ESTCP
Cost and Performance Report
(ER-200835)

A Low-Impact Delivery System for *In Situ* Treatment of Sediments Contaminated with Methyl Mercury and other Hydrophobic Chemicals

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ESTCP

ENVIRONMENTAL SECURITY
TECHNOLOGY CERTIFICATION PROGRAM

U.S. Department of Defense

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ACRONYMS

AC	activated carbon
APG	Aberdeen Proving Ground
BC	black carbon
BPW	Maryland Board of Public Works
BSAF	biota-soil/sediment accumulation factor
CCSA	Canal Creek Study Area
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
DDx	dichlorodiphenyltrichloroethane and related degradation products
DOC	Dissolved Organic Carbon
DoD	U.S. Department of Defense
DOM	dissolved organic matter
EMNR	enhanced monitored natural recovery
ENR	enhanced natural recovery
EPA	U.S. Environmental Protection Agency
ESTCP	Environmental Security Technology Certification Program
Hg	mercury
ICP-OES	inductively coupled plasma-optical emission spectroscopy
Kd	partitioning coefficient
LCC	Lower Canal Creek
MeHg	methylmercury
MNR	monitored natural recovery
NIEHS	National Institute of Environmental Health Services
PAC	powdered activated carbon
PCB	polychlorinated biphenyl
POM	polyoxymethylene
QA/QC	quality assurance and quality control
RPM	Remedial Project Manager
SAOB	sulfide anti-oxidant buffer
SAV	submerged aquatic vegetation
SBIR	Small Business Innovative Research
SERC	Smithsonian Environmental Research Center
SERDP	Strategic Environmental Research and Development Program
SUVA280	specific UV absorbance at 280 nm
the Vortex	the Vortex TR-Aquatic system developed by Vortex Granular Systems, LLC
TOC	total organic carbon
UCC	Upper Canal Creek
UMBC	University of Maryland Baltimore County
USACE	U.S. Army Corps of Engineers
UXO	unexploded ordnance
WREC	Wye Research and Education Center

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EXECUTIVE SUMMARY

Objectives of the Demonstration

Environmental Restoration Project ER-200835 involved field demonstrations of *in-situ* treatment of sediment contamination with activated carbon (AC) delivered using the SediMite® delivery system. While ER-200835 focused on Canal Creek at the Aberdeen Proving Ground (APG) in Maryland, data from two other sites—Bailey Creek at Ft. Eustis, Virginia, and Berrys Creek in the Hackensack Meadowlands of New Jersey—are incorporated, to broaden the assessment and enable the evaluation of performance for various types of habitats. Collectively, the report provides information on the treatment efficacy of activated carbon delivered by SediMite® for two wetland/marsh environments and two tidal creeks. Contaminants present in sediments and/or wetland soils at one or more of these sites include polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT) and related degradation products (DDx), and mercury.

Technology Description

The treatment material—SediMite®—is agglomerate that is composed of the treatment agent (AC in this case), a weighting agent, and an inert binder. The agglomerate is manufactured as pellets that can be easily handled and dispersed. The product is delivered using either blower-type devices (Vortex) or spreaders. An application of SediMite® by tele-belt has also been performed for Mirror Lake in Delaware. Once the pellets are distributed on sediments or wetland soils, the SediMite® pellets disaggregate and release the active treatment agents.

Demonstration Results

The projects demonstrated that:

- SediMite® pellets were effectively delivered to wetland soils and aqueous sediments using either the Vortex blower system or the TurfTiger spreader system.
- Most of the applied AC was retained in wetland/marsh systems over the duration of the demonstration.
- Retention and/or AC concentrations for subaqueous applications varied over time. These variations are thought to reflect edge effects in the case of Bailey's Creek, and possible storm effects on resuspension or burial in the case of Canal Creek.
- Mixing of SediMite®-applied AC into sediments occurred throughout the targeted biologically active zone for applications to subaqueous sediments. Vertical mixing of SediMite®-applied AC into wetland/marsh sediments was slower and to less depth than that observed for subaqueous sediments.

- Based on field-collected sediments or wetland soils, SediMite®-applied AC significantly reduced the bioavailability for PCBs and DDx over the period of study.
- Results for mercury are considered equivocal, in part because the applied activated carbon did not remain in the treatment area.
- Applications of AC via SediMite® had negligible adverse effects on native benthic invertebrate communities in Bailey and Berrys Creeks.

Implementation Issues

- SediMite® can be effectively applied topically to wetland and open-water environments.
- The physical fate of applied AC varied among environments due to variations in physical and biological conditions. These processes should be better understood and planned for as a part of designing full-scale implementations.

Projected Costs

Projected costs for applying SediMite® over 1, 5, and 10 acres were developed for mobilization, travel, application, and the cost for SediMite with 50% activated carbon. These assume a 10-cm treatment depth into the sediment. The costs of SediMite® combined with application costs were calculated as follows, based on data from the pilot study:

	Unit Costs			Site Size (acres)		
Cost Elements	Fixed per Project	Cost per Acre	Cost per Application Day	1	5	10
SediMite material cost		$74,000		$74,600	$373,000	$746,000
Mobilization/ Demobilization	$23,000			$23,000	$23,000	$23,000
Application travel and staging	$47,000			$47,000	$47,000	$47,000
Per diem application			$10,000	$10,000	$40,000	$80,000
			Project cost =	$154,600	$483,000	$896,000
			Cost/acre =	$154,600	$96,600	$89,600

Note: Costs do not include a feasibility study, within which there would have been a $15,000 treatability study. Costs do not include monitoring.

1.0 INTRODUCTION

This report presents the cost and performance results of field demonstrations of *in-situ* treatment efficacy of activated carbon (AC) delivered using the SediMite® delivery system. SediMite® is a pelletized means of delivering treatment amendments (Figure 1). The project involved two sites within Canal Creek at the Aberdeen Proving Ground (APG) in Edgewood, Maryland. Application at these two sites was funded under Environmental Security Technology Certification Program (ESTCP) Project ER-0835. SediMite® was also applied by the project team at a third site in Bailey Creek at Fort Eustis in Virginia funded under National Institute of Environmental Health Services (NIEHS) Grant # 5R01ES16182 to Upal Ghosh at the University of Maryland Baltimore County (UMBC). Finally, data from a fourth site—Berrys Creek in the Hackensack Meadows—are included. Collectively, this information provides insights into the treatment efficacy of SediMite®-delivered AC in a variety of habitats.

Figure 1. SediMite® pellets containing powdered activated carbon (PAC). The pellet is an agglomerate that includes the treatment agent (PAC), a weighting agent (sand), and a binding agent. Once wetted, the pellet releases the fine-particle-sized treatment agent to sediments or wetland soils. SediMite® can include PAC or any other treatment agent or mixture of agents that can benefit from pelletized delivery.

