IV-2. EVALUATION OF AQUABLOK™ ON CONTAMINATED SEDIMENT TO REDUCE MORTALITY OF FORAGING WATERFOWL

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INTRODUCTION

For 50 years the U.S. Army has used Eagle River Flats (ERF) of Fort Richardson, Alaska, as an impact area for explosive ordinance. In August 1981, hunters discovered large numbers of duck carcasses at ERF. On 8 February 1990, the Army suspended firing into ERF because of a correlation between waterfowl mortalities and contamination of the flats by chemical debris from ordnance (i.e. white phosphorus [WP]; Quirk 1991). In February 1991, WP ingestion was causally linked to waterfowl deaths (CRREL 1991), and efforts to reduce hazards began. One strategy to prevent ingestion of WP by ducks may be the use of physical barriers applied to the substrate.

In 1993, we evaluated the feasibility of applying two materials, ConCover™ (recycled paper mulch [99%] and polymers [1%]) and AquaBlok™ (calcium bentonite/organo clays, gravel and polymers), to provide a physical barrier to foraging waterfowl. Laboratory trials were performed to determine if either

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product would stand up to field trials. Visual inspections during laboratory trials, indicated that the ConCover™ was immediately penetrated by the water and readily torn up by mallard (*Anas platyrhynchos*) activity. In contrast, daily inspections of the AquaBlok™ indicated it appeared to maintain its structure under duck use. Therefore, the AquaBlok™ was used in the pilot study.

The pilot study was conducted from 14 to 30 June 1993 at ERF. During the pretreatment all of the mallards died in the control (six) and half of the mallards died in the AquaBlok™ (three) pen within the first six days. During the post-treatment (six days), all of the control (six) mallards and none of the AquaBlok™ mallards died. Observations of the AquaBlok™ 42 days post-application indicated that algae was growing on it. During a follow-up trial 6–13 August, more control than treated ducks died up to 55 h of exposure. However, there were no differences in mortality after 70 h. Removal of the plastic panels surrounding the enclosure was believed to have allowed contaminated sediment to migrate on top of the barrier and probably explains these results.

Because the posttreatment period of the 1993 pilot study was successful, a definitive study was conducted in 1994. Our objectives were to evaluate the stability of AquaBlok™ when applied to an isolated pond up to 0.5 ha in size and to measure its effects on waterfowl foraging behavior and mortality. Two ponds, one in Area C and one on Racine Island, were selected based upon WP concentrations in the sediment and because treating the Racine Island pond would not interfere with other research activities. The pond in Area C was used as the control and the pond in Racine Island was treated with about 141,200 kg of AquaBlok™. During pretreatment, 23 mallards died in the control pen and 15 died in the treated pen over 10 days; during posttreatment, 24 mallards died in the control pen and 3 mallards died in the treated pen over 20 days. It was suspected that unevenly covered craters were responsible for the three mortalities observed in the treated pen. Foraging observations indicated that during pretreatment, the mallards in the treated pen fed more than those in the control pen. However, control ducks fed more frequently posttreatment.

ERF falls under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process because of its designation as a Superfund site. Potential remediation actions that will interrupt the exposure pathway, as presented in the Conceptual Site Model (CH2M HILL 1994), need to be investigated. This will generate data that can be used in feasibility studies to determine their efficacy as remediation strategies. Subsequently we are continuing to evaluate AquaBlok™ as per the ERF Task Force recommendations on data needs. Our objective in 1995 was to continue to evaluate the effectiveness of the 1994 AquaBlok™ application. Our hypothesis was that the frequency of mortality observed on Racine Island before the 1994 treatment was the same as observed in 1995. Vegetative recovery was an issue that needed to be examined because the application of the AquaBlok™ appeared to mechanically destroy the vegetation. Follow-up was important to determine if the vegetation could reestablish on the barrier. Another issue was to determine if WP could migrate into the AquaBlok™ barrier, which would reduce its effectiveness. Therefore, samples of the AquaBlok™ were sent to a contract lab for gas chromatographic analysis. A third issue was if ice would impact the barrier, because some areas on ERF are impacted by ice heaving. Thus, we needed to measure the potential impact of ice heaving on the barrier. Finally, tide plots were constructed in two areas on ERF to measure the impacts of tide events and water actions on vertical displacement and horizontal movement of the AquaBlok™ barrier.

METHODS

Study site

Two sites on ERF were used for this study, one located in Area C and the other on Racine Island. Area C includes a single large pond (~15 ha) with a connected series of smaller ponds and inlets along the east edge of ERF (Racine

