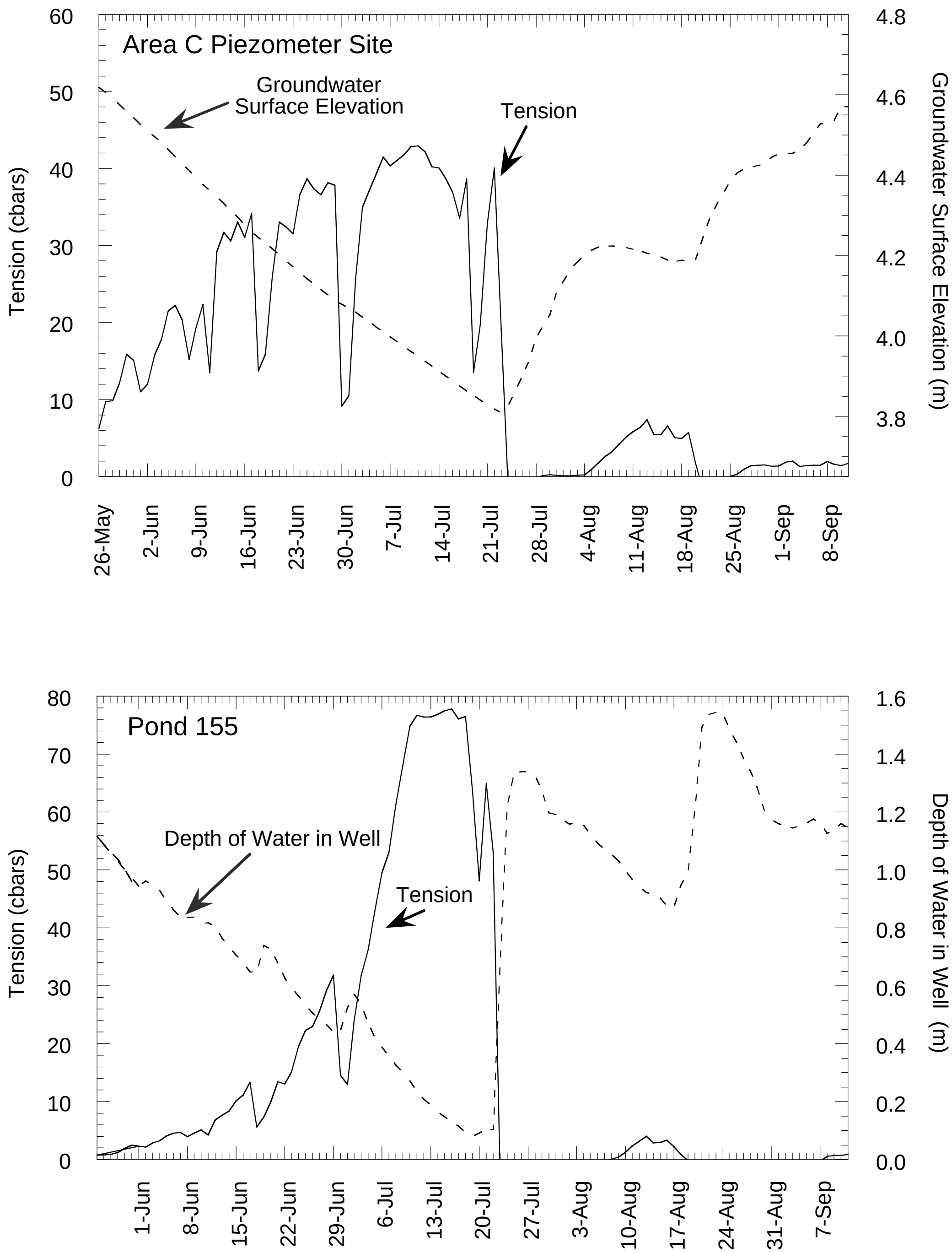
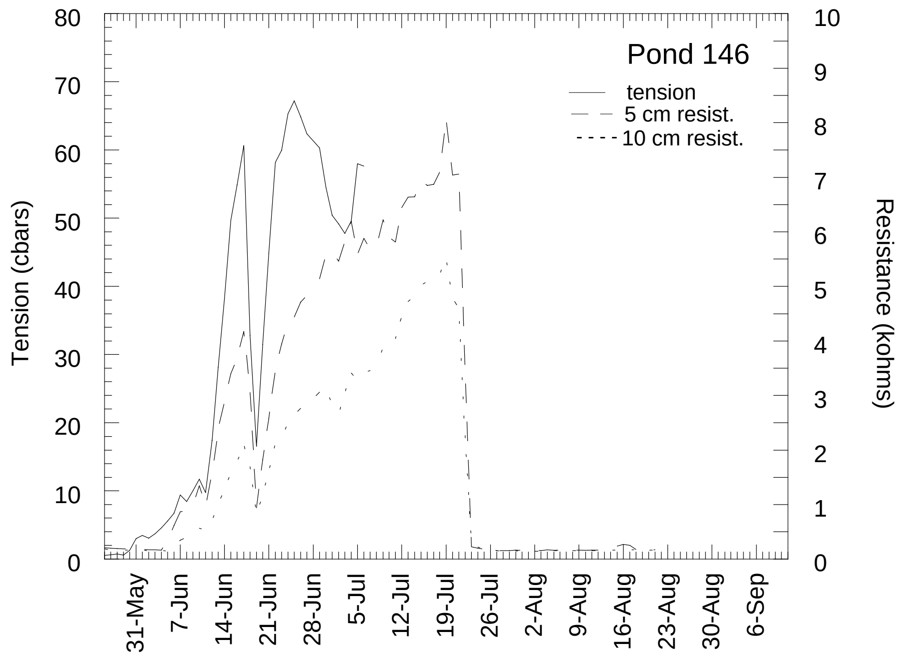
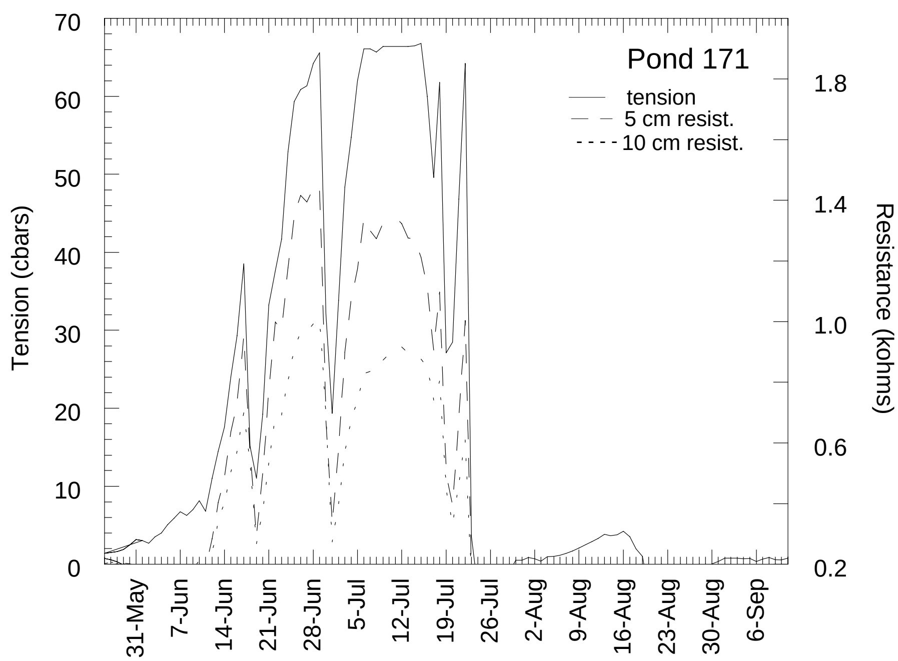


Figure III-2-9. Output from the Soil Moisture tensiometers and Druck pressure transducers in two locations in Area C. Tension increases as the groundwater level drops and the sediment dries.