1.1 Background

There has been increased interest within DoD and within the U.S. EPA in finding reliable in-situ remedies for contaminated sediments. These could be used in place of or in concert with traditional alternatives such as dredging and capping. In-situ remedies can be attractive when risks are low to moderate; the site sediments are relatively stable; valuable habitats and ecological receptors are present that could be damaged by excavation, dredging, and/or isolation capping; and where communities of people are present at and around the area to be remediated, and there is a desire to minimize the types of construction-related impacts associated with excavation, dredging, or isolation capping. At DoD sites, there may be practical considerations, such as when contaminated sediments are located under piers and against retaining walls, as well as safety considerations such as when the sediments are located in areas where there is unexploded ordnance (UXO). SediMite® was developed as a low-impact means of accomplishing *in-situ* remediation for sediments and wetland soils contaminated with hydrophobic chemicals such as methylmercury (MeHg), PCBs, DDT, other pesticides, and polycyclic aromatic hydrocarbons.

1.2 Objective of the Demonstrations

The objectives of the field demonstrations were to:

- Field demonstrate applications of SediMite® with activated carbon that are scalable to full-scale applications
- Demonstrate the efficacy of activated carbon delivered by SediMite® on reducing the bioavailability of several hydrophobic contaminants, including MeHg, PCBs, and DDx
- Evaluate the performance of activated carbon delivered by SediMite® for different types of habitat and physical conditions
- Evaluate the potential for adverse environmental effects.

1.3 Regulatory Drivers

Environmental restoration activities at DoD sites with contaminated sediments are being conducted in accordance with a variety of regulatory programs. Larger sites are often regulated under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986. Many smaller sites are being addressed as part of voluntary waste site programs.

2.0 TECHNOLOGY

SediMite® was developed with support from an EPA Small Business Innovative Research (SBIR) grant and a Strategic Environmental Research and Development Program (SERDP) project (ER-1491) by Drs. Charles Menzie and Upal Ghosh and Bennett Amos to deliver treatment amendments (e.g., activated carbon, zero-valent iron, biodegrading organisms, and powdered apatite) to wetland soils and aquatic/marine sediments contaminated by organic chemicals and metals. The distinguishing feature of the technology is that it can deliver small amounts (a thin layer, e.g., <1 cm thick) of highly concentrated amendments directly to the surface of the sediment or wetland soil; these pellets release the amendment, which is subsequently mixed into the soil or sediment via natural processes. The goal is to deliver amendments that have low impact on the environment and do not the natural sediment characteristics, geologic conditions, or topography.

The SediMite® delivery process is covered under U.S. Patent # 7,824,129: A Low-Impact Delivery System for *In-Situ* Treatment of Contaminated Sediment. The use of activated carbon as an amendment for treating hydrophobic chemicals in sediments is covered under U.S. Patent 7,101,115: *In-Situ* Stabilization Of Persistent Hydrophobic Organic Contaminants In Sediments Using Coal-and Wood-derived Carbon Sorbents.

2.1 Technology Description

2.1.1 Overview

SediMite® pellets are designed as a means of packaging amendments into an agglomerate that can be transported, readily handled, and delivered without the loss of amendment or the creation of dusts. While the pellets may be produced in dimensions of 0.25 to 1 cm, they contain amendments that may be powders (i.e., microns in diameter). SediMite® makes it possible to deliver substantial quantities of these fine-diameter materials. Once delivered, the pellets take in water and begin to break down, releasing the amendment materials contained within them. The amendments are released over time (hours to days, but the rate can be adjusted) and, as they are released, are mixed into the sediment by natural processes such as bioturbation. To the extent that mixing is provided by biological processes, the amendments are delivered to the depths in sediments or wetland soils that are occupied by benthic or soil invertebrates. As a result, the delivery system can target the sediment or soil strata most relevant for exposure to sediment surface-dwelling organisms and the animals that feed on these organisms. In some cases, this can be a relatively thin layer (e.g., on the order of a few centimeters), while in other cases, the mixing depth may be greater. While not evaluated in this report, SediMite® can also be incorporated into thin-layer sand caps, materials applied for EMNR, and treatment mats. For these applications, SediMite® offers a means of handling AC or other amendments with a fine particle size.

Treatment of a surface layer of sediment or wetland soil can also create a barrier that treats chemicals migrating from below the treatment layer. This is how SediMite® is envisioned working for: (1) Hg-contaminated sites at which MeHg is being produced at depth in sediments or wetland soils, and (2) environments where there are concerns about vertical upward migration of PCBs and other persistent organic chemicals present at deeper sediment or soil layers. For most vegetated marsh systems, such as that present at APG and Bailey's Creek, this treatment layer would become progressively buried over time as a result of marsh accretion, a natural process within vegetated marshes. This aspect of treatment is important for the vegetated marsh at APG, because this system exhibits slow vertical mixing of treatment material, and thus, a layer of AC is formed in the upper few centimeters.

SediMite® is applied as a thin layer (<1 cm); therefore, there is limited physical impact on the system and virtually no change in bathymetry. As this material is mixed into the surficial soils, the soils retain most of their original physical characteristics, with the exception of containing an elevated level of AC or other amendment. This makes it possible to conduct in-situ treatment in environmentally sensitive areas (for example, where there are sea-grass beds or a valued invertebrate prey base for fish and wildlife) and larger areas.

2.1.2 Formulation

SediMite® used in this study is formed from a blend of activated carbon as the active treatment agent, sand for weight, and a clay binder that is pelletized to form tubular pellets that are approximately 1 cm in length and 3 mm in diameter. The blend's moisture content and the compression strength, production rate, and drying temperature are manipulated during production to form pellets with the following properties:

- Sufficiently heavy to sink in water
- Sufficiently compact to minimize internal air space, which otherwise could cause re-suspension of and/or rapid degradation of the pellets
- Dried to cure the binder, forming a solid pellet that will degrade slowly underwater over time.

The SediMite® pellets are easily packaged and transported, and they can be broadcast on surface waters, under piers, and/or on exposed intertidal mudflats or the surfaces of marshes and wetlands. The demonstrations described in this report involve activated carbon, but the SediMite® delivery system can be used with other treatment agents and combinations of agents.

2.1.3 Application

SediMite® can be delivered by methods that can distribute pellets. These can include blower-based approaches such as the Vortex TR-Aquatic system developed by Vortex Granular Systems, LLC (the Vortex), as well as various types of mechanical spreaders. Both types of devices were used in the demonstrations discussed in this report.

2.2 Limitations of the Technology

The technology depends on natural mixing processes. These processes vary from site to site, and thus, the depth and speed of mixing are variables that need to be understood. The technology is designed as a topical application and thus focuses on surface sediments and wetland soils. Retention of the amendment depends on site-specific physical conditions.