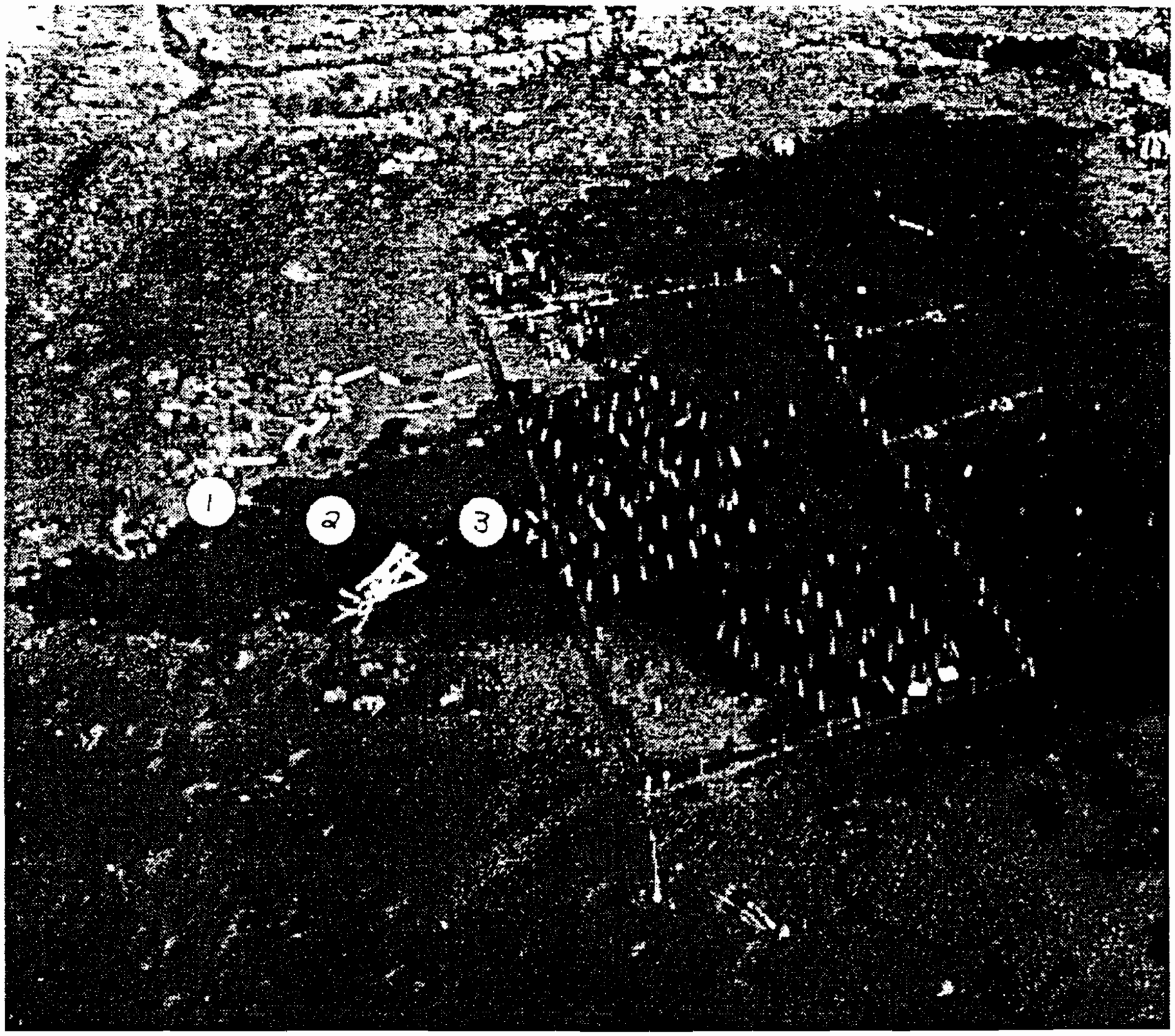

Figure IV-2-1. Area C, where the three pairs of tide plots were installed next to the 1994 control pen to measure vertical displacement and horizontal movement of AquaBlok™, 10 May through 14 September.

and Walsh 1994). A 3200-m^2 pen was used as the control pen in 1994 (Fig. IV-2-1). However, a control was not used in 1995 because distribution of WP varies widely on ERF resulting in differences in mortality in discrete areas. For example, pretreatment results in 1994 showed 96% mortality in the Area C pen compared to 62% mortality in the Racine Island pen over 10 days. This effect (34% difference) was considered to be stronger than any temporal effects that might occur. Several years of mortality data have been taken from pens in Area C to support this theory (Cummings 1993, unpublished data). However, for the

AquaBlok™ barrier to be considered effective enough to be used as a remediation action on ERF ≤5% mortality should be observed in pen studies.

In the northwest portion of the large pond in Area C we installed three pairs of tide plots (Fig. IV-2-1). One of each of the three pairs of plots was installed with a form to measure vertical movement of AquaBlok™ and one was installed without a form to measure horizontal flow of AquaBlok™.

Racine Island, which is formed by two channels of Eagle River, has a large pond formed by an old channel which is surrounded by bulrush marsh and a smaller pond to the north (Racine and Walsh 1994). The smaller pond, which has numerous water-filled impact craters associated with it, was used as the treated pen. This pen was irregularly shaped but encompassed approximately 4500 m^2 during the 1994 pretreatment and 4000 m^2 during the 1994 posttreatment. The size was reduced during the posttreatment because there was not enough AquaBlok™ to treat the farthest northwest corner of the site. The pen encompassing the pond was constructed of polypropylene netting (2-cm mesh) at a height of 2 m above the sediment. Three pairs of tide plots were installed in the northwest corner of the site (Fig. IV-2-2) as described in Area C.

Vegetative recovery

Photographs of the Racine Island pen were taken from a height of approximately 240 m during 21 July 1991, 30 August 1994 and 16 August 1995. A grid (1 × 1 cm) was placed over each photograph and the amount of each grid's vegetation was estimated. Values of all cells were added together and divided from the total of number of cells (incomplete + complete) determined to cover the pen area.

Barrier effectiveness

Water depths were measured each morning. The six stakes with stream gauges were left in place from 1994 (Pochop et al. 1994). The gauges were located inside the pen within 1 m of the netting, two in craters and four distributed

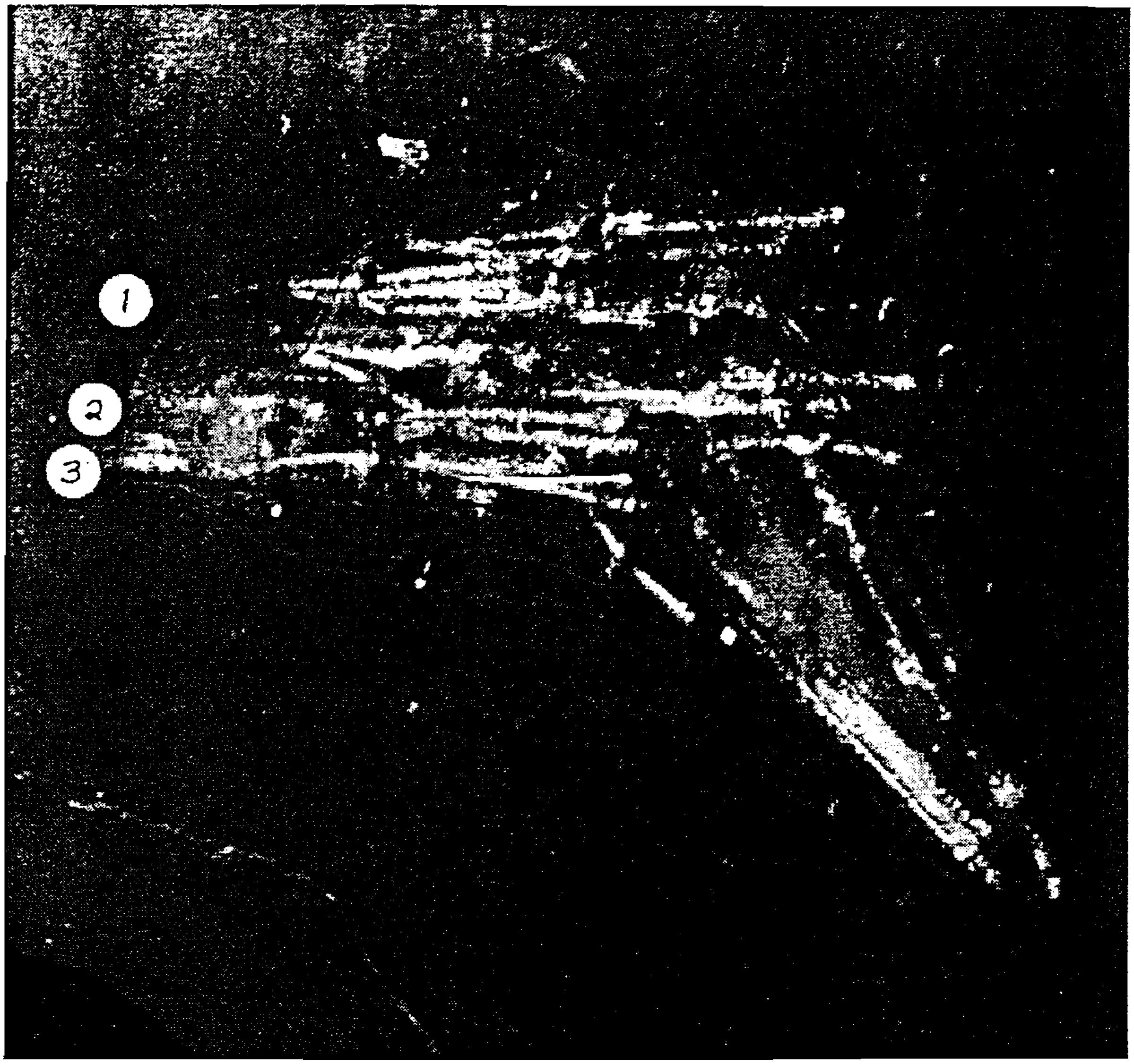

Figure IV-2-2. Racine Island pen, where the three pairs of tide plots were installed next to the 1994/1995 treated pen to measure vertical displacement and horizontal movement of AquaBlok™, 10 May through 14 September.

throughout the large pond. The stream gauges were realigned with the AquaBlok™/sediment surface before taking measurements.