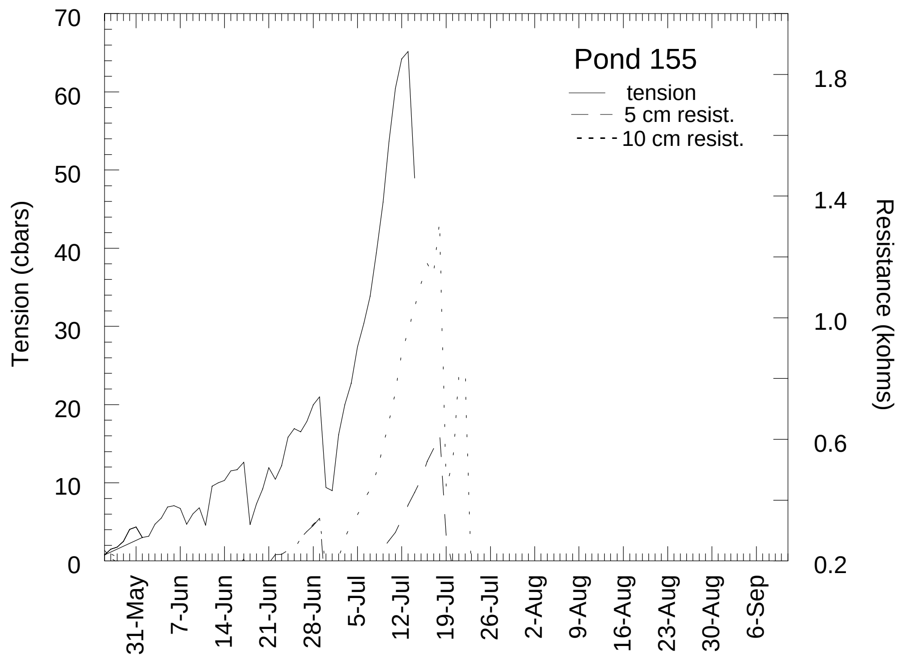


a. Pond 146

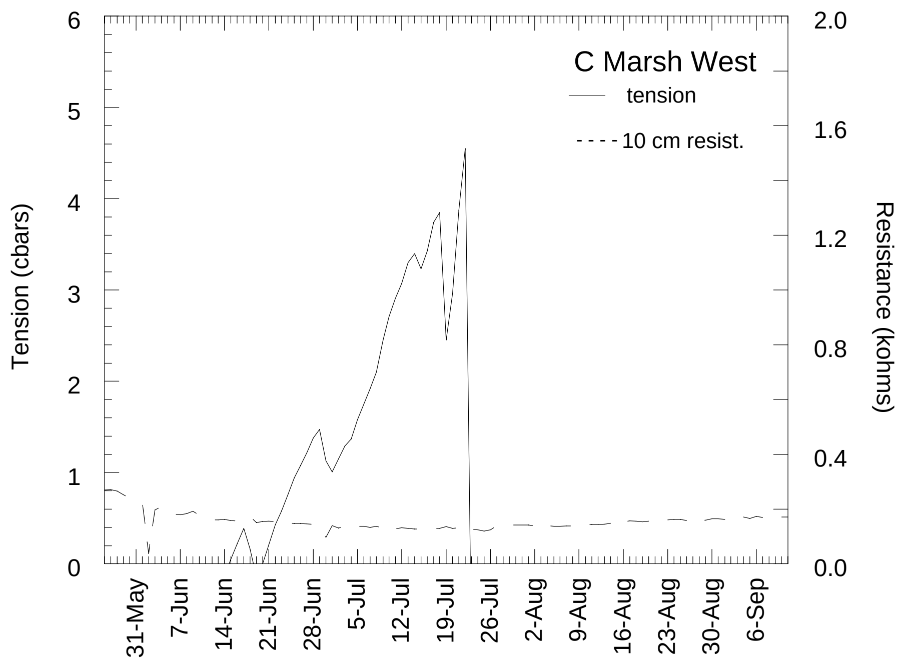


b. Pond 171

Figure III-2-10. Output from moisture sensors during the summer of 2005. Increases in tension and resistance indicate the sediment was drying.

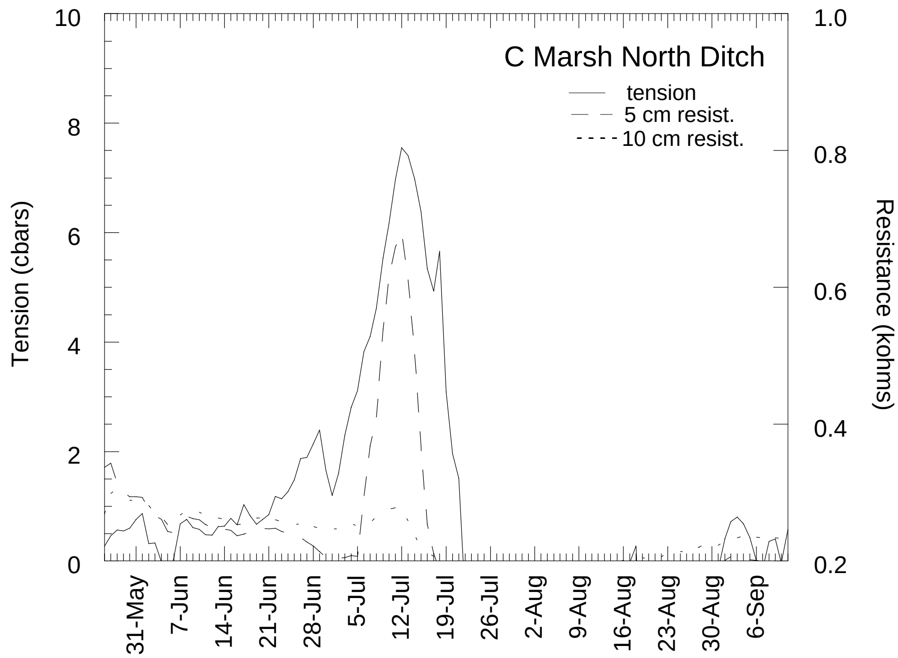


c. Pond 155

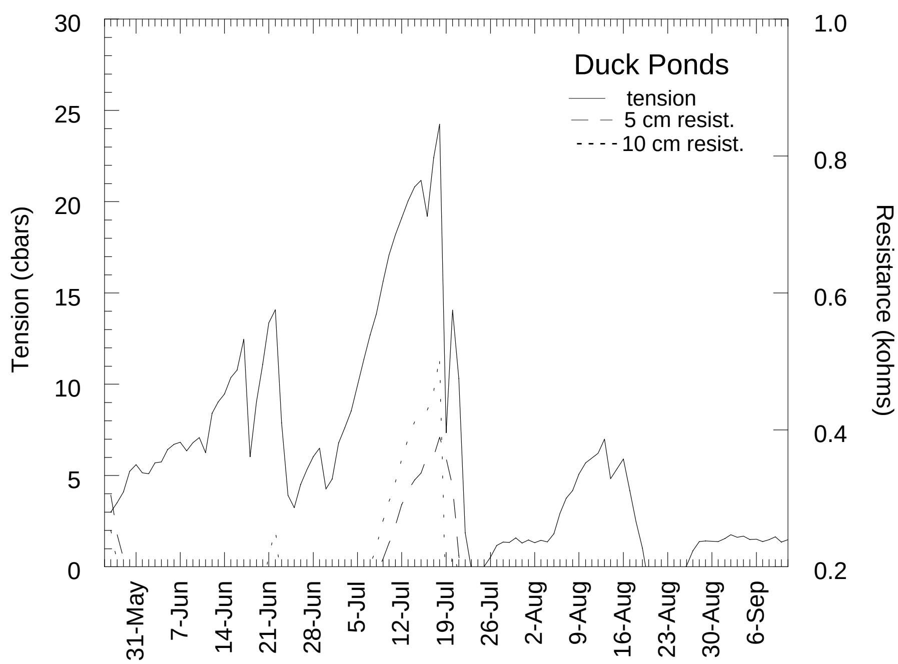


d. C Marsh West (BIPS)

Figure III-2-10 (cont.). Output from moisture sensors during the summer of 2005. Increases in tension and resistance indicate the sediment was drying.



e. C Marsh North (Ditch)



f. Duck Ponds

Figure III-2-10 (cont.). Output from moisture sensors during the summer of 2005. Increases in tension and resistance indicate the sediment was drying.