3.0 PERFORMANCE OBJECTIVES

The performance objectives of this study are summarized in Table 1. While most of the performance objectives will apply to more than one of the study areas, some of the performance objectives apply only to a specific study area. This section describes the performance objectives as they relate to proving the technology and the criteria used to make this assessment. The results are described further in Section 5, Performance Assessment.

Table 1. Performance Objectives and Summaries of Results.

Performance Objective	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives			
Effective placement and treatment levels for AC delivered via SediMite®	Measurements of AC in multiple cores to evaluate spatial distribution to evaluate vertical distribution	AC is present (i.e., retained) in the mixed treatment level during follow-up monitoring events at levels that provide effective treatment. The planned target range for AC in the treatment zone is 3% to 7% of sediment dry wt in the treatment zone.	For UCC, AC was present and largely retained in all plots for wetland soils throughout the monitoring period. Variability in the horizontal and vertical distribution of AC was noted initially, but diminished over time. Over the time period of 10 months, vertical mixing was limited to the upper 5 cm and the concentration of AC > 7% dry wt in this treatment zone. Vertical mixing occurs more slowly in wetland soils than in aquatic sediments. Two large storm events—Lee and Irene—occurred during this period, but retention in the marsh remained high. For LCC, the concentration of AC in tidal creek sediments was slightly greater than 1% dry wt six months after application and was only slightly greater than controls 10 months after application. The December 2010 application was followed by a large rainfall event in the spring. Following the June sampling event, Hurricane Irene and Tropical Storm Lee passed through the area prior to the October sampling. The diminishment of AC in LCC could reflect resuspension of sediments and washout, deposition of solids brought into the system, and/or greater than anticipated vertical mixing. For Bailey Creek, AC was within the target range for treatment 2 months after application; 70% of the mass of applied AC was estimated to be present. After 15 months, lateral mixing with

Performance Objective	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives			
			untreated sediments (i.e., edge effects) had reduced AC to ~2.5% in upper 5 cm; 50% of the mass of the applied AC was present within the plots while the rest had been mixed laterally into areas outside the plots. Data are also included for a *Phragmites* marsh in Berrys Creek to provide additional insight into AC retention in a marsh plot treated with SediMite®. Retention of AC was high, despite the occurrence of a major storm event (Superstorm Sandy) that flooded the area.
Reduced bioavailability of PCBs, Hg, MeHg as revealed by reduced bioaccumulation into exposed invertebrates	Measurements of contaminants in tissues of invertebrates from either field, *in situ,* and/or laboratory exposures to SediMite®-treated wetland soils or sediments	Statistically significant or substantial (e.g., >50%) decrease in average concentrations of total Hg, MeHg, and PCBs, measured in tissues of exposed invertebrates. Significance testing was based on a test of mean concentrations using a t-test ($p < 0.05$)	**PCBs** Observations for UCC marsh and Bailey Creek are based on *ex-situ* exposures to field-collected treated and untreated wetland and creek sediments. The laboratory test methods for bioaccumulation are consistent with current approaches used to evaluate bioavailability and bioaccumulation at DoD sites. Bioaccumulation of total PCBs in worm tissues was reduced by 57% after 6 months (not statistically significant) and was reduced by 92% after 10 months (statistically significantly). Reductions in availability of PCBs as measured by worm concentrations normalized (i.e., divided by) soil concentrations (i.e., BSAF values) were all statistically significant in comparison with controls. For these normalized values, mean reductions of PCBs in tissues ranged from 60%

Performance Objective	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives			
			for the pentachlorobiphenyls to more than 90% for trichlorobiphenyls. (Treatment effectiveness as judged by normalized data was likely greater, because the presence of AC will reduce measured concentrations of PCBs in soils due to the influence of AC on the measurement of the soil PCBs.) For Bailey Creek, PCBs in tissues were reduced by 90% after 2 months. Reductions were ~50% after 15 months, likely due to reduction in AC levels and influx of new PCBs from surrounding untreated sediments. These were statistically-significant reductions. Data from Berrys Creek provide additional insight into treatment efficacy for AC delivered by SediMite®. Relative to a control plot, PCBs in a treated plot were lower by 78% for native animals, 98% for caged animals (*in situ* exposures), and 84% for amphipods exposed *ex-situ* to field-collected soils in the laboratory. **DDx** The efficacy of AC treatment delivered by SediMite® was evaluated for UCC only. Following 10-months of treatment, the bio-accumulation of DDx in worms exposed to surface wetland soils (0-2 inches) from SediMite®-treated plots was 80% lower than worms exposed to wetland soils from controls.

Performance Objective	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives			
			Methyl Mercury For LCC, MeHg in tissue of laboratory exposed organisms was significantly reduced by ~50% after 6 months. Measurements were not made at 10 months because of the low concentration of AC. The performance metric is relative and was derived for intact cores to maintain the vertical structure and geochemistry of mercury.
Reduced porewater concentrations of PCBs and MeHg	Laboratory equilibrium studies were used to evaluate the change in PCB and MeHg equilibrium partitioning from sediments after amendment with SediMite® in the field Polyoxymethylene (POM) samplers were placed in intact cores to examine vertical profiles Data for Berrys Creek include POM samplers placed into marsh sediment in the field.	Statistically significant or substantial (>50%) reduction in porewater concentrations Significance testing was based on a test of mean concentrations using a t-test ($p < 0.05$)	**PCBs** After 6 months of treatment, results for the slowly mixed samples showed that PCBs in pore water in SediMite®-treated surface (0–2 inch) wetland soils were 65% lower than the control soils, but this difference was not statistically significant; after 10 months of treatment, porewater concentrations in treated surface soils were 92% lower than the control soils, and this difference was statistically significant. POM samplers in intact cores from UCC showed strong vertical gradients in porewater, increasing with depth. This makes it difficult to discern the influence of AC-related treatment. When porewater concentrations are normalized to wetland soil concentrations, a treatment effect of AC with the treatment zone is evident. At Berrys Creek, the efficacy of SediMite® on reducing porewater concentrations of PCBs in the *Phragmites* wetland was evaluated *in situ* using passive samplers. After 21 months, porewater concentrations of PCBs in the SediMite®-treated plot were significantly lower than the untreated