Core samples were collected to determine the thickness of the AquaBlok™ application and sedimentation as described in Pochop et al. (1994).

We collected 15 AquaBlok™ samples from immediately outside or inside the pen for WP analysis; samples were collected near previous sample locations.

This involved the collection of AquaBlok™ to an approximate depth of 3 cm from a 30 cm^2 area. Any samples taken from inside the pen had new AquaBlok™ applied to the area to reduce any holes that would affect the integrity of the barrier. The sample was placed in an acid-washed 500-mL sample jar and taken to a contract lab (ChemTrack, Anchorage, AK) for gas chromatographic analysis.

Before introducing ducks into the pen, two craters believed to have been unevenly treated with AquaBlok™ via helicopter and associated with the deaths of three mallards in 1994 were again covered with AquaBlok™. In one crater, 100 kg of AquaBlok™ was applied and in the other 200 kg was applied by hovering in the helicopter about 2 m above the crater and pouring AquaBlok™ as evenly as possible throughout the crater.

To determine waterfowl mortality, 24 wing-clipped mallards were placed into the enclosed pond for 46 days. By day 3, two mallards were observed escaping from the enclosed pen. Therefore, the height of the pen was increased to about 3 m by installing new stakes (5 × 5 × 300 cm) and attaching the bottom of the new polypropylene netting to the top of the existing netting. A rope was strung tightly across the tops of the stakes and supported the top of the netting. Throughout testing, supplemental food was available *ad libitum* on two floating platforms in the pen. We conducted surveys via helicopter or foot to determine the number of live or dead mallards in the pen each day. Observations of foraging activity were not conducted because the vegetation was too tall to see the ducks feed. However, observations conducted in 1994 indicated ducks continued to sample the sediment even when supplied with supplemental food (Pochop et al. 1994). The test mallards were released to the wild from the pen on 9 August. On day 46, during the high tide, an individual on a small rubber raft was pulled throughout the pen area to determine if any carcasses were present that could not be detected using other methods.

Ice effects

Observations of the ice melt during the spring break-up indicated that the ice was melting from the top down (e.g. no heaving occurred). Therefore, no measurements or samples could be taken in or near the AquaBlok™ pen.

Tidal impacts

On May 10, three paired plots (1 × 1 m) were established on Racine Island and in Area C to measure vertical displacement and horizontal movement of AquaBlok™ as it relates to tide action. On each of the paired plots, a metal form 8 cm wide was placed around one plot so that the top of the form was even with the bottom sediment. AquaBlok™ (70 kg) was poured evenly into the plot. In the remaining plot the AquaBlok™ was applied into a form placed on top of the bottom sediment and then the form was removed. Metal stakes (0.8 cm dia. × 90 cm) were placed in the corners of the plot without the form to mark the corners of the plot. Additional metal stakes (two/corner/distance) were then placed at 90° angles at each of the corners 30 and 60 cm from the corner stake to aid in measuring horizontal flow.

Pairs of plots within each area were established at water level and at 30 and 60 cm below water level. However, this was highly dependent upon the pond bottom (i.e. the two deeper pairs of plots on Racine Island were placed in craters).

RESULTS

Vegetative recovery

The amount of vegetative cover estimated to be in the Racine Island pen in the photographs was 51.8%, 45.9% and 76.4% in 1991, 1994 and 1995, respectively (Fig. IV-2-3). Vegetation appeared to encroach into the pond area over the years the photographs represent.

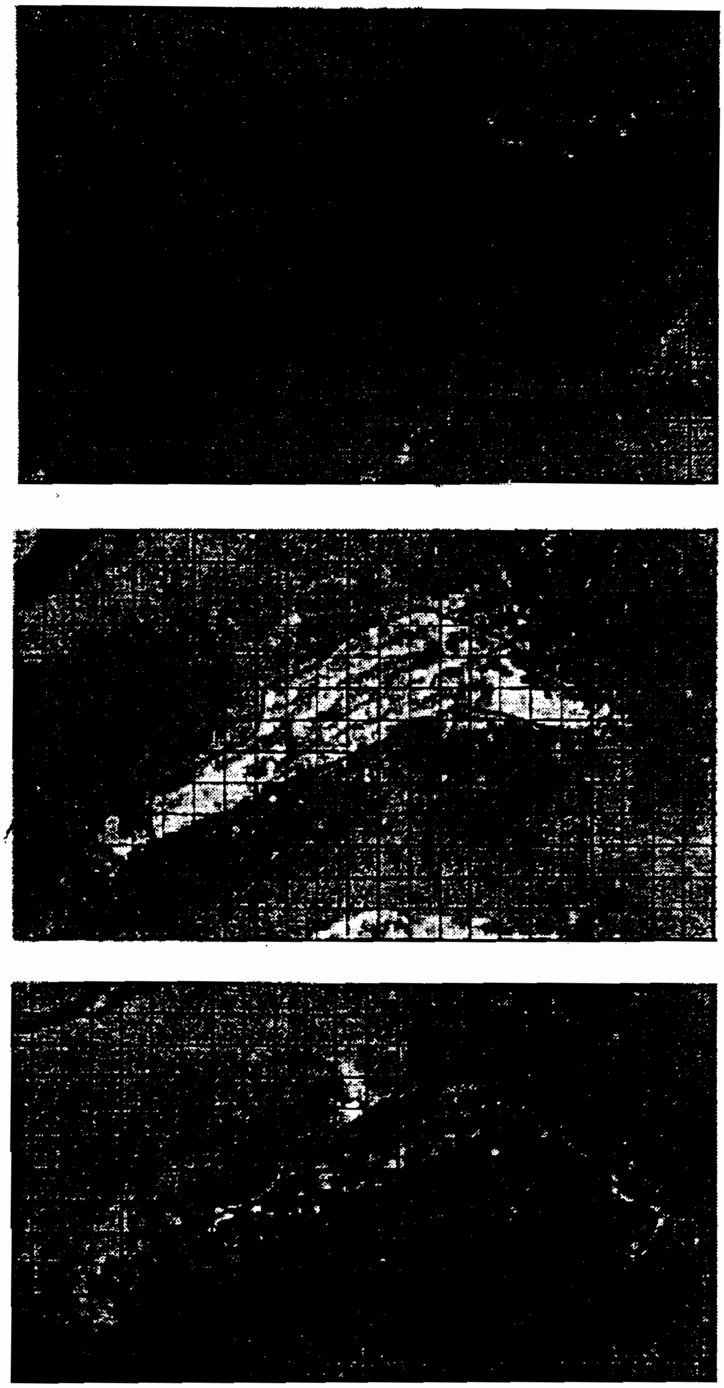

Figure IV-2-3. Racine Island pen, 21 July 1991 (top), 30 August 1994 (middle) and 16 August 1995 (bottom). A grid system similar to the one shown (each grid was approximately equivalent to a 10- × 10-m area of the pen) was used to estimate vegetative coverage.