Table III-2-4. Loss of white phosphorus from particles planted in the top 5 cm of sediment. Locations correspond to data stations in Table III-2-3.

Area	Datalogger Site	Loss (%)*
Area C	C Marsh North (Ditch)	6.2
	C Marsh West (BIP Craters)	85
	Pond 146	100
	Pond 155	48
	Pond 171	97
Area BT	Duck Pond	14

* Nominal initial mass was 5.6±0.5 mg for each of five particles yielding an initial total mass of 28 mg. Loss (%) was computed as follows: 100 X [1-(sum of mass remaining)/(total initial mass)]

Pond 171 is located on the southwestern edge of the C Marsh. Waterfowl carcasses were found in this pond in previous years and WP concentrations in multi-increment samples previously showed the presence of lethal quantities of WP in the surface sediments. In 2005, the surface sediments were unsaturated (Fig. III-2-10b) for a total of 41 days (same as in 2004); the mean temperature while the sediments were unsaturated was 18.7°C. Loss of mass from planted white phosphorus particles was 97% (Table III-2-4), which is the same as last year and similar to 2003 when the loss was 98%. In May 2004, we found buried ordnance scrap at the edge of the pond and we detected 60.5 µg/g WP in the subsurface sediment. In September 2005, we sampled the surface sediment from 0 to 10 cm at the point where this ordnance scrap was found and we did not detect white phosphorus. Pumping has been successful at remediating the surface sediments of this pond.

Sampling results and data from the three surface sediment monitoring stations in C Marsh (Fig. III-2-11) confirm that remediation is occurring within this part of the ERF, but at an apparently slower rate than Ponds 146 and 171. White phosphorus is still detectable in multi-increment samples from the southwest grid in Pond 155, and the high sampling error between field replicates implies that a hotspot remains within the southwest part of this pond (Table III-2-5). Fortunately, there is no evidence that Pond 155 was recontaminated from the blow in place detonations in August 2004; white phosphorus was not detectable in the multi-increment sample collected from the northeast grid, the part of the pond closest to the detonations. Surface sediments at the monitoring station in Pond 155 (Fig. III-2-10c) were unsaturated for 36 days; the mean temperature was 19.8°C. Web camera images (Fig. III-2-12) show cracking and salt precipitation on the sediment surface, both of which are evidence of drying sediment. Of the five white phosphorus particles planted in this pond, two particles lost over 90% of their mass, while the other three lost 20% or less, equating to an average loss of 48% for the 2005 season.

Figure III-2-11. Aerial oblique photograph taken in May 2005 looking east over C Marsh showing locations of datalogger stations, web cameras and sampling grids.

Table III-2-5. White phosphorus concentrations found in multi-increment samples from the SW grid in Pond 155.

Date Collected	Concentration (µg/g)
August 1998	0.023
June 1999	0.45
September 1999	0.018, 0.015
August 2000	0.034, 0.044
September 2001	0.005, 0.004
August 2002	0.003, 0.008
September 2003	0.001, 2.25
May 2005	0.006, 0.32
September 2005	0.0006, 0.002

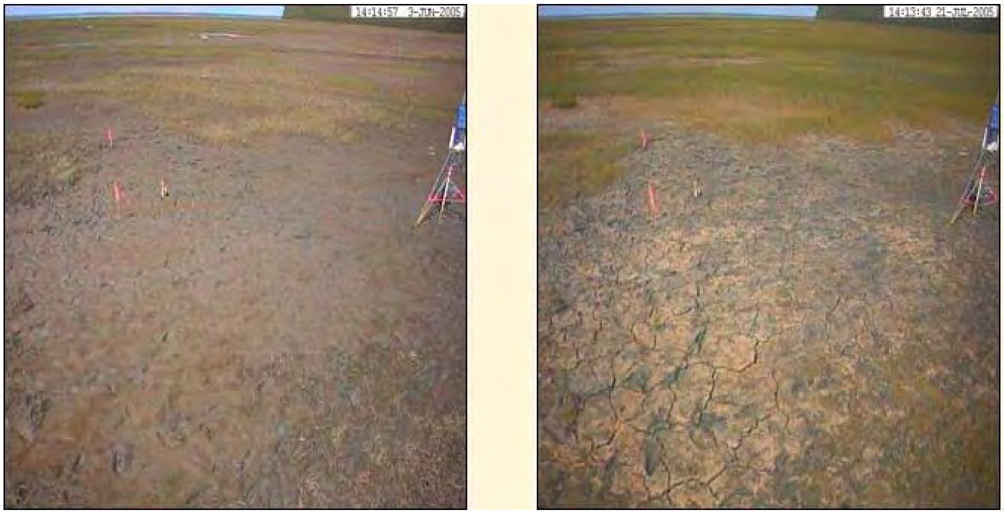


Figure III-2-12. Webcamera images taken on 3 June and 21 July 2005 showing visual evidence of significant drying of the surface sediments of Pond 155.

Sensors placed within the mud of the BIP craters east of Pond 155 showed little drying (Fig. III-2-10d), but total loss of mass of planted white phosphorus particles at the surface of the craters was 85% (range of 67 to 97%). Sediment samples from the BIP craters (Table III-2-2) collected in June and again in September showed considerable decreases in concentration, indicating that most of the white phosphorus was at or near the surface where sublimation/oxidation would be faster than at depth.

Sensors in the sediment of the C Marsh north drainage ditch showed little drying (Fig. III-2-10e); loss from the planted particles was only 6.2%, not significantly different than the quality control particles stored under water the in lab for the same time period (3.2% loss). The sediments of the north ditch are not likely to dry due to the influx of water from Area C/D. To dry the sediments of the north ditch, a shallow diversion ditch north of and parallel to the present ditch will be needed. Drying the sediments of this ditch is certainly desirable in light of the sediment sampling results from the ditches (Table III-2-6). One sieved multi-increment sample from a section of the north ditch recovered 90 mg of white phosphorus as particles (Fig. III-2-13). This one sample contained enough white phosphorus to kill over 20 mallards. Samples from the south ditch and cross ditch also had particulate white phosphorus. These sampling results are consistent with the results from the ground-based mortality transects in that waterfowl carcasses and featherpiles were concentrated in and around these drainage ditches. Fortunately, sections of the south ditch do appear to dry (Fig. III-2-14). In 2006, an additional pump within this ditch network would enhance the removal of surface water and expose the sediments so that white phosphorus particles could sublime.

Table III-2-6. Sampling results for multi-increment samples from drainage ditches in Area C.

Ditch Segment	WP Concentration in Sediment (µg/g)		WP Mass (mg) Sieved Sample (>0.59mm)
	May 2005	Sept. 2005	
1	0.21	0.49	50
2	0.028	not detected	0.18†
3	0.023	0.001	86
4	not detected	not sampled	not sampled
5	0.49	0.002	4.2
6	0.21	0.0002	0.43
7E	0.0002	not detected	not analyzed
7W	1.55	16.6	90
8	0.0001	0.0001	not detected
9	not detected	not sampled	not sampled
10	not detected	not sampled	not sampled
11	not detected	not sampled	not sampled
12	not detected	not sampled	not sampled
13	not detected	not sampled	not sampled
14	not detected	not sampled	not sampled
15	0.0027	0.0003	0.0007
16	not detected	not sampled	not sampled
17	not detected	not sampled	not sampled
18	0.0013	0.061	0.0007
19	0.0005	0.0002	not analyzed

†Potential carryover in sieve bucket from Segment 1 sample.