Performance Objective	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives			
			plot through the upper 10 cm. For LCC sediments in June 2011, porewater concentrations for MeHg were similar between control and treated plots.
Increased partitioning of Hg and MeHg to solid-phase sediment	Hg and MeHg were measured in bulk sediment and pore water, and partition coefficients were calculated	Statistically significant or substantial (e.g., >50%) increase in partition coefficients for Hg and MeHg in treated plot compared to control. Significance testing was based on a test of mean concentrations using a t-test ($p < 0.05$)	For LCC sediments in June 2011, partitioning coefficient (Kd) factors were significantly higher in the treatment plot as compared to the control plot by a factor of 2.5 for MeHg and 7.5 for inorganic Hg. (Analyses were not performed in October because of low AC.)
Potential for environmental effects	Benthic macrofauna abundance and community structure; benthic macrofauna coloniza-tion tests; laboratory bioassays for treatment agent; submerged aquatic vegetation (SAV) presence and general abundance (cover)	Community metrics and abundance are similar in the control plots and treatment plots; negligible adverse dose-response relationships are observed over the treatment range. Aquatic and wetland plants and general plant cover are similar between pre- and post-application	LCC and Bailey Creek exhibited no significant differences in composition or abundance of benthic invertebrates between the treatment and control plots. (There may have been a small effect on species richness at 15 months for Bailey Creek.) While AC was present in sediments of Bailey Creek throughout study, AC in LCC was diminished to a concentration of less than 1% prior to the end of the study in October 2011. All colonization trays exhibited a diverse community of invertebrates, with no differences among treatments. AC had decreased from levels as high as 20% to low levels (a few percent) by 17 months. Based on the age of clams, colonization of these animals occurred within a few months of placement of colonization trays, when AC presumably was at the higher end of the exposure range. Because AC declined over

Performance Objective	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives			
			time, specific effects and no-effects thresholds cannot be determined. Aquatic and wetland plants were present in the treated areas at 6 and 10 months following treatment.
Ease of application	Feedback from field personnel on effort of mobilization, movement, application, and demobilization	Field personnel able to apply SediMite® to treatment plots efficiently.	Application was easily performed rapidly by a few personnel.
Scalable to large-scale application	Feedback from field personnel on practicality and efficiency of application equipment	Equipment used for application could feasibly be used for large-scale application	Application methods could easily be used for large-scale application.

4.0 DESCRIPTION OF SITES

This report relies on four application sites to assess the performance of SediMite® as a delivery mechanism for activated carbon for *in situ* treatment of contaminated sediment. These included a freshwater vegetated marsh at the head of a tidal creek (Upper Canal Creek [UCC] at APG in Maryland), an oligohaline tidal creek (Lower Canal Creek [LCC] at APG in Maryland), a mesohaline tidal creek (Bailey Creek at Fort Eustis in Virginia), and a *Phragmites* marsh in an oligohaline tidal system (Berrys Creek in the Hackensack meadowlands of new Jersey). Sediments at all sites were contaminated with low levels of PCBs (generally between 1 and 10 mg/kg [ppm]. Canal Creek was also contaminated with DDx and mercury. (Berrys Creek is also contaminated with mercury, but those results are not included in this assessment.) Environmental Restoration Project ER-200835, the ESTCP Project that is the primary focus of this study, took place in Canal Creek at APG and involves UCC and LCC. A summary of conditions at these locations is provided here.

4.1 Characteristics of Canal Creek

Canal Creek is located in the Edgewood Area of APG, a 72,000-acre installation controlled by the U.S. Army. Canal Creek is part of the Canal Creek Study Area (CCSA), which was identified as an Army Environmental Database-Restoration site due to historical discharges and disposal practices. Parts of the CCSA have been used for chemical warfare research and development activities since 1917, including laboratory research, field testing, and pilot- and full-scale chemical materials manufacturing (EA 2008). Other activities within the CCSA included operation of machine and maintenance shops and garages, metal parts fabrication, degreasing, and metal plating. Prior to the late 1960s and early 1970s, almost all municipal and industrial wastewater generated by CCSA facilities was discharged into Canal Creek and its marsh (EA 2008). Portions of the Canal Creek marsh were used for landfilling of sanitary wastes and production waste disposal (EA 2008). The CCSA, including sediments of Canal Creek, is currently being evaluated for remediation. Canal Creek no longer receives wastewater. Canal Creek is considered “off limits” for all recreational and commercial use because of the presence of ordnance, and is posted as such by the U.S. Army. No use of the Creek is allowed unless approved by APG and under the escort of a UXO support team that clears areas with regard to ordnance.

Canal Creek ranges from non-tidal to tidal oligohaline along its approximately 2-mile length. It is bordered by various wetlands. The salinity of the creek ranges from freshwater to approximately 5 ppt, and the headwaters are drainages and small streams north of Magnolia Road fed by overland runoff and seeps (EA 2008). The creek is bordered by tidal marsh emergent vegetation with small areas of scrub-shrub and forested wetland, and receives some input from contaminated groundwater seeps (EA 2008).

The key contaminants in Canal Creek are PCBs, DDx, and mercury.

5.0 TEST DESIGNS

The evaluation of efficacy of AC delivered by SediMite® for all four application sites involved laboratory treatability studies followed by field evaluations. The field evaluations all included comparisons between field plots at which SediMite® was applied and control plots. In addition, plots were compared both before and after the applications were made. The designs for each site are provided below.

Upper Canal Creek (UCC) at APG: SediMite® was applied in December 2010 to four 8×8 m plots. Two 8×8-m plots served as controls. The locations of some plots were changed between baseline and post-application sampling. Thus, performance assessment relies mainly on comparisons between application and control plots on two post-application sampling dates that occurred six and ten months following application. On each post-application sampling date, a composite wetland soil sample was taken from the treated layer of each plot for assessment of bioaccumulation of PCBs and DDx into the worm *Lumbriculus* in the laboratory. In addition, cores were taken for analysis of vertical distribution of AC and porewater concentrations as measured with passive samplers.

Lower Canal Creek (LCC) at APG: SediMite® was applied bank to bank over a 0.25-acre (1,012 m^2) plot in the creek. An upstream 0.25 acre plot served as a control. Each of these was divided into five subplots. The application occurred in December 2010, and the plots were sampled in June and October of 2011. Each plot was divided into five subplots. Sediment samples were collected from each of the subplots before and after application. Composite samples were made for each subplot on each date, yielding five samples per plot for comparison on each date. Intact cores (five per plot) were collected for the assessment of bioaccumulation at each location where the collection of cores was made for porewater and sediment. These intact cores were evaluated in the laboratory using the oligochaete worm, *Lumbriculus variegatus*, as the test organism for assessing changes in mercury bioavailability and bioaccumulation following treatment of the field sediments under field conditions. Analysis of treatment effects for LCC is limited to the first post-treatment sampling (June 2011) during which treatment-related effects were observed despite the low level of AC present in surficial sediments. The second post-treatment samples (October 2011) were not analyzed due to an apparent lack of AC in sediment, presumably due to the effects of major storms that passed through the area in 2011. Samples were also collected for analyses of benthic invertebrate community composition and abundance.

Bailey Creek at Fort Eustis: The Bailey Creek design involved two side-by-side plots (treated and untreated) in the creek, covering an area of approximately 225 square meters. Each of the plots was subdivided into eight subplots for sampling. The plots extended into the *Spartina* salt marsh, including subtidal areas. Samples were collected from each subplot prior to application and at 2 and 15 months after the application. These were analyzed in the laboratory for concentrations of AC, bulk levels of PCBs in sediments and porewater, and for bioaccumulation of PCBs with the amphipod *Leptochieerus*.