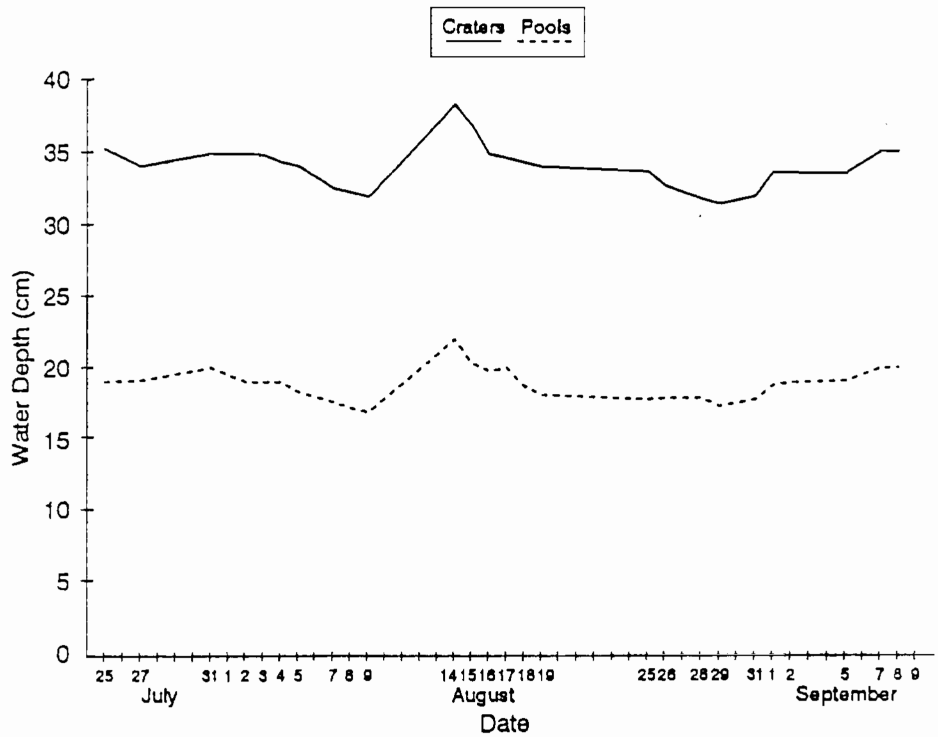

Figure IV-2-4. Water levels in the treated (Racine Island) pool, 25 July through 9 September 1995.

Barrier effectiveness

Water depths ranged from 15–25 cm in pools and from 30–40 cm in craters (Fig. IV-2-4). The pools and craters were deepest 14 August because of a flooding tide event.

WP concentrations from AquaBlok™ samples in the treated pen ranged from <MLOD to 0.02 mg/kg (mean = 0.01 ± 0.01 s.e; Table IV-2-1).

The thickness of the AquaBlok™ ranged from 3.0 to 6.7 cm over level ground (mean = 5.2 ± 0.3 s.e.) and craters appeared to be unevenly covered with the thickness ranging from 6.1 to 21.9 cm (mean = 14.5 ± 2.0 s.e.; Table IV-2-2). This indicates a reduction in the thickness of AquaBlok™ of only 0.5 cm from 1994 values. Sedimentation on top of the AquaBlok™ ranged from 0.2 to 1.1 cm (mean = 0.6 ± 0.1 s.e.).

No carcasses were found during the 46 days mallards spent in the pen. The number of ducks observed in the pen decreased from 24 to 12 after the first 600 h,

Table IV-2-1. Mean concentrations of WP in the treated (Racine Island) pool at ERF.

Date	*Concentration (mg/kg)*
5-25-95 AquaBlok™	n[1] = 9/15 mean = 0.01 s.e. = 0.01 Range = 0.01–0.02
6-21-94 Posttreatment pen	n[1,2,3] = 19/29 mean = 1.27 s.e. = 0.84 Range = 0.01–18.95
6-21-94 Pretreatment pen	n[1,2] = 24/29 mean = 1.59 s.e. = 1.06 Range = 0.01–18.95
6-8-93 (CRREL 1994)	n = 4 mean = 0.11 s.e. = 0.10 Range = 0.01–0.42

[1]Samples below Method Limit of Detection (<MLOD) were not included in mean. Number of samples used in the mean/total number of samples taken.
[2]The average of duplicate subsamples was used to calculate mean.
[3]Five samples were not included in mean because the size of the posttreatment pen was reduced.
The MLOD value was <0.01 mg WP/kg sediment.

and from 9 to 4 during the final 504 h before release (Fig. IV-2-5). Even though primaries were initially clipped, ducks were beginning to replace feathers at the start of the test. Duck disappearance was attributed to feather replacement and escape from the pen.

Tidal impacts

Vertical displacement of water by AquaBlok™ in Area C ranged from 10 to 12 cm (Fig. IV-2-6). This was the amount of swelling above the initial 8-cm thickness at which the AquaBlok™ was applied. Tide action and water currents eroded from 2 to 8 cm of AquaBlok™

Table IV-2-2. Thickness of AquaBlok™ and sedimentation from core samples taken outside of the treated (Racine Island) pen at ERF.