The last monitoring station was located within the pond complex in the southeast corner of Area BT, known as the Duck Ponds (Fig. III-2-8 and III-2-15). These ponds were sampled in 2003 after three Green-winged Teal carcasses were found. Subsequent sampling of the ponds and surrounding marsh in 2003 and 2004 detected several white phosphorus hotspots. Drainage channels and a tide gate were installed in July 2004 to remove as much surface water as possible and remove the ponds as waterfowl habitat between flooding tides. In 2005, the sediment at the monitoring station was desaturated for 22 days (Fig. III-2-10f). However, loss of mass from the planted white phosphorus particles was only 14%. In 2006, we will establish a number of gridded areas from which we will collect multi-increments samples for future monitoring following the sampling methods we used in the large waterfowl feeding ponds of Area C and BT. In these ponds, white phosphorus became undetectable after several seasons in gridded areas that contained significant concentrations prior to treatment.

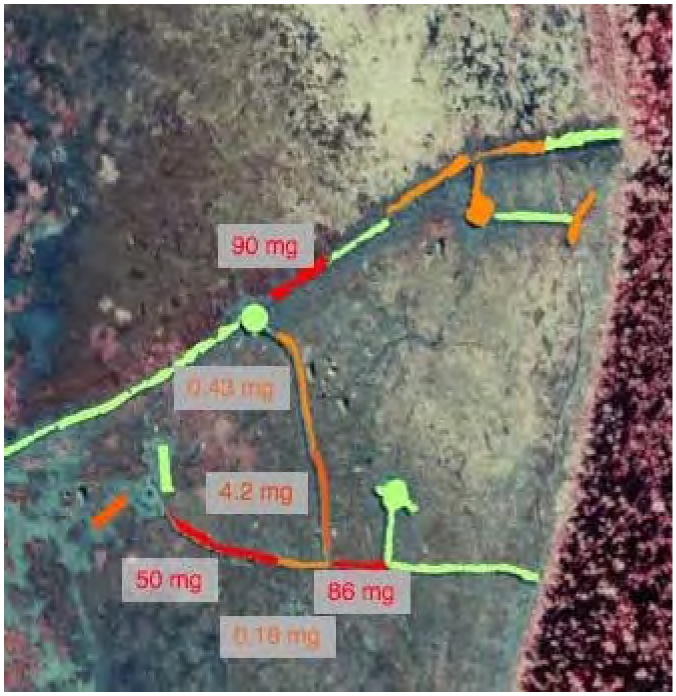


Figure III-2-13. Sieved multi-increment samples from the drainage ditches recovered over 231 mg of white phosphorus in the greater than 0.6 mm size fraction.

Figure III-2-14. Web camera images looking north from the intersection of the south drainage ditch and the cross ditch.

Resampling hotspots is useful for monitoring remediation in the large waterfowl feeding ponds. Even though the sampling error for white phosphorus is high due to the heterogeneous size and distribution of the WP particles, repeated sampling over time reveals remediation trends as white phosphorus reached undetectable levels with repeated drying cycles. We chose 24 hotspots in the Area C marsh and in the Duck Ponds for resampling in September 2005. We resampled 12 locations in the marsh near Ponds 155 and 171 (Fig. III-2-2), a site where we had found high (33 to 4,300 µg/g) concentrations of white phosphorus in May and September 2003. We also sampled 12 locations where we found WP ordnance scrap and high WP concentrations in May 2004 – in the marsh near Ponds 155 and 171, the southeast part of Area BT, and the south drainage ditch in Area C. When the 2005 samples were collected, the small pools in the marsh were filled with water and the mud was soft, which made precise control of sampling depth difficult, unlike in 2004 when the mud was firm (Fig. III-2-16). Sample results were mixed for the hotspots first sampled in 2003.
A downward concentration trend is evident at some locations, notably 03DIS19 and 03DIS44, but significant white phosphorus remains at most of the locations. All locations first sampled in 2004 showed a decrease in WP concentrations. These results indicate that remediation of the surface sediments of the marsh is feasible, but more drying seasons are needed to decontaminate the surface sediments.

Figure III-2-15. Aerial oblique view in May 2005 looking south over the pond complex (Duck Ponds) in the SE corner of Area BT. Ponds were drained by a network of shallow ditches in July 2004. The numbers are sample identification numbers replacing XX in 04DISXX in Table III-2-1.

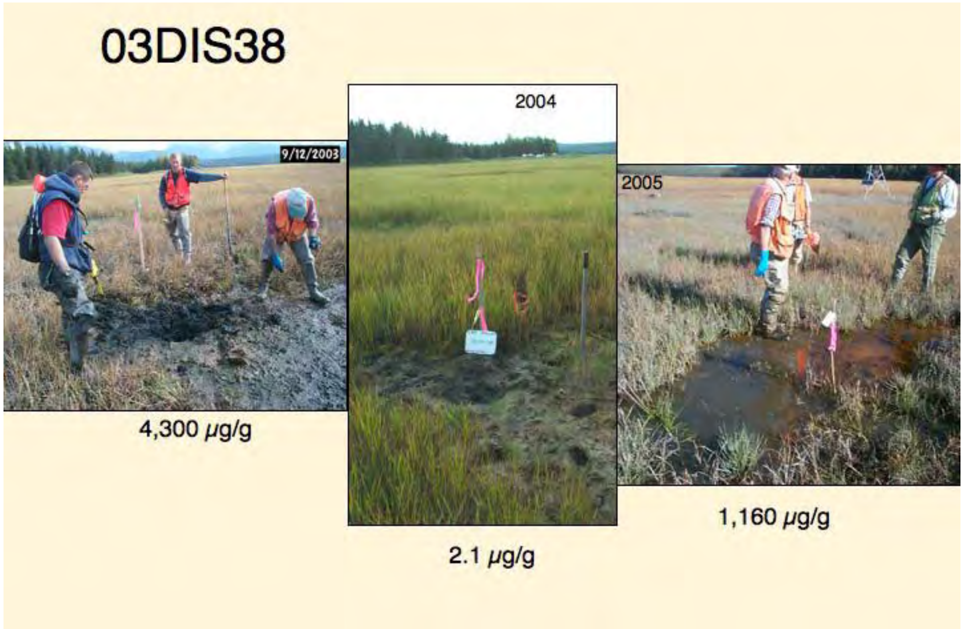


Figure III-2-16. Ground view of a discrete sample location within the Area C marsh where significant concentrations of white phosphorus persist.

CONCLUSIONS

Sublimation/oxidation conditions were excellent in June and July 2005 in Ponds 146 and 171, where losses from planted white phosphorus particles were 100% and 97%, respectively, for these two ponds. Sublimation/oxidation conditions were marginal for Area C Pond 155 and the eastern side of Area BT, but some decontamination was evident. Fortunately, the blow-in-place detonations in August 2004 of WP-filled projectiles did not recontaminate the nearby large waterfowl feeding ponds. However, the Area C Marsh still has lethal quantities of WP, especially in parts of the drainage ditches.

Based on the predicted tide cycles, 2006 and 2007 have the greatest number of days between flooding tides than any of the active remediation years (1998 to 2003). Consequently, decontamination of much of the remaining surface sediments in the marsh of Area C and in Area BT (Figure III-2-17) is possible prior to capping of the remaining contaminated pools. To minimize the amount of capping material, sampling will be needed to define the boundaries of the locations that need treatment. Landmarks will need to be established that will be exposed when there is an ice cover. The vertical distribution of white phosphorus within the drainage ditches also needs to be defined to determine if the ditches need to be completely or partially refilled.