Design and Sampling for Berrys Creek

With permission of The Dow Company, we include results from the Berrys Creek site, where SediMite® was applied to a plot in a *Phragmites* marsh in 2011. Comparisons were made over time (2011–2014) between this plot and a control plot. Results are included for measurements made in the field and laboratory.

6.0 PERFORMANCE ASSESSMENT

Performance is described below for each major performance objective.

6.1 Performance Objective: Effective Placement and Treatment Levels for AC Delivered via SediMite®

AC was spread evenly throughout the treatment areas, but retention over time and resultant treatment levels varied among the systems. The hydrodynamic nature of these areas can influence how the AC is distributed over space and time. Therefore, for planning applications, information should be gathered in advance to help predict behavior and design applications accordingly. Because AC is applied topically and then mixes into underlying sediment, applications are best done at times of the year when biological activity is higher.

6.2 Performance Objective: Reduced Bioavailability of PCBs, Hg, and MeHg as Revealed by Reduced Bioaccumulation into Exposed Invertebrates

Based on laboratory tests of soil and sediment samples from in-field treatment plots, AC applied in the field by SediMite® can reduce the bioavailability of PCBs, DDx, and MeHg, and the bioaccumulation of these chemicals into biota. Performance over time was directly related to the concentration of AC in the sediment, and thus, retention of AC is a key consideration for longer-term treatment efficacy at a location.

6.3 Performance Objective: Reduced Porewater Concentrations of PCBs, DDx, and MeHg

AC applied in the field by SediMite® can reduce the concentrations of PCBs in porewater of wetland soils and aquatic sediments. The results for MeHg were more equivocal, because approximately the same levels of MeHg in porewater were observed in the treated and control plot 6 months after treatment.

6.4 Performance Objective: Increased Partitioning of Hg and MeHg to Solid-Phase Sediment

Kd was significantly increased by the addition of AC, and by a factor much greater than the performance criterion. This observation was made for the sediments at 6 months following treatment, when a small amount of AC was still present. Although there was a difference between the controls and treatment plots at 6 months, there was no significant difference between pre-treatment and post-treatment plots. Thus, the effect of AC at levels of approximately 1% on MeHg porewater is judged to be small.

6.5 Performance Objective: Potential for Environmental Effects

No treatment-related adverse effects—reduced abundance or a shift in the benthic community—were observed in these studies. Evidence for lack of adverse effects in the field is strongest for Bailey's Creek, because AC was retained in the sediments for two rounds of post-application benthic studies. A 17-month-long field test did not reveal effects on colonization However, the interpretation of a dose-response relationship was precluded because of the reduction in AC levels within the exposures over the 17-month period. Based on qualitative observations, the addition of SediMite® did not have an adverse effect on species composition or cover of submerged aquatic or emergent marsh plants.

6.6 Performance Objective: Ease of Application

SediMite® was applied by two application methods: a Vortex blower and a TurfTiger spreader. Both worked well.

6.7 Performance Objective: Scalable to Large-Scale Application

The application techniques used to apply SediMite® are scalable to larger areas. There is now considerable experience with applications of sand for thin-layer caps such as those used for EMNR. These application techniques can be used to handle the application of SediMite® pellets.

6.8 Conclusions Regarding Performance

The demonstration projects for Canal Creek, Bailey Creek, and Berrys Creek with SediMite® support the following conclusions:

1. SediMite® can be effectively delivered to wetland soils and aqueous sediments using either blower systems such as Vortex or spreader systems such as TurfTiger. The demonstration projects involved topical applications either to wetland soils or to surface waters of shallow tidal creeks (< 3m in depth).

2. Hydrodynamic and biological conditions varied among the demonstration sites, and this can affect the retention of AC and the rate of mixing of AC into the wetland soils and sediments. Retention was highest for wetlands for which the AC concentrated in surficial soils of the upper 5 cm. This created a surface treatment layer.

3. For subaqueous sediments, AC retention varied. AC concentrations for LCC diminished over the 10-month observation period, possibly as a result of runoff and sediment deposition associated with major storms.

4. Bioaccumulation of PCBs into invertebrates in laboratory and/or field test systems were reduced for the SediMite®-treated wetlands of Canal and Berrys creeks and for the sediments of Bailey Creek. The magnitudes of reduction appeared to be related to the AC treatment concentrations. Bioavailability was also reduced in porewater. Results for MeHg are considered equivocal.

5. Adverse effects of treatment on benthic invertebrates and plants were not observed.

7.0 COST ASSESSMENT

Table 2 presents a cost model for deploying SediMite® at a site. It is assumed that the site has been thoroughly characterized in terms of chemical concentration and distribution, as would be expected for sites where remediation alternatives for the site are being considered. Therefore, many of the characterization activities performed in this study, which were designed to determine the efficacy of SediMite® in treating sediment *in-situ*, would not be required.

Table 2. Cost Model for SediMite® Application.

<table>
<tr><th>Cost Element</th><th>Data Tracked during the Demonstration</th><th colspan="2">Costs</th></tr>
<tr><td rowspan="3">Treatability Study and Baseline Characterization</td><td rowspan="3">• Personnel and Labor
• Materials
• Analytical laboratory costs</td><td>Field technicians, 80 h
Project manager, 15 h</td><td>$4,000
$1,500</td></tr>
<tr><td>Sampling materials</td><td>$5,000</td></tr>
<tr><td>Analytical laboratory</td><td>$130,000</td></tr>
<tr><td>Cost for SediMite®</td><td>Unit: $ per ton for SediMite®
Data requirements:
• Initial amount of material required based on treatability and baseline characterizations
• Area to be treated</td><td colspan="2">• Current cost is $3,730 per ton for SediMite® containing 50% AC by weight (bituminous coal based
• Loading rate is 10 lbs SediMite® per square meter based on typical native TOC/BC content
• One ton of SediMite® would treat approximately 0.05 acres
• Cost per acre is $74,600</td></tr>
<tr><td>Application Cost: Mobilization and Demobilization of Equipment for Spreading</td><td>• These are presumed to be fixed charges for acquiring equipment, mobilization, and demobilization</td><td colspan="2">• Preparation and mobilization of equipment and supplies including labor is estimated at $23,000 and this is presumed to be constant over a range of 1 to 10 acres</td></tr>
<tr><td>Application Cost: Set up and Incremental Cost for Field Work involving a Spreader such as a TurfTiger</td><td>• Time it takes to apply SediMite® to an area using a spreader</td><td colspan="2">For 1 acre = $57,000 (includes set up and breakdown and 1 day for application); this is composed of $47,000 of set-up and staging and travel and a daily operational cost of $10,000

Sites up to 10 acres are presumed to have same fixed costs plus operational costs of $10,000/day over application duration</td></tr>
</table>

7.1 Material Cost

The SediMite® manufacturing process involves purchasing and processing several raw materials, the most expensive of which is the treatment amendment. As with any manufactured material, the raw material and manufacturing costs are affected by market conditions. The amount of SediMite® needed to treat sediment with AC will vary depending on the TOC levels of the sediments and the mixing depth. As noted earlier in the report, for wetlands where vertical mixing is slower than for aquatic sediments, it may make sense to apply small amounts of SediMite® over a long period of time. However, a typical value of 10 lbs of SediMite® per square meter is used for the cost comparisons, based on several rules of thumb:

- The target post-application AC sediment content is 4%–7%
- The typical native TOC content is 6.5%
- The biologically active zone of sediment is 0–10 cm.