	Measurement (cm; mean ± s.e.)		
	1994	*1995*	
Location	*AquaBlok™*	*AquaBlok™*	*Sedimentation*
	Beginning of run		
Initial drop	~30	16.1 ± 2.1 to 24.5 ± 0.4	1.0 ± 0.3 to 1.1 ± 0.3
Dry ground	9.1 ± 0.8	4.7 ± 0.4 to 6.7 ± 0.4	0.4 ± 0.1 to 0.6 ± 0.1
Wet ground	----	5.0 ± 0.4	0.8 ± 0.4
Crater (edge)	4.6 ± 0.4 to 19.0 ± 1.3		
(bottom)	~15.2 to ~25.4	21.9 ± 1.0	0.6 ± 0.1
	Middle of run		
Dry ground	----	5.4 ± 0.5	0.6 ± 0.2
Crater (edge)	----	6.1 ± 0.6 to 15.4 ± 0.1	0.2 ± 0.1 to 0.6 ± 0.1
	End of run		
Dry ground	7.0 ± 1.3	3.0 ± 0.6	0.9 ± 0.1
Wet ground	2.7 ± 0.2 to 6.1 ± 0.3	6.2 ± 1.2	0.5 ± 0.1

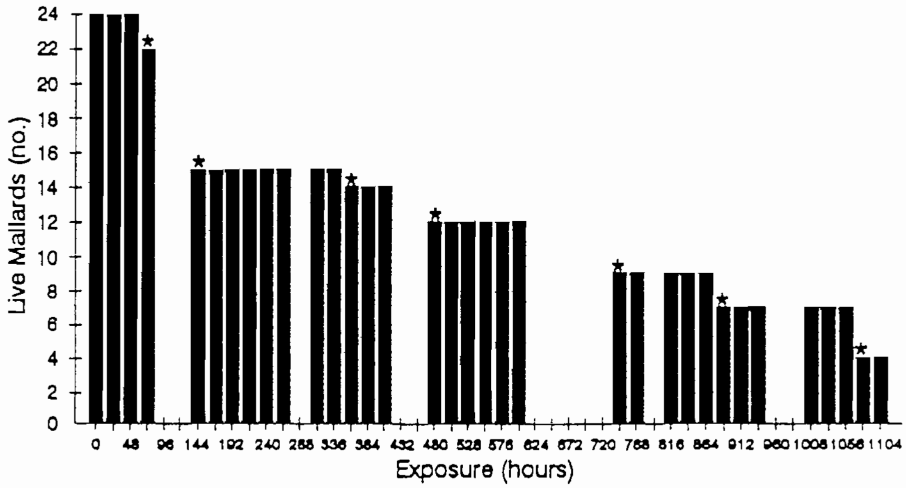

Figure IV-2-5. Counts of live mallards (n = 24) adjusted for observer error that were observed in the treated (Racine Island) pen, 25 July through 9 September 1995. The asterisk indicates that the reduced number of ducks in the pen is attributed to escaping under or flying over the perimeter fence.

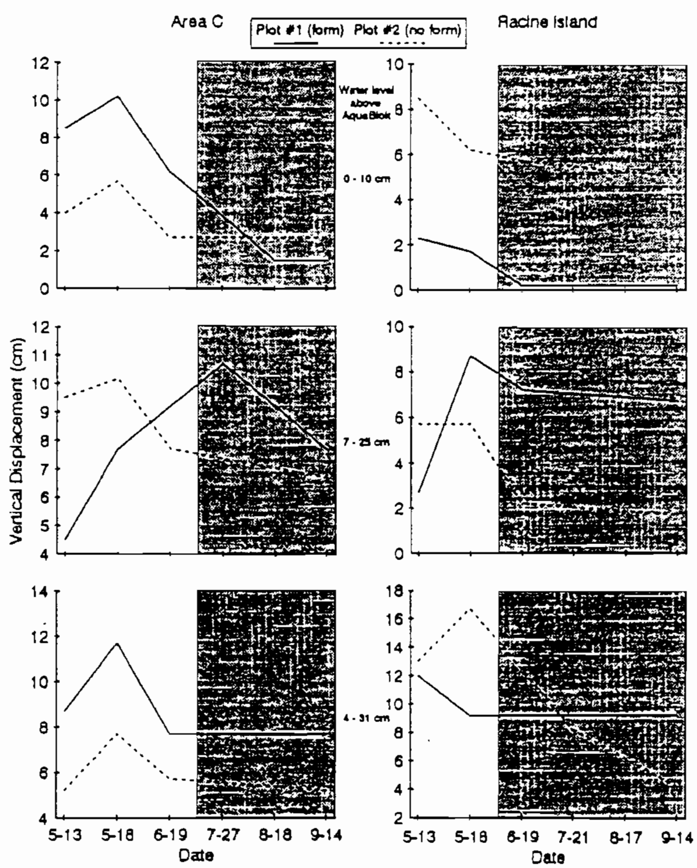

Figure IV-2-6. Vertical displacement of water and erosion of AquaBlok™ from tide plots (1 × 1 m) in Area C and on Racine Island, 10 May through 14 September 1995. Data are the amount of swelling above the initial 8-cm thickness at which the AquaBlok™ was applied. The May 13 data were collected 1–3 days after the plots were installed and before the first tide event. Plant growth (shaded area) obscured tide plots by July in Area C and by the June on Racine Island.

material in Area C over 127 days or five flooding tide cycles. On Racine Island, vertical displacement of water by AquaBlok™ ranged from 2 to 12 cm. Tide actions and water currents eroded from 2 to 3 cm of AquaBlok™ during the same period. The small amount of vertical displacement observed on Racine Island in plot #1, 0–10 cm water level above AquaBlok™ was probably due to vegetation which prevented the form being placed as far into the sediment as the other plots with forms. Plant growth obscured tide plots by July in Area C and by June on Racine Island.

Horizontal movement of the AquaBlok™, based on bentonite material only, in Area C averaged 15.8 cm (range 7–25 cm) over 127 days or five flooding tide cycles and on Racine Island averaged 10.3 cm (range 5–14 cm) during the same period (Fig. IV-2-7). Vegetation again obscured tide plots as described earlier. The movement of AquaBlok™, based on gravel, averaged 5.8 cm in Area C and 9.9 cm on Racine Island after four flooding tides.

DISCUSSION

The number of ducks observed in the pen varied for several reasons. First the type of survey (helicopter, foot or boat) affected the observers' ability to locate ducks. The most reliable censuses were conducted by helicopter. However, environmental conditions were sometimes such that helicopters could not fly and surveys had to be conducted by foot. Second, on some days ducks were simply easier to flush out of the grass to be counted than on other days. Whether this was due to variability in helicopter pilot ability or different weather conditions is unclear. Finally, some mallards escaped and some ducks were suspected of being visitors. We were able to capture one of the ducks that escaped on 28 July and confirm it was one of ours. However, other mallards observed flying out of the pen could have been wild ducks just visiting the area to feed or loaf.