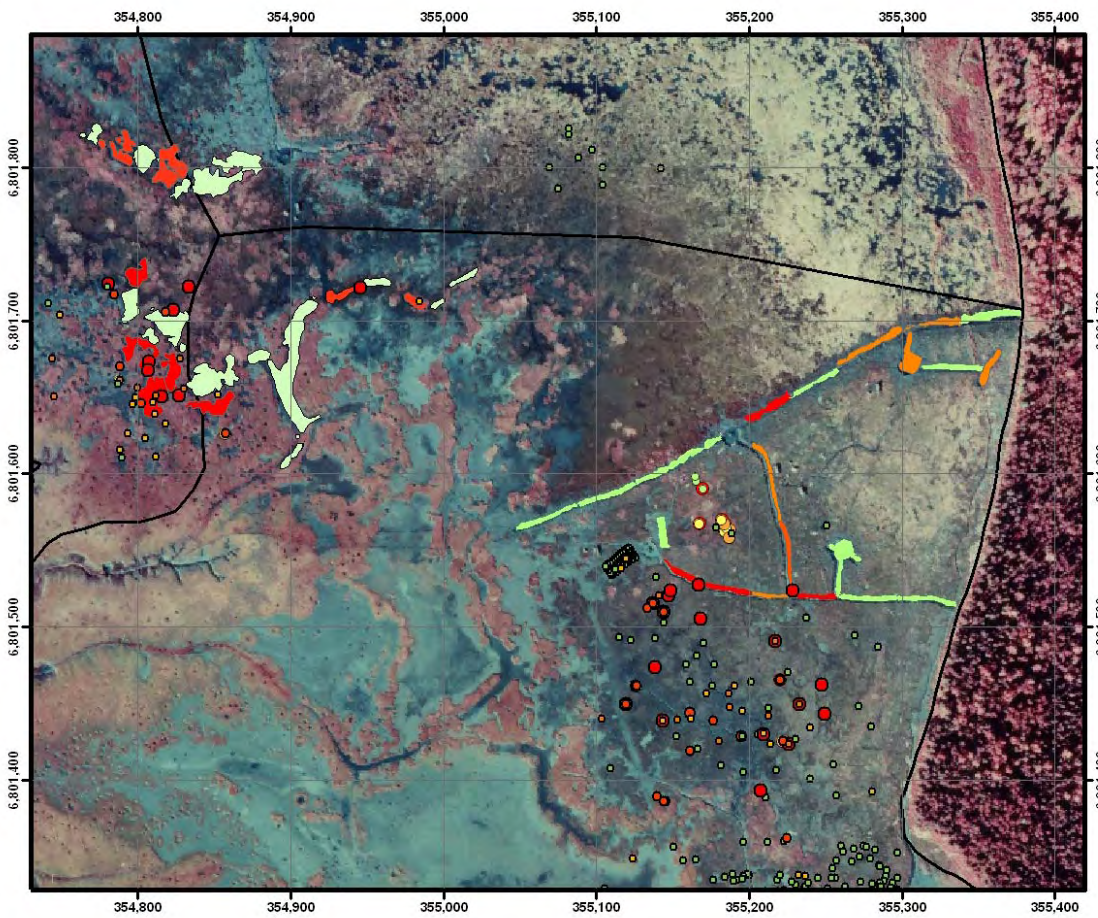


Figure III-2-17. Aerial photo depicting ponded areas where white phosphorus was detected (red or orange) or not detected (green) in 2003 to 2005. Also shown are locations of discrete samples (red: 10 to 100,000 µg/g; orange: 1 to 10 µg/g; yellow: detection limit to 1 µg/g; green not detected).

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III-3. 2005 WEATHER DATA FOR EAGLE RIVER FLATS

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INTRODUCTION

Weather, a major parameter affecting success of the remediation process in Eagle River Flats, is one we cannot control. Other parameters affecting success are the water levels in the ponds, which we can control with the automated pump systems, and flooding from the tides, which we are partially able to control with tide gates we have installed at the heads of a number of the tidal gullies. A meteorological data station was first installed at the edge of the EOD pad in May 1994 (Haugen 1995), and a standard suite of meteorological data including air temperature, wind speed and direction, radiation, precipitation, and evaporation has been collected every summer since then to support the remediation site investigation and the subsequent site remediation in Eagle River Flats. In 1998, the meteorological station was revamped with a new, higher 4-m tower and updated sensors and data collection procedures. In 1998 and 1999, a cell phone connection was used to download the meteorological data automatically on a daily basis to a computer in CRREL-Hanover. However, poor cell phone connections prevented reliable transfer of the data. From 2000 to 2003, we used a radio modem to link the meteorological station to a relay station at Route Bravo Bridge. At the relay station a telephone modem transfers data via an FTS telephone line to the computer server in Hanover. This connection was also subject to periodic disruptions. Finally, starting in 2004, we have used a wireless connection between the meteorological station and an Ethernet RF modem base station at Building 724 to transmit data and transfer it by the Corps network. The meteorological data are posted daily on the Eagle River Flats web page (www.crrel.usace.army.mil/erf), linked to the CRREL public web site, allowing interested personnel to check on-site conditions on a regular basis from off site.

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 an 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-m 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, consisting of a CR10 Measurement and Control Module and a SM716 Storage Module. All meteorological data collected for the season are stored on the storage module. Also mounted in the enclosure is a radio modem for communicating between the met station and the Ethernet RF modem base station at Building 724. The radio antenna is attached to the top of the tower. A wind-shielded precipitation gage is located 5 m east of the tower. A second backup unshielded precipitation gage is located nearby. 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, which is 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 EOD pad in Area C. Note the 4-m tower in right center, the evaporation pan to the right, and the shielded rain gage to the left.

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	Tipping bucket 15-min precipitation (mm) Tipping bucket total daily precipitation (mm)
Druck 357/D pressure transducer	Evaporation pan water level 15-min sample

RESULTS

The meteorological station collected data this year between 15 May and 15 September 2005. Station reliability was good throughout the season.

Table III-3-2 summarizes the 2005 Eagle River Flats weather data. Monthly average temperatures at Eagle River Flats are compared with this season's monthly temperatures and long-term normal temperatures at the National Weather Service (NWS) station in Anchorage. The NWS Anchorage data are presented along with the Eagle River Flats data because we have no long-term average data for the Eagle River Flats site. Monthly total rainfall for Eagle River Flats and Anchorage are also shown, along with normal monthly rainfall for Anchorage. Temperatures at Eagle River Flats were normal to slightly above normal throughout the summer remediation season between mid May and mid September.

Figure III-3-2 plots the maximum, minimum, and average air temperatures for the summer. From mid May through mid September 2005, 58 days experienced maximum temperatures of 20°C or more: one day in May, 18 in June, 24 in July, and 15 in August. This is fewer than last year, when ERF had

Table III-3-2. Monthly summary of temperature and precipitation for Eagle River Flats and Anchorage, showing the 2005 monthly (or partial monthly) average temperatures for both sites, the normal monthly average temperatures for Anchorage, the monthly total measured precipitation for ERF, and the monthly total and normal average precipitation for Anchorage

	Average Temperature (°C)			Rainfall (mm)		
Period	ANC normal	ANC 2005	ERF 2005	ANC normal	ANC 2005	ERF 2005
May	8.2	9.5	–	17.8	12.7	–
15–31 May	9.8	9.8	10.0	8.6	7.6	7.1
June	12.6	13.2	13.8	26.9	20.6	19.1
July	14.7	15.1	15.8	43.2	26.2	50.3
August	13.5	13.6	14.3	74.4	87.4	62.0
1-15 Sept	9.0	10.0	10.6	38.1	85.1	66.5
Sept	8.5	9.2	–	72.9	116.1	–.

67 days with a maximum temperature over 20°C, but still more than normal. ERF experienced 48 days with a maximum temperatures over 20°C in 2003, 42 in 2002, 39 in 2001, and 38 in 2000, all of which were also good drying years (Collins 2001, 2002, 2003, 2004). This contrasts with only 18 days during the summer of 1998 and 30 days during the summer of 1999. The highest temperature of the 2005 summer was 27.8°C on 12 August, which was nearly equaled by the 27.6°C on 28 June.