The actual loading rate would be calculated based on TOC/BC analytical results, and the total cost would then be a function of the true loading rate and the total area to be treated. Shipping, storage, and staging costs would be based on site-specific logistics.

7.2 Application Costs

The costs associated with application depend on factors of the individual sites, becausethese factors dictate the equipment that can be used for application, as well as the methods for moving the equipment, SediMite®, and other materials in and around the site. Application is the primary cost driver for using SediMite® for smaller sites but diminishes in relative contribution as the size of the site increases.

7.3 Long-Term Monitoring

The long-term efficacy of *in-situ* sediment remediation has been identified as a critical research need by SERDP-ESTCP (2012) in a recent workshop. As such, long-term monitoring of the efficacy of AC delivered as SediMite® to a site would be recommended to ensure that the reductions in exposure, as seen in this study, are maintained. The monitoring events would include measuring AC in sediment profiles, chemical analysis in bulk sediment and porewater, and tissue analysis using bioaccumulation assays. The estimated cost for a single round of monitoring is based on a 1-acre site with typical access and logistical considerations, and would take approximately 2 days of collection. The results of the monitoring would be used to determine whether the remedy is effective over the long term, or if re-application or another remediation alternative is appropriate.

7.4 Cost Drivers

The cost drivers associated with the use of SediMite® for *in-situ* remediation at a site are discussed in this section.

The costs for SediMite® itself are based on material costs, production, shipping, and storage, as well as site-specific conditions. For the conditions outlined in Table 2, the per-acre cost of SediMite® is $74,600. There are several categories for application costs, some of which are fixed and others are variable. The greatest variance in application costs for a particular application involves site-specific characteristics affecting application logistics. Examples of site characteristics that will influence the application costs include:

- **Site Setting:** Open water, submergent wetland, emergent wetland, or intertidal wetland sites will restrict the equipment that may be used for application
- **Water Depth and Tidal Fluctuation:** In all site settings, the water depth and tidal fluctuation will restrict the equipment that may be used for application, as well as the work hours the equipment may be used. Site access will also be restricted.
- **Vegetation:** The type of vegetation at the site will heavily influence the application, for a broad spectrum of reasons. A *Phragmites*-dominated marsh will restrict the movement of most heavy and light equipment that might be used for application. Additionally, application in areas of sensitive, environmentally beneficial vegetation would restrict the use of heavy application equipment.
- **Site Infrastructure:** A site that is remote from major roadways for equipment and material delivery will require additional time and logistics for receiving, staging, and transporting equipment and material. A site without access from an established boat launch would require additional logistics if application were to be done by boat or barge.

For example, the estimated application times that drive the costs given in Table 2 assume that both large- and small-scale equipment (i.e., turf spreader and Vortex, respectively) could be used in conjunction with minimal logistical challenges. However, if that acre site was entirely intertidal *Phragmites* marsh, the turf spreader and most other heavy equipment would be impractical, and application time would therefore increase significantly because smaller equipment might be used. There may be a tradeoff between crew size and equipment cost between large and small projects. The latter could be performed by a smaller crew with smaller equipment and associated costs, but the time may be longer per unit area.

However, none of the factors affecting application costs are specific to the use of SediMite®. These factors would affect the application of any other *in-situ* treatment material, sediment cap, or reactive barrier. The ability to use small-scale applicators such as the Vortex allow for application of SediMite® to areas where other technologies would be impractical. For example, SediMite® has been demonstrated, when applied from the Vortex to the crown of a *Phragmites* stand, to fall through the vegetation directly to the sediment surface allowing for application to a *Phragmites*-dominated wetland without necessitating the need of removing the vegetation. This would not be possible with other AC delivery methods, such as below a sand cap or as a slurry.

7.5 Cost Analysis

This section presents estimates of the costs of implementing SediMite® for remediating contaminants *in-situ* at hypothetical sites of 1, 5, and 10 acres and compares this cost with the traditional remediation technique of dredging and disposal.

The assumptions behind the cost analysis for the three different sized sites include:

- The sites have been thoroughly characterized for chemical concentration and gradient through sediments, as would be typical with a site in the phase of selecting remediation alternatives
- The sites are open, navigable waters
- The sites are operable units of a larger terrestrial site that includes logistical support such as roadways and paved staging areas close to the water body
- The sediments of the sites are contaminated with low to moderate levels of PCBs, pesticides, and Hg.

The cost of applying SediMite® to the LCC test plot is used for this analysis, because the techniques used for this application are readily scalable to a large, open-water site. Costs included in the analysis include the labor and equipment for application at LCC.

Mobilization and demobilization for the LCC application was approximately $23,000. For LCC, the onsite mobilization and demobilization was completed in 3 days, and included several UXO-avoidance activities that would not be applicable to all sites. It is anticipated that mobilization and demobilization for each of the 1-, 5-, and 10-acre sites could be accomplished in 7 days. A cost of $47,000 is estimated to cover the types of onsite staging of equipment and materials that may be required for DoD sites, as well as travel, which is determined by backing out actual time for application.

The delivery time is estimated using the experience gained during the application of SediMite® to LCC via a spreader mounted on a barge. The application of SediMite® to LCC took approximately 4 hours, including the launching and coupling of the barge, setting the spreader and generator onto the barge, launching the push boats, loading the SediMite®, moving to the application area, applying the SediMite®, and returning to the staging area. Many of these tasks would have been completed during one of the mobilization days, but the application took place in extremely cold temperatures, and the equipment could not be left either in the creek or exposed overnight. The actual application of SediMite®, where approximately 4,500 square feet of the creek was treated, took approximately 30 minutes. Using this application rate, the estimated time to apply SediMite to a 1-, 5-, and 10-acre site would be 5, 25, and 50 hours, respectively. However, this would represent only the time of active application, and would not include loading or onsite travel time. The estimated number of days for application of SediMite® to a 1-, 5-, and 10-acre site would be 1, 4, and 8 days, respectively.