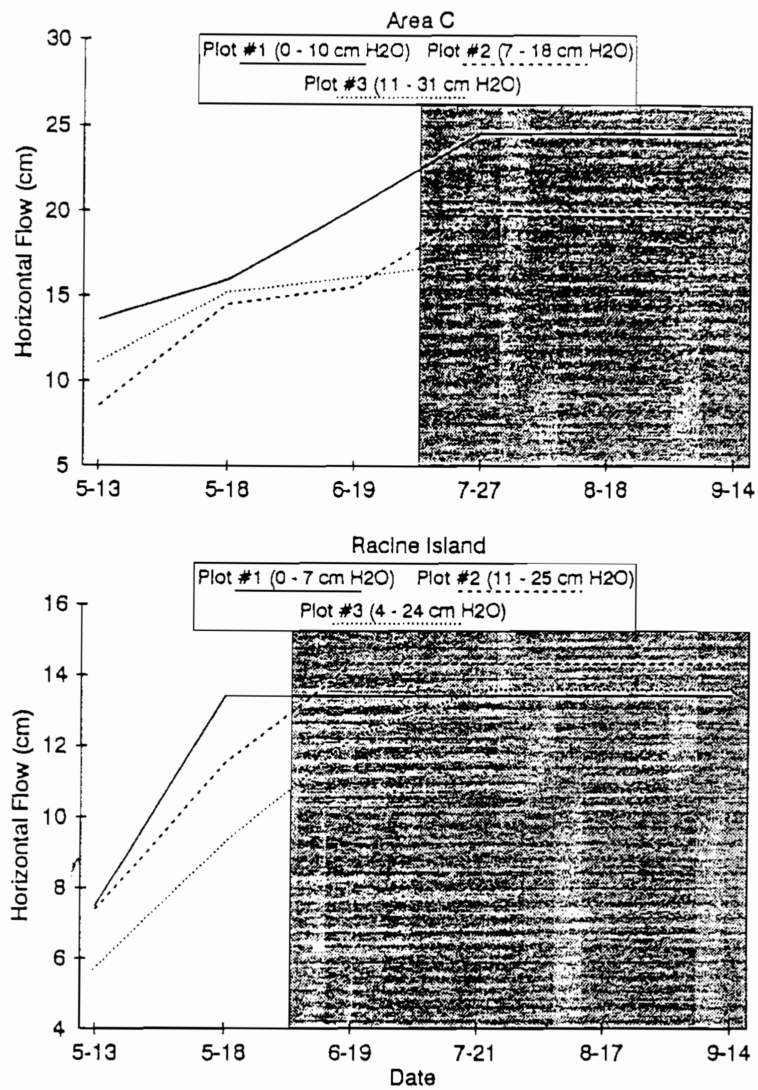

Figure IV-2- 7. Horizontal flow of AquaBlok™ from tide plots (1 × 1 m) in Area C and on Racine Island, 10 May through 14 September 1995. The May 13 data were collected 1–3 days after the plots were installed and before the first tide event. Plant growth (shaded area) obscured tide plots by July in Area C and by June on Racine Island.

We feel that the chances of a mortality occurring and it not being observed were small for several reasons. First, the pen was visited on a regular basis as it was in 1994 when all mallard carcasses were observed. Second, the occurrence of a predator picking up a carcass and removing it from the pen was not observed in any of the pen studies that were conducted on the Flats since 1992. Third, no feather piles or scavenged bones were ever found in the pen except for a fledgling yellowlegs (*Tringa* spp.), which probably got caught in the net and could not escape. Fourth, the helicopter parted the grass as it moved across the pen, making it easier to see areas in the center of the pen. Then, after counts were conducted, water levels were measured and this involved a person walking around the pen and observing the vegetation around the edge of the pen for carcasses. Finally, carcasses could not have floated away in any of the flooding tides because they would have gotten hung up in the netting of the pen.

The water levels in 1995 were similar to the levels observed during the 1994 pretreatment but were higher than the 1994 posttreatment levels. This affected the study because ducks in the 1994 posttreatment were forced to feed in the deepest areas such as craters where the potential for picking up high concentrations of WP was greatest, therefore creating a stronger test of the AquaBlok™. However, because water levels were similar to the 1994 pretreatment levels when 13 of 24 ducks died the AquaBlok™ still proved its effectiveness during a second year of exposure to weather, tide effects and water actions.

Vegetation in the Racine Island pen was lush by June 1995, and it appeared that the process used to apply the AquaBlok™ only temporarily affected the vegetation in the area. Areas where the AquaBlok™ was too thick to allow the vegetation to grow through it was beginning to show some signs of plant invasion. We expect that as sedimentation/organic matter deposition occurs more plant growth will occur on these areas.

The thickness of the AquaBlok™ in 1995 varied similarly to the thickness in 1994. The loss of material between the two years is misleading because core samples could not be taken in exactly the same locations due to loss of integrity of the barrier. For example, taking a core sample compacts the portions of the AquaBlok™ closest to the wall of the sampler, and then as the core sample is removed it expands and may even tear. Further, cores were taken from outside of the pen, where there was high human traffic so the differences observed are a worst-case scenario.

WP concentrations in the AquaBlok™ material were negligible. The concentrations that were observed were probably residue from the underlying sediment that could not be avoided in the taking of the sample. The only way to determine if a sample of AquaBlok™ was contaminated with WP in the barrier itself would be to take ice cores of the barrier and section the sample. Samples of the AquaBlok™ and underlying sediment could then be analyzed separately and the results compared.

Displacement of water by tide plots in both Area C and Racine Island were similar. The one exception (Plot #1, 0–10 cm water level above AquaBlok™) was set higher above ground than the other tide plots with forms causing the AquaBlok™ to spill over and erode quicker than the other plots. Erosion of the AquaBlok™ was greater in Area C than on Racine Island tide plots. Area C tide plots were in a large pool with little to no vegetation to protect them from tide action or water currents until late in the growing season. The Racine Island tide plots were protected by vegetation early in the growing season. Protection by vegetation is important because tide action varies between large and small ponds. High tides flow and ebb into large ponds (i.e. Area C) slowly in contrast to small ponds (i.e. Racine Island) into which tides quickly flow and ebb (Racine 1995, pers. comm.).

Horizontal movement of AquaBlok™ on Racine Island was more cohesive than in Area C. In Area C the bentonite component of AquaBlok™ moved farther than the gravel component. This was also likely a result of vegetation protecting the tide plots on Racine Island from tide action or water currents in contrast to tide plots in Area C, indicating that most of the horizontal movement of AquaBlok™ on Racine Island was probably due to normal settling. Only plot #3 (in a crater) on Racine Island continued to be affected beyond the first tide event and was only affected until the second tide event.

AquaBlok™ coverage varied but didn't break down and the movement observed was small. It reduced mortalities during the first season of application and eliminated them in the second. Vegetative growth was inhibited by the AquaBlok™ application method in the first season of application. However, in the second season vegetative growth was lush and only inhibited in areas where the AquaBlok™ application was thickest. We expect that as sedimentation and organic matter deposition progresses plant growth will also occur in those areas. Although no formal evaluation was done, fish and invertebrates were observed in areas treated with AquaBlok™.

FEASIBILITY OF USING THE AQUABLOK™ AS A REMEDIATION METHOD

Successes and limitations

AquaBlok™ has many attributes which make it an ideal covering material for ERF. Vegetation, initially knocked down by the aerial application, will eventually grow through the barrier with almost complete recovery observed by the next season. The pH under which the AquaBlok™ has been tested (pH 6 to $\leq$9) has proven to have little impact on the barrier. Further, the level of salinity which would cause the barrier to flocculate is unknown. However, if a particular area known to have an extreme pH or salinity needed to be treated, other clays similar to bentonite but known to be pH/saltwater resistant could be formulated in a compound similar to the AquaBlok™. A permeability test was conducted on the AquaBlok™ and found to be very good (10^9; Nachtman 1995, pers. comm.). In addition, no change in aggregate distribution was observed over the year that the AquaBlok™ was in place on ERF (Nachtman 1995, pers. comm.). Most importantly, AquaBlok™ was able to reduce/eliminate waterfowl mortality in the 1994/1995 tests on Racine Island. It is uncertain what amount of maintenance would need to be done on the AquaBlok™, but on Racine Island the 1994 winter/1995 spring had no measurable impact; therefore, no maintenance needed to be done (i.e. the retreatment of the two craters was related to the application).