Precipitation was normal for the summer and above normal for the first two weeks of September, with cumulative precipitation from 15 May to 15 September of 205 mm (Fig. III-3-3). However, most of the precipitation occurred during one week at the end of July and from the third week of August onward. The largest single rainfall event of the summer was on 6 September, with 22.9 mm of rain.

Clear sunny days are indicated on the plot of average incoming and reflected short-wave radiation (Fig. III-3-4) when incident radiation levels are above 300 W/m^2 in May, 350 in June and July, and 200 in September. There were 6 such days in May, 10 in June, 4 in July, 12 in August, and 2 in September. This summer had fewer long blocks of clear sunny days compared to the last few summers. The longest period of clear sunny days was from 4-13 August.

Finally, the good drying conditions throughout most of the season can be seen in the cumulative evaporation data from the evaporation pan (Fig. III-3-5). Evaporation was consistent through the season until steady rains began in mid August.

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

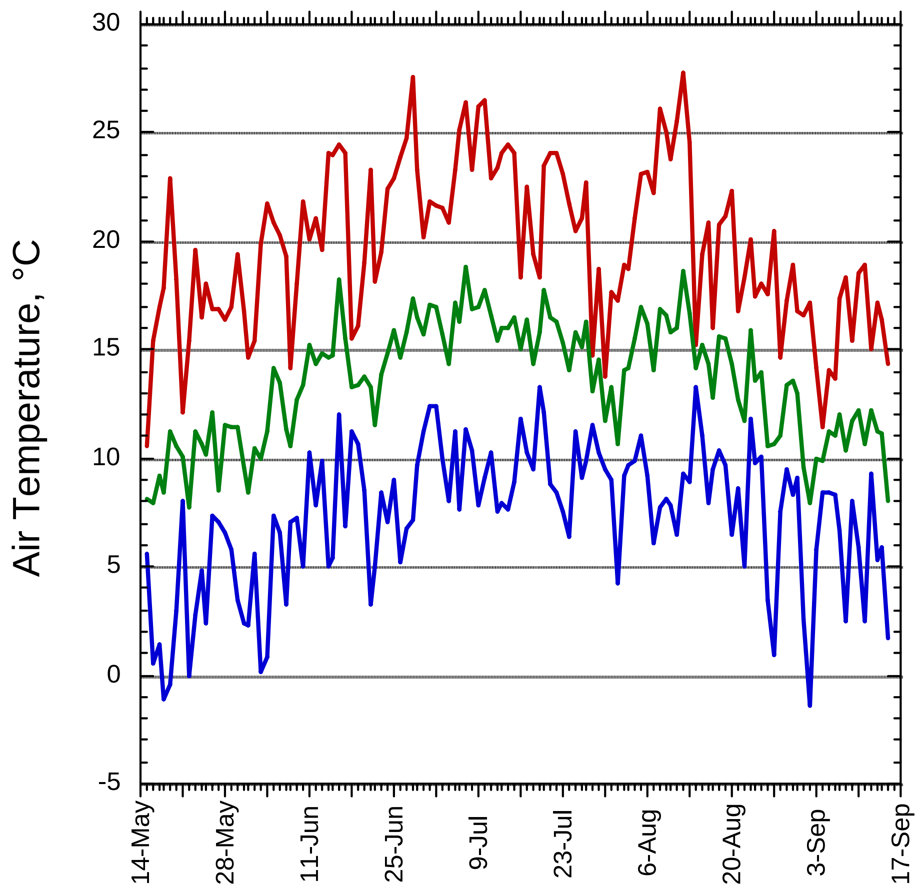

Figure III-3-2. Maximum (red), minimum (blue), and average (green) air temperatures for the Eagle River Flats meteorological station from 15 May to 15 September 2005. The season had normal temperatures with 58 days having maximum temperatures of 20°C or more. The two warmest days were 12 August (maximum temperature 27.8°C) and 28 June (maximum temperature 27.6°C).

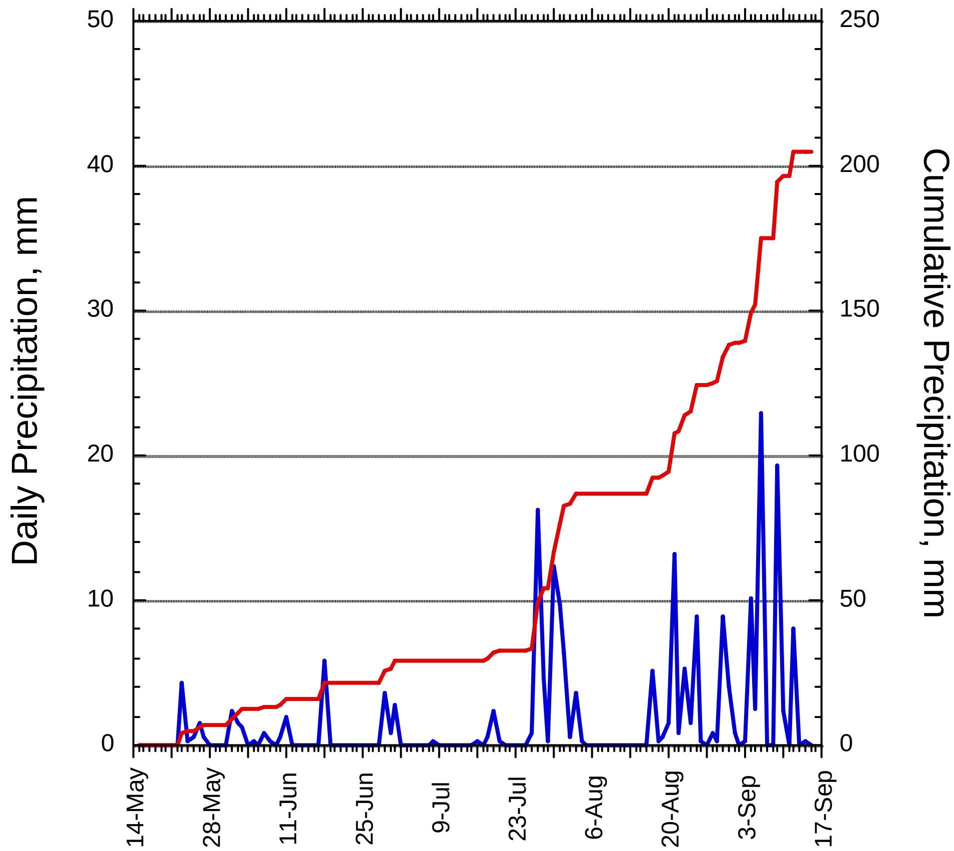

Figure III-3-3. Daily (blue) and cumulative (red) precipitation at the ERF meteorological station for the season from 15 May to 15 September 2005. Cumulative precipitation measured during the season was 205 mm, above normal. However, most of the precipitation occurred during one week at the end of July and from the third week of August onward.