Realized application times can also be compared to the time it takes to lay down thin-layer sand caps. These vary in relative thickness and that can be used as a basis for comparison. A layer of SediMite® is approximately ¼ to ½ inch in thickness, which is considerably thinner than a sand cap of 2 to 6 inches. If the materials are being delivered by the same device, it would take much less time to complete the application for SediMite® compared to the sand cap. Using the information from LCC, an estimated per diem daily application cost would be $10,000. This daily cost is added to the mobilization costs and to the travel and site staging costs.

Using these figures, the estimated costs for 1-, 5-, and 10-acre applications of SediMite® are provided in Table 3.

Table 3. Cost of *In-Situ* Remediation with SediMite® for Sites 1, 5, and 10 Acres in Size.

	Unit Costs			Site Size (acres)		
Cost elements	Fixed per project	Cost per acre	Cost per application day	1	5	10
SediMite material cost		$74,600		$74,600	$373,000	$746,000
Mobilization/Demobilization	$23,000			$23,000	$23,000	$23,000
Application travel and staging	$47,000			$47,000	$47,000	$47,000
Per diem application			$10,000	$10,000	$40,000	$80,000
			Project cost =	$154,600	$483,000	$896,000
			Cost/acre =	$154,600	$96,600	$89,600

Note: costs do not include a feasibility study within which there would have been a $15,000 treatability study
costs also do not include monitoring

Project costs (excluding feasibility study and monitoring) would be:

- Approximately $154,600 for a 1-acre site
- Approximately $483,000 for a 5-acre site
- Approximately $896,000 for a 10-acre site

As the scale of the site increases, the fixed costs become spread over a larger number of acres, and some efficiency in operations would be expected. Thus the per-acre cost decreases as follows:

- $154,600/acre for a 1-acre site
- $96,600/acre for a 5-acre site
- $89,600/acre for a 10-acre site.

7.6 Comparison to Dredging/Removal Costs

The rule-of-thumb costs for dredging increase significantly when considered for sites with contaminated sediment that require not only dredging but de-watering, and disposal. A review of Superfund contaminated sediment megasites, or sites at which sediment remediation activities cost at least $50 million, provided remediation costs of $145/CY, $260/CY, and $530/CY of contaminated sediment (NRC 2007). These figures included the costs of design, mobilization, marine demolition, and construction/EPA oversight, which would likely be included in any sediment remediation program.

Recent estimates for sediment remediation are also available for the Lower Duwamish Waterway Superfund Site, where remediation alternatives ranging from dredging to enhanced monitored natural recovery (EMNR) are being considered. The recently published proposed plan for the Lower Duwamish Waterway Superfund site (U.S. EPA 2013) details the remediation alternatives being considered for approximately 412 acres of contaminated sediments. Six remediation alternatives were considered, with the preferred alternative being a combination of dredging, capping with possible amendment with activated carbon, and ENR, which also includes amendment with activated carbon. Under this scenario, 84 acres would be dredged, resulting in an estimated 790,000 CY of sediment being disposed in an upland landfill. Twenty-four acres would be capped, with possible amendment with activated carbon, and a further 48 acres would receive a thin-layer cap, possibly amended with activated carbon, for ENR. The estimated cost of this alternative is $305,000,000. Detailed cost estimates for this alternative are presented in the project Final Feasibility Study (AECOM 2012): the costs directly associated with dredging operations include direct dredging operations ($26,341,156), sediment handling and disposal ($76,016,104), and sediment capping/dredging residuals/dredge backfill ($21,243,378). The sum of these values, $123,600,638, account for a total dredging volume of 790,000 CY (U.S. EPA 2013), resulting in a cost of approximately $156/CY. From this estimate, the calculated per acre cost for the dredging component of this alternative is ([$156/CY * 790,000 CY]/84 acres) = $1,467,142/acre. U.S. EPA (2013) also presented a removal alternative involving 274 acres, 3,900,000 CY of dredged sediment, at a cost of $810,000,000. A dredging cost of approximately $3,000,000/acre at a cost of approximately $208/CY is derived using those values. This range of values calculated for the Lower Duwamish ($156–$208/CY) falls within the range ($145–$530/CY) reported by the NRC (2007) but are nearer the lower range.

Because dredging involves a volume to be removed, as compared to alternatives that treat surface sediments, costs for environmental dredging projects are very sensitive to the depth of the dredging and need for backfill. Therefore, another way to compare costs is to consider alternative dredge depths. To dredge sediment to a depth of 1 yard would deliver approximately 4,840 CY of sediment; a depth of 0.5 yard would yield approximately 2,420 CY. Using the value for remedial dredging cost of $156/CY for the Lower Duwamish yields costs of $755,040/acre and $377,520 for environmental dredging projects of involving sediment depths of 1 and 0.5 yards, respectively.

7.6 Comparison to Thin-Layer Capping/EMNR Costs with and without AC Addition

The equipment and methods used to apply SediMite® to LCC were first designed for placement of thin-layer sand caps. Therefore, to compare the costs of SediMite® to thin-layer capping, the material cost, volume required, and time required to apply the material are the primary variants. Presumably, the feasibility studies and monitoring requirements would be similar. The following unit cost information was available from Merritt et al. (2009), ENVIRON et al. (2008), and Johnston et al. (undated):

1. The costs for sand capping material ranged between $4 and $18/CY, and thin-layer sand caps are typically around 6 inches (15 cm) thick.
2. The cost for sand amended with 4% AC was $161.48/CY; the method for accomplishing mixing would add cost on the application side.
3. The cost for AquaGate+PAC™ is ~$700/ton for the product and shipment. An application of 2−3 inches would require 280 tons; an application of 4 inches would likely require at least 50% more, or 420 tons. Thus, material costs for AquaGate+PAC™ are $147,000 per acre for a 2- to 3-inch layer and $294,000 per acre for a 4-inch layer.
4. Because of the larger volumes to be delivered per acre, the duration for delivery will be longer for sand caps, and AquaGate+PAC™ and staging will require more equipment and space.

For purposes of comparison, it is assumed that each type of application has the same mobilization and demobilization and other fixed costs as does the estimate for SediMite® (Table 3). However, for similar pieces of equipment, the duration needed to treat an acre will vary. For SediMite®, the treatment of the upper 4 inches of sediment with ~5% AC would involve placing about 0.25 inch of SediMite®, compared to a 15-inch thickness for a thin-layer sand cap and a 4-inch thickness for a sand cap augmented with AC or an AquaGate+PAC™ cap. Thus, thicknesses may vary by 8 times higher than SediMite® for AC-based thin-layer caps, to 12 times higher than SediMite® for a thin-layer sand cap without AC. The fastest application duration identified from the literature was a thin-layer sand cap over 27 acres that took approximately 30 days (ENVIRON et al. 2008). Table 3 details that it would take approximately 8 days to treat 10 acres, or approximately 21 days to treat 27 acres. Thus, a factor of 1.42 is used to adjust delivery times. This factor seems an appropriate adjustment for the variable thicknesses, because it is less than a factor of 2, while actual differences in thicknesses vary by 8 to 12. A value of $11/CY for sand is assumed, because this is the mid-point of the reported range. Table 4 provides the comparison of costs using these values.