There are also some limitations of using AquaBlok™ as a remediation method on ERF. It is unknown what can be expected in long-term effectiveness of the AquaBlok™, and this is tied to the effects of ice on the barrier. Ice plucking would most likely be the most destructive force on the AquaBlok™. The 1994 winter/1995 spring did not cause any measurable damage to the barrier; however, conditions were such that ice did not freeze deeply into the sediments which creates the conditions for ice plucking.

Data gaps

The most important piece of data that should be considered is that AquaBlok™ as a remediation method on ERF eliminates waterfowl mortality. Data gaps that are less important because inferences can be made on data already collected are whether WP can be transported into the barrier, the effects of ice on the barrier (ice plucking), impacts of salt water, maintainability, and particle size limitations in manufacturing the product. In the case of salt water, inferences can be made on sites that have similar characteristics to Racine Island and Area C where the AquaBlok™ was tested successfully. These sites would probably be appropriate to consider using AquaBlok™ as a remediation method. Further, tests are currently being conducted by the manufacturer to determine at what salt concentration the bentonite material will begin to flocculate. However, tests results will not be available for about another three months. In the case of maintainability, site history could be evaluated to give some idea on what can be expected on a site-by-site basis. Ice plucking and erosion would be the biggest issues that would affect the maintainability of the AquaBlok™, so areas known to be high risks for these two forces in the natural sediments would be lower considerations for applying the barrier. AquaBlok™ would be somewhat more resistant than the natural sediments to these forces but until it is known by how much, the barrier would be considered as susceptible as the natural sediments to evaluate it in the worst-case scenario. In the case of whether there would be a particle size limitation in formulating the AquaBlok™, the function of the gravel must be considered. The gravel acts as an anchor to help the bentonite seal to the sediments to which it is applied. The use of smaller gravel, pebbles or sand would not be recommended because the smaller particles would need more bentonite and polymers added to account for the greater surface area, thus increasing costs.

Measure of success

The most effective method to measure the effectiveness of AquaBlok™ is to conduct pen studies. Waterfowl, such as mallards, are the most effective and nondestructive samplers available. Further, an actual measure of reduction in mortality can be measured, especially when the experimental design includes both a pretreatment and posttreatment test. In areas that are larger than 0.5 ha, treated pens can be smaller than the actual pond size to sample areas where the barrier is applied. The disadvantages of conducting pen studies are trying to limit the amount of traffic on the AquaBlok™ and eliminating sample bias when pens are smaller than the treated area. If several areas on ERF are treated with AquaBlok™ and the majority of contaminated areas on the flats have been remediated then, a radiotelemetry study would become the most effective means of determining the effectiveness of the clean-up.

Where to apply AquaBlok™

AquaBlok™ can be applied to any pond in ERF (Fig. IV-2-8). However, there are some limitations in data knowledge and the product itself which should be considered. Ponds which have similar characteristics to Racine Island and Area C on ERF in which the AquaBlok™ product has been tested will make the best

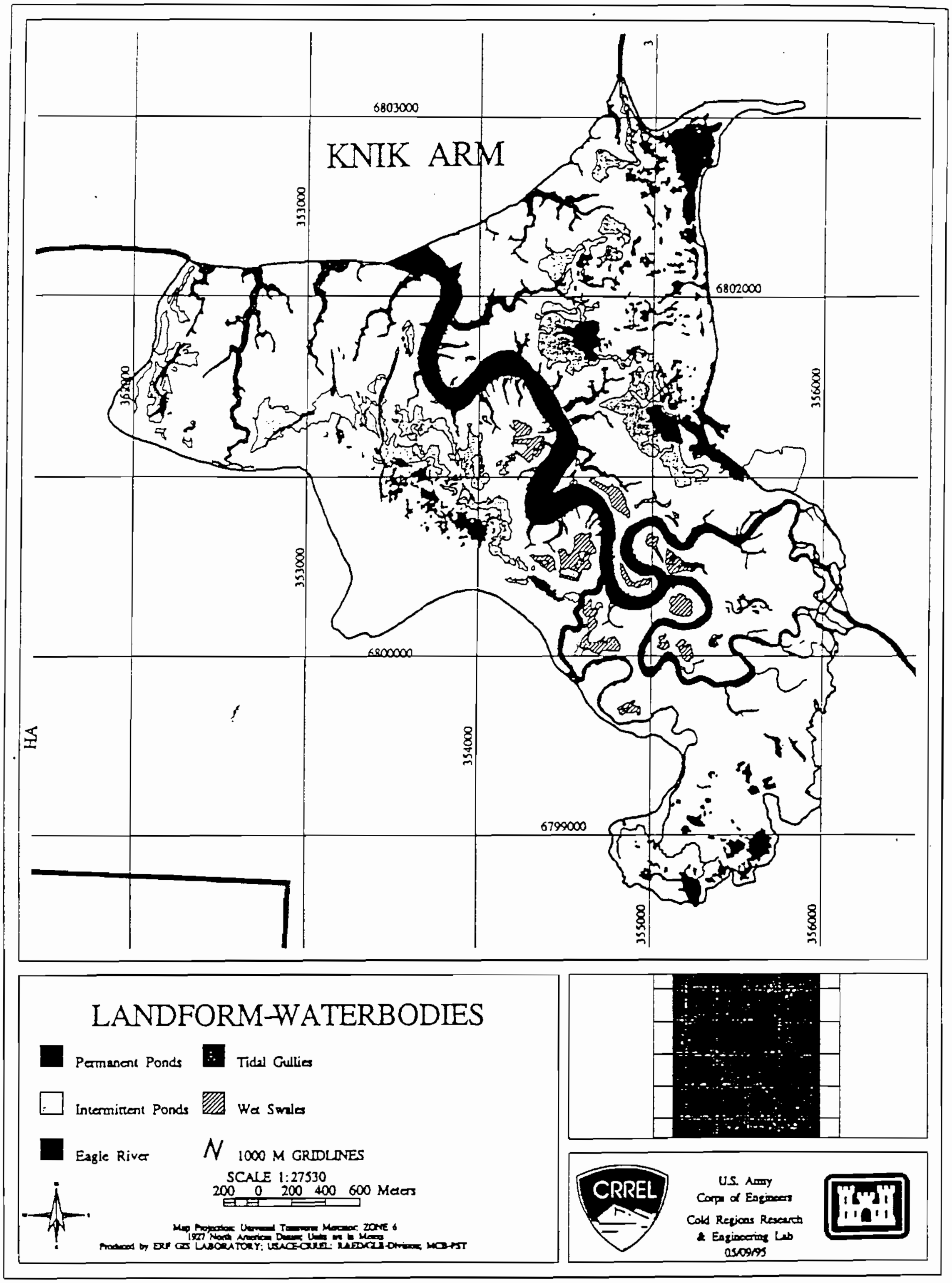

Figure IV-2-8. Possible permanent ponds that could be treated with Aqua-Blok™ as a remediation method.

candidates for treatment with this product. It is also apparent that there are certain characteristics that have not been tested but would make sense to consider when deciding to use AquaBlok™ as a treatment. Areas of low gully encroachment (≥10 years for the gully to cause the pond to drain) would be target areas because it is unknown how much damage would occur to the barrier once a gully began to drain a pond. Some areas on ERF have characteristics that would make applying AquaBlok™ the best choice, such as, any combination of the following; areas of low sedimentation, highly vegetated areas, wet areas (difficult to dry), small areas (too small to dredge).