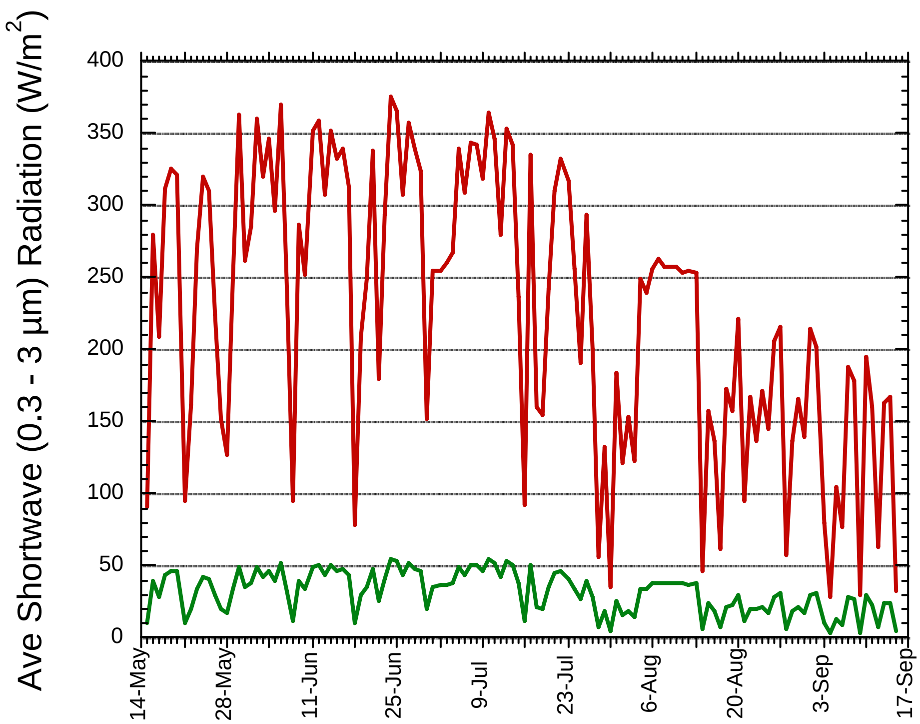

Figure III-3-4. Average incoming (red) and reflected (green) shortwave radiation (0.3 to 3 µm) for the season from 15 May to 15 September 2005 at the ERF meteorological station. There were fewer long blocks of clear sunny days this summer as compared to the last few summers. The longest period of clear sunny days was from 4-13 August.

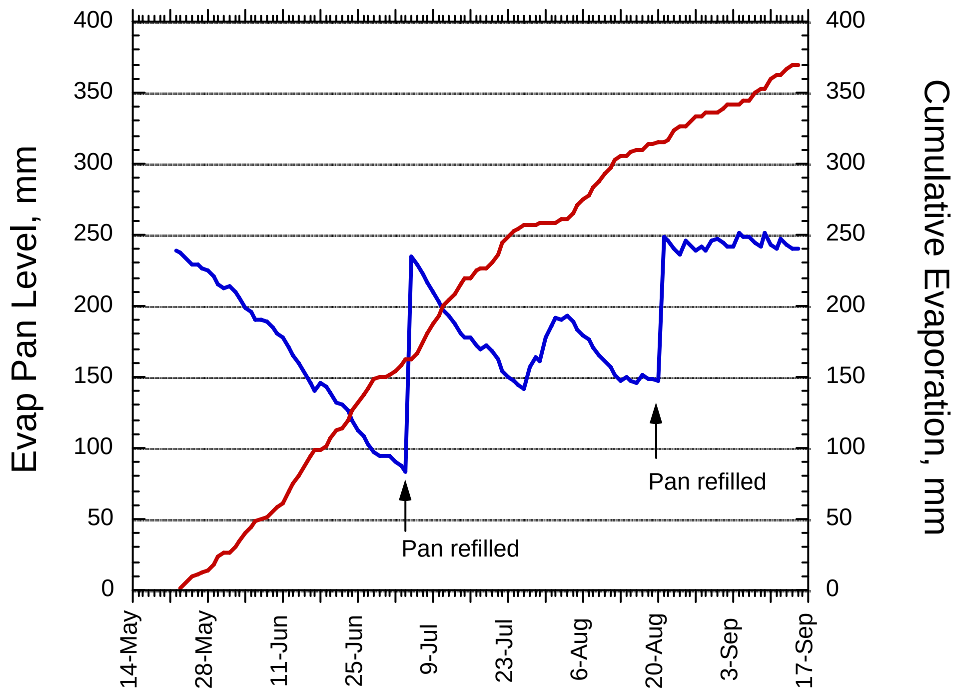

Figure III-3-5. Evaporation pan data showing the evaporation pan water level data (blue) and the net cumulative evaporation (red) for the season. The evaporation rate is consistent over the season, reflecting the normal to slightly above normal temperatures. Evaporation pan water levels show decreases due to evaporation, the addition of make-up water on 5 July and 21 August, and increases due to major rain events on 27 July–3 August, and steady rains from 21 August–12 September.

Table III-3-3. Daily climatic data for Eagle River Flats meteorological station during May–September 2005.

Date	Air temperature (°C)			Precip. (mm)	Wind speed (m/s)		Ave Radiation (W/m^2)	
	Max	Ave	Min		Ave	Max	Incident	Reflected
15-May	10.6	8.1	5.6	0.0	1.2	4.6	90	10
16-May	15.4	7.9	0.5	0.0	1.4	5.2	280	40
17-May	17.0	9.2	1.4	0.0	1.1	4.4	209	28
18-May	17.9	8.4	-1.1	0.0	1.5	5.1	312	44
19-May	22.9	11.2	-0.4	0.0	1.4	4.9	326	46
20-May	18.2	10.6	3.0	0.0	2.2	6.8	321	47
21-May	12.1	10.1	8.0	0.0	0.4	2.9	95	10
22-May	15.4	7.7	0.0	0.0	0.6	3.4	162	20
23-May	19.6	11.2	2.8	4.3	1.0	4.9	270	34
24-May	16.5	10.7	4.8	0.3	1.3	5.8	319	42
25-May	18.0	10.2	2.4	0.5	1.0	4.6	311	41
26-May	16.9	12.1	7.4	1.5	0.7	4.6	224	30
27-May	16.9	8.5	7.1	0.5	0.9	4.8	153	19
28-May	16.4	11.5	6.6	0.0	0.6	4.2	127	17
29-May	17.0	11.4	5.8	0.0	1.2	7.7	250	34
30-May	19.4	11.4	3.5	0.0	1.5	7.7	364	49
31-May	16.8	9.6	2.4	0.0	1.2	5.4	262	35
1-Jun	14.6	8.4	2.3	2.3	0.9	6.7	285	37
2-Jun	15.4	10.5	5.6	1.5	0.8	4.2	361	49
3-Jun	19.9	10.0	0.2	1.3	0.9	5.4	320	43
4-Jun	21.7	11.2	0.8	0.0	0.8	7.9	347	47
5-Jun	20.9	14.2	7.4	0.3	1.0	6.3	297	40
6-Jun	20.3	13.5	6.6	0.0	1.0	8.2	370	52
7-Jun	19.3	11.3	3.3	0.8	1.0	6.3	244	33
8-Jun	14.2	10.6	7.1	0.3	0.5	2.5	95	12
9-Jun	18.0	12.7	7.3	0.0	1.2	4.7	287	40
10-Jun	21.8	13.4	5.0	0.5	0.8	5.1	252	34
11-Jun	20.1	15.2	10.3	2.0	1.2	6.4	351	49
12-Jun	21.1	14.4	7.8	0.0	1.0	5.0	359	50
13-Jun	19.6	14.8	9.9	0.0	1.5	6.2	307	43
14-Jun	24.1	14.6	5.0	0.0	1.0	4.3	352	50
15-Jun	24.0	14.7	5.4	0.0	1.1	4.7	332	46
16-Jun	24.5	18.2	12.0	0.0	1.2	5.0	340	48
17-Jun	24.1	15.5	6.9	0.0	1.1	4.6	313	44

Table III-3-3 (cont.). Daily climatic data for Eagle River Flats meteorological station during May–September 2005.