Table 4. Comparative Costs among SediMite® and Thin-Layer Capping Alternatives.

Cost elements	Unit Costs: Fixed per project	Unit Costs: Cost per acre	Unit Costs: Cost per application day	Site Size (acres): 1	Site Size (acres): 5	Site Size (acres): 10
SediMite material cost		$74,600		$74,600	$373,000	$746,000
Sand cap without AC and assuming a 6" thickness		$8,873		$8,873	$44,365	$88,730
Sand cap with AC and assuming a 4" thickness		$86,840		$86,840	$434,200	$868,400
Aquagate + PAC and assuming a 4" thickness		$294,000		$294,000	$1,470,000	$2,940,000
Mobilization/Demobilization	$23,000			$23,000	$23,000	$23,000
Application travel and staging	$47,000			$47,000	$47,000	$47,000
Per diem application for SediMite			$10,000	$10,000	$40,000	$80,000
Per diem application for caps			$14,200	$14,200	$71,000	$142,000
			SediMite Project cost =	$154,600	$483,000	$896,000
			Sand cap without AC project cost	$93,073	$185,365	$300,730
			Sand cap with AC project cost	$171,040	$575,200	$1,080,400
			Aquagate + PAC project cost	$378,200	$1,611,000	$3,152,000
			SediMite cost/acre	$154,600	$96,600	$89,600
			Sand cap without AC cost/acre	$93,073	$37,073	$30,073
			Sand cap with AC cost/acre	$171,040	$115,040	$108,040
			Aquagate + PAC cost/acre	$378,200	$322,200	$315,200

Note: costs do not include a feasibility study within which there would have been a $15,000 treatability study
costs also do not include monitoring

Among the comparisons in Table 4, a thin-layer sand cap without AC is the least expensive alternative. Among the alternatives that include AC amendment, SediMite® is the least expensive. Figure 2 compares costs per acre of treatment for a 10-acre site. Approaches are arrayed from least expensive to most expensive. The *in-situ* approach involving SediMite® and the thin-layer capping methods are obviously less expensive than dredging alternatives.

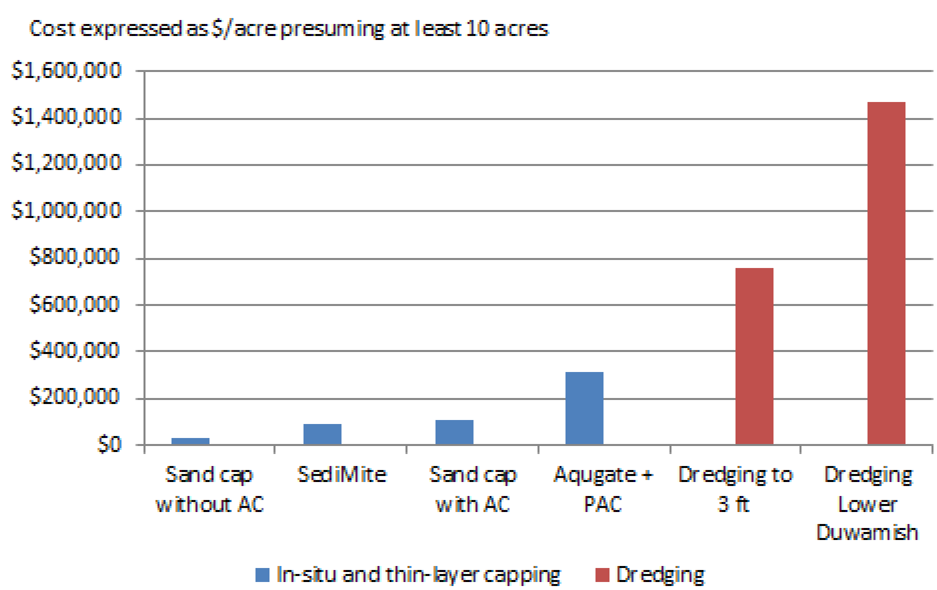

Figure 2. Costs/acre for various remedial approaches for a 10-acre site. Approaches are arrayed from least to most costly. Costs do not include feasibility work or monitoring. The graphic also does not indicate value with respect to effectiveness of remedies.

8.0 IMPLEMENTATION ISSUES

This section describes implementation issues that arose during the performance period of this research.

The project was severely delayed due to an unforeseen need for permitting outside of the APG's ability to authorize or oversee work as part of the ongoing CERCLA program. The permitting requirement was initiated by a review of the demonstration work plan by U.S. EPA stakeholders in the CCSA, who determined that the project should be reviewed by Maryland and federal agencies under whose authority the study may lie. Representatives of these agencies regularly meet to allow applicants the opportunity to present their projects and determine the agencies that would require a permit application. Exponent attended one of these meetings and presented the study's scope of work. It was determined that two agencies would require permits: the wetlands divisions within the Maryland Board of Public Works (BPW), as well as the U.S. Army Corps of Engineers (USACE). The BPW permit was required to ensure that the project complied with the provisions of Title 16, Environmental Article, Annotated Code of Maryland (1996 Replacement Volume and Supplement) titled *Wetland and Riparian Rights*. The primary concern expressed by BPW was whether the project would constitute filling an area of wetland. The USACE permit was required to ensure that the project complied with Section 404 of the Clean Water Act. The specific concern expressed by the USACE was whether the project would constitute a discharge of fill material into a navigable waterway. The process of obtaining these permits took more than a year.

It is believed that future applications will not have to undergo such extensive examination to obtain or be exempt from permits, because this and similar projects have familiarized many regulatory agencies with SediMite®. However, it is recommended to submit a work plan for review to the agencies, to ensure that project timelines are met.

Another implementation issue that arose at the LCC study area was the presence of an American bald eagle nest. The presence of the nest restricted the activities that could take place in the LCC study area between the time when eggs are typically laid (mid-February) and the time when any chicks had successfully fledged (typically mid-June). APG allowed sampling to occur in the LCC study area during this time period, but restricted the use of powered equipment, such as the turf spreader and Vortex, during the nesting period. APG was specifically concerned that the use of powered equipment in the vicinity of the nest, which is in a restricted waterway and therefore is otherwise disturbed, would cause stress to the nesting eagles. This restriction led to the application of SediMite® in December 2010, under conditions that were not ideal.

This issue is not expected to affect future applications, because the instances requiring restrictions were so specific to the demonstration area.

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APPENDICES

Appendix A: Points of Contact

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