Costs

1994/1995 study

The cost of the initial application of AquaBlok™ to the 0.5 ha used in the 1994 study was about $26,000 ($0.15/kg materials and $0.02/kg manufacturing). This cost did not include the gravel (supplied by the U.S. Army), labor (two U.S. Army personnel to operate heavy equipment) or application ($1,616/h Blackhawk helicopter for a total of 9 h to apply the AquaBlok™, UH1 helicopter 1.5 h support at $463/h, supplied by the U.S. Army). Also, NewWaste Concepts personnel oversaw the production (Product Quality Control) and contributed labor to the study project at no cost to the U.S. Army. It cost an additional $1,350 ($4.50/kg materials, manufacturing and labor) to treat the two craters in 1995 that were unevenly covered from the previous year's application. This additional cost did not include the 0.5 h of UH1 helicopter ($547/h, supplied by the U.S. Army) time and labor (provided by DWRC) used to apply the AquaBlok™.

The costs associated with the 1994/1995 study are reasonable estimates of what it would cost the U.S. Army to treat small areas (≤0.5 ha) on ERF. To treat larger areas on ERF (>1 ha) a cost assessment would need to be conducted. This is primarily because a cement mixer ($400/day) would not be able to handle the larger production needed to treat large areas. A machine would need to be built to handle the production of the AquaBlok™. At this point the manufacturer has a prototype that could be developed, but actual development would need a commitment from one of the companies currently using the manufacturer's products to spread out development costs. Also, factors that need to be considered before treating large areas are that more people and equipment will need to be figured into the cost, and an appropriate storage area (protection from moisture) for storing the finished product until application would need to be obtained. An advantage of the U.S. Army using AquaBlok™ is that it can use resources already available (materials, storage and some equipment and labor) with input from the manufacturer on set-up and design, product manufacturing on site (manufacturing of the product is key to making it work), and application strategies.

The best cost estimates the manufacturer was able to provide at this time for the AquaBlok™ was $80,000/ha not including the application. For larger areas, where the cost of producing the material per ha would actually go down, an estimate of $6,000,000 to treat 320 ha was obtained which includes applying the AquaBlok™ by truck.

Application

To apply AquaBlok™ by Blackhawk helicopter (1995 cost $2,252/h), drop bags (U.S. Army already owns 10 PVC bulk bags, Model HD 32-36, Springfield Special Products, Springfield, MO), a fork lift, a front-end loader, riggers and a UH1 helicopter (1995 cost $547/h) for support was needed. This method to apply the AquaBlok™ was relatively quick and efficient. However, this method of application could be expensive.

Another method to apply AquaBlok™ would be to truck it over ice using a dump truck (9,000-kg capacity) and either a road grader, or low-ground-pressure bulldozer to smooth it. A top-coat could be formulated onto the AquaBlok™ to delay activation of bentonite until after the ice melted. Although uneven melting of ice or heaving of ice by flooding tides could cause the AquaBlok™ to be unevenly distributed in the pond, trucking it over the ice is probably the most economically feasible method of application, especially for large areas.

A method using a pneumatic pumping system could be tried but little is known about how effective it would be. The pump and pipes from the dredge could be used but the technique itself could be cost-prohibitive. Further, it is possible that there could be an additional detrimental effect by introducing high volumes of air causing disturbance of the water and resulting in the possible resuspension of contaminants in the marsh waters which would then resettle on top of the AquaBlok™ layer.

Cost/benefit analysis

Things that generally would need to be considered in any cost/benefit analysis in deciding to use AquaBlok™ as a remediation method are as follows. AquaBlok™ is less expensive than other methods of cover (i.e. Plastic Membrane Barrier System). It is possible to manufacture the product on-site, thus reducing costs. AquaBlok™ is easy to apply with several application methods and there are specific reapplication methods that can be used, i.e. spot treating can be done using either hovercraft or UH1 helicopters. AquaBlok™ is a tried and tested product which was able to produce satisfactory results. Finally, bentonite slurries and mats are used extensively in the arena of environmental engineering of landfills, ponds, drilling, etc. and are a multi-layer defense in the minimization of resuspension of contamination.

RECOMMENDATIONS

We feel that the data collected indicate that AquaBlok™ is a promising strategy for waterfowl mortality reduction on ERF. Investigations over a second season have shown AquaBlok™ will be most effective in ponds where vegetation is present to help stabilize the barrier. The formulation of AquaBlok™ used in the study used gravel of varying sizes to anchor the bentonite to the bottom sediment so that a seal could be created. However, the larger sizes of gravel used could interfere with current dredging activities on ERF. Future studies should incorporate smaller gravel or a biodegradable material to help anchor the bentonite to the substrate so that dredging can remain a viable option as the potential for gully erosion may begin to threaten treated ponds. Further, ice core sampling of the existing AquaBlok™ application would be useful in determining any WP movement into the barrier.

CONCLUSIONS

The results of a study conducted in 1994 indicated that AquaBlok™ could reduce mortality of waterfowl when applied to a WP contaminated pond up to 0.5 ha in size. Our objective in 1995 was to continue to evaluate the effectiveness of this barrier. Vegetation recovered from 45.9% in 1994 to 76.4% in 1995. Vegetative cover in 1991 was only 51.8%, indicating that after the initial mechanical effect of the treatment application, there was no adverse impact on the vegetation by the AquaBlok™. WP analysis of AquaBlok™ indicated <MLOD to 0.02 mg/kg (mean = 0.01 ± 0.01 s.e.) of WP and was probably contamination from the sediment below the barrier. No mortality of waterfowl was observed during a second year of AquaBlok™ exposure to weather and tide events. AquaBlok™ thickness was reduced from 0 to 5 cm from values in 1994. However, this was largely influenced by heavy traffic (animal and human) and limitations in the sampling method. Tide plots indicated that erosion and movement of AquaBlok™ were lowest on Racine Island, where vegetation was important in stabilizing the barrier. We feel that the data collected indicate that AquaBlok™ is a promising strategy for hazard reduction on ERF.

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