Date	Air temperature (°C)			Precip. (mm)	Wind speed (m/s)		Ave Radiation (W/m^2)	
	Max	Ave	Min		Ave	Max	Incident	Reflected
18-Jun	15.5	13.3	11.2	5.8	0.7	6.3	78	10
19-Jun	16.1	13.4	10.7	0.0	2.0	6.9	209	29
20-Jun	19.0	13.8	8.5	0.0	1.6	6.1	250	36
21-Jun	23.3	13.3	3.3	0.0	0.9	4.7	338	48
22-Jun	18.1	11.5	5.0	0.0	0.5	3.9	180	25
23-Jun	19.5	13.9	8.4	0.0	1.0	4.6	294	42
24-Jun	22.4	14.8	7.1	0.0	1.4	5.3	376	55
25-Jun	22.9	15.9	9.0	0.0	1.2	4.6	366	53
26-Jun	23.9	14.6	5.2	0.0	0.8	4.0	308	44
27-Jun	24.8	15.8	6.8	0.0	1.0	4.6	357	52
28-Jun	27.6	17.4	7.2	0.0	1.1	7.2	340	48
29-Jun	23.3	16.5	9.7	3.6	1.4	5.4	324	47
30-Jun	20.2	15.7	11.2	0.8	0.5	4.2	152	21
1-Jul	21.8	17.1	12.4	2.8	0.7	4.3	255	36
2-Jul	21.6	17.0	12.4	0.0	1.2	4.9	255	37
3-Jul	21.5	15.7	10.0	0.0	1.1	5.6	261	37
4-Jul	20.9	14.4	8.0	0.0	1.0	4.2	268	38
5-Jul	23.3	17.2	11.2	0.0	1.1	4.5	339	49
6-Jul	25.1	16.3	7.6	0.0	1.0	7.9	309	44
7-Jul	26.4	18.8	11.3	0.0	0.7	5.4	344	51
8-Jul	23.3	16.9	10.4	0.3	1.3	5.4	342	50
9-Jul	26.2	17.0	7.8	0.0	0.9	4.4	319	47
10-Jul	26.5	17.8	9.1	0.0	1.4	6.9	365	55
11-Jul	22.9	16.6	10.3	0.0	1.1	5.4	347	52
12-Jul	23.4	15.4	7.5	0.0	1.3	9.9	280	42
13-Jul	24.1	16.0	7.9	0.0	0.7	5.4	354	54
14-Jul	24.5	16.0	7.6	0.0	0.7	4.4	342	51
15-Jul	24.1	16.5	8.9	0.0	0.8	4.8	237	38
16-Jul	18.3	15.0	11.8	0.3	0.3	3.0	93	12
17-Jul	22.5	16.4	10.3	0.0	1.1	5.9	336	50
18-Jul	19.4	14.4	9.5	0.5	0.7	3.8	160	22
19-Jul	18.3	15.8	13.3	2.3	0.6	3.4	155	20
20-Jul	23.5	17.8	12.1	0.3	0.4	4.5	242	35
21-Jul	24.1	16.5	8.8	0.0	1.3	8.4	310	46

Table III-3-3 (cont.). Daily climatic data for Eagle River Flats meteorological station during May–September 2005.

Date	Air temperature (°C)			Precip. (mm)	Wind speed (m/s)		Ave Radiation (W/m^2)	
	Max	Ave	Min		Ave	Max	Incident	Reflected
22-Jul	24.1	16.3	8.4	0.0	1.0	5.4	332	46
23-Jul	23.1	15.3	7.5	0.0	1.1	5.2	317	41
24-Jul	21.7	14.1	6.4	0.0	0.8	5.3	257	35
25-Jul	20.5	15.8	11.2	0.0	0.7	5.6	191	26
26-Jul	21.1	15.1	9.1	0.8	0.8	4.4	294	40
27-Jul	22.7	16.3	9.9	16.3	0.9	5.0	201	28
28-Jul	14.7	13.1	11.5	4.6	0.1	2.6	56	7
29-Jul	18.7	14.5	10.3	0.3	0.4	3.2	132	18
30-Jul	13.8	11.7	9.5	12.4	0.2	2.2	35	4
31-Jul	17.7	13.3	9.0	9.7	0.2	3.8	184	26
1-Aug	17.3	10.7	4.2	6.4	0.2	3.5	121	16
2-Aug	18.9	14.1	9.2	0.5	0.3	3.3	154	19
3-Aug	18.7	14.2	9.7	3.6	0.3	3.0	123	15
4-Aug	21.1	15.5	9.9	0.3	0.6	3.7	249	34
5-Aug	23.1	17.0	11.0	0.0	0.6	4.5	239	34
6-Aug	23.2	16.2	9.2	0.0	0.9	5.4	256	37
7-Aug	22.2	14.1	6.1	0.0	0.7	4.4	263	38
8-Aug	26.1	16.9	7.7	0.0	0.8	4.3	257	38
9-Aug	25.0	16.6	8.1	0.0	0.9	4.1	258	38
10-Aug	23.8	15.8	7.8	0.0	0.7	3.8	258	38
11-Aug	25.5	16.0	6.5	0.0	0.8	3.8	254	38
12-Aug	27.8	18.6	9.3	0.0	0.7	3.7	254	37
13-Aug	24.6	16.7	8.9	0.0	0.8	4.0	253	38
14-Aug	15.2	14.2	13.3	0.0	0.4	2.8	46	6
15-Aug	19.4	15.2	11.0	0.0	0.8	3.7	158	24
16-Aug	20.9	14.4	7.9	0.0	0.2	3.2	136	19
17-Aug	16.0	12.8	9.5	5.1	0.1	2.5	62	7
18-Aug	20.8	15.6	10.4	0.3	0.2	2.4	172	22
19-Aug	21.2	15.5	9.7	0.5	0.8	4.6	158	23
20-Aug	22.3	14.4	6.5	1.5	0.7	4.2	221	30
21-Aug	16.8	12.7	8.6	13.2	1.4	6.1	95	12
22-Aug	18.3	11.7	5.0	0.8	0.9	6.9	167	20
23-Aug	20.1	15.9	11.8	5.3	3.4	12.5	136	20
24-Aug	17.5	13.6	9.8	1.5	0.5	3.9	171	22

Table III-3-3 (cont.). Daily climatic data for Eagle River Flats meteorological station during May–September 2005.

Date	Air temperature (°C)			Precip. (mm)	Wind speed (m/s)		Ave Radiation (W/m^2)	
	Max	Ave	Min		Ave	Max	Incident	Reflected
25-Aug	18.0	14.0	10.1	8.9	0.1	3.3	144	18
26-Aug	17.6	10.6	3.5	0.3	0.5	5.0	206	29
27-Aug	20.5	10.7	0.9	0.0	0.4	2.6	216	31
28-Aug	14.6	11.0	7.5	0.8	0.1	3.2	58	7
29-Aug	17.3	13.4	9.5	0.3	0.7	6.2	137	19
30-Aug	18.9	13.6	8.3	8.9	0.4	2.8	166	22
31-Aug	16.8	13.0	9.1	4.1	0.5	5.5	139	18
1-Sep	16.6	9.6	2.6	0.8	0.4	3.9	214	30
2-Sep	17.2	7.9	-1.4	0.0	0.7	4.1	202	31
3-Sep	14.2	10.0	5.8	0.3	0.6	4.6	80	10
4-Sep	11.4	9.9	8.4	10.2	0.3	3.1	28	3
5-Sep	14.1	11.2	8.4	2.5	0.2	3.2	105	13
6-Sep	13.7	11.0	8.3	22.9	0.5	6.4	77	9
7-Sep	17.4	12.0	6.7	0.0	0.8	8.0	188	28
8-Sep	18.3	10.4	2.5	0.0	0.5	4.0	178	26
9-Sep	15.4	11.7	8.0	19.3	1.9	12.5	30	4
10-Sep	18.5	12.2	5.9	2.3	1.2	6.3	195	30
11-Sep	18.9	10.7	2.5	0.0	0.4	3.9	160	23
12-Sep	15	12.2	9.3	8.1	1.3	6.9	64	8
13-Sep	17.2	11.2	5.3	0.0	1.2	5.9	163	24
14-Sep	16.4	11.1	5.9	0.3	0.5	4.4	167	25
15-Sep	14.4	8.0	1.7	0.0	1.2	11.0	33	4

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