WORKSHOP REPORT

SERDP and ESTCP Workshop on Research and Development Needs for Long-Term Management of Contaminated Sediments

October 2012

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
OCT 2012		**00-00-2012 to 00-00-2012**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
SERDP and ESTCP Workshop on Research and Development Needs for Long-Term Management of Contaminated Sediments	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Strategic Environmental Research and Development Program (SERDP),Environmental Security Technology Certification Program (ESTCP),4800 Mark Center Drive, Suite 17D08,Alexandria,VA,22350-3605**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**125**	

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EXECUTIVE SUMMARY

Sediment contamination remains a significant liability for the Department of Defense (DoD), with overall liabilities estimated to approach $2 billion. Contaminants at DoD sites include a wide variety of compounds including polychlorinated biphenyls, polycyclic aromatic hydrocarbons, various metals and metalloids, and military-unique compounds such as munitions constituents. Most of these contaminants tend to remain in the sediment long-term, resulting in persistent exposure to ecological and human receptors. Environmental restoration and closure of these contaminated sites is a top priority for DoD.

Since 1996, the Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP) have supported research and demonstration strategies for sediment characterization, site restoration and long-term monitoring to support DoD restoration goals. Beginning in 2004, SERDP and ESTCP recognized the need to hold strategic planning sessions to identify and prioritize research needs that could have the greatest impact on sediment site restoration. Workshops were previously held in 2004, and again in 2008, to identify high priority needs for research, development, and field demonstrations.

As DoD site management priorities for contaminated sediments are changing, SERDP and ESTCP identified the need to update the strategic research investment plan. Over the next five to ten years, the DoD programs will emphasize achieving site closure. Sediment sites will be completing feasibility studies, designing and implementing remedies, or be engaged in the long-term monitoring of the success of those implemented alternatives. Any new investigation work will largely be associated with identifying recontamination sources within the local and regional watersheds, and with emerging contaminants.

SERDP and ESTCP convened a Workshop on Research and Development Needs for Long-Term Management of Contaminated Sediments on July 25-26, 2012, in Seattle, Washington. The objective of this workshop was to summarize the state of work conducted by SERDP and ESTCP to date, review where DoD facilities are in their long-term management implementation of contaminated sediments, and learn directly from the Remedial Program Managers (RPMs) specific tools, demonstration, or information-transfer needs that will facilitate both long-term management decision making and long-term monitoring of these sites. To that end, the workshop goals were as follows:

1. Examine the current state of the science and technology for the long-term management of contaminated sediment sites,
2. Review the current and projected future status of DoD long-term management activities,
3. Identify data gaps that, if addressed, could aid in the long-term management of contaminated sediments, and
4. Prioritize research and demonstration opportunities to facilitate regulatory and public acceptance of long-term management strategies for contaminated sediment sites.

Approximately 40 experts participated in the workshop which was designed to define the key issues and the critical and high-priority needs for both research and demonstration projects. The research and demonstrations needs that emerged from the discussions are summarized in Table-E-1.

Table E-1. Workshop-Identified Research and Demonstration Needs

	Critical	High
Research	Improved understanding and use of passive sampling measures in sediments Improved understanding of off-site source assessment and potential recontamination of sites Improved assessment of parameters that impact long-term effectiveness of in situ amendments and amended caps Evaluation of confined aquatic disposal for dredged materials Evaluation of food web models in setting remedial goals and long term monitoring requirements	Extension of passive samplers to other contaminants Tools for measuring facilitated transport in sediment New approaches for implementing in situ amendments or amended caps
Demonstration	Demonstration of the utility and application of passive samplers Demonstration of enhanced monitored natural recovery design and operation Demonstration of long-term efficacy of in situ amendments or amended caps Demonstration of tools to evaluate amendment placement Development and demonstration of new monitoring tools	Decision analysis support
Technology Transfer	State of the science for using activated carbon Munitions constituents compendium Confined aquatic disposal guidance and training Incorporation of vessel-created erosion into remedy evaluation	

1.0 INTRODUCTION

The Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP) are the Department of Defense's (DoD) environmental research programs, harnessing the latest science and technology to improve DoD's environmental performance, reduce costs, and enhance and sustain mission capabilities. SERDP and ESTCP fund basic and applied research as well as field demonstration and validation efforts. For additional information, refer to www.serdp-estcp.org.

1.1 Sediment Contamination

Sediment contamination remains a significant liability for the DoD. Collectively, the Services contaminated sediment sites represent upwards of $2 billion in estimated restoration costs. The Navy currently has over 200 sites, and remediation of these sites represents 35% of the Navy's environmental restoration budget. The Navy estimates that while 67% of those sites are still in the investigation stage (with 33% currently in remediation), within the next five years the majority of those sites will be either in restoration or will have completed remediation and will be implementing long term monitoring. Contaminated sediment restoration challenges in the Army share technical similarities with those faced by the Navy, but are smaller in scale. Many sediment sites at active Army bases are principally freshwater sites; wetlands, streams or small lakes. Contaminant sources include drainage from bombing or training ranges, as well as former ammunition manufacturing.

To gain an understanding of what contaminants are frequently driving remedial decisions at DoD sites, a review was conducted of Records of Decision (RODs) published by the U.S. Environmental Protection Agency (USEPA) between 2003 and 2008. This review was conducted as part of a 2008 Expert Panel Workshop on Research and Development Needs for Understanding and Assessing the Bioavailability of Contaminants in Soils and Sediments (SERDP and ESTCP, 2008). Over 650 RODs were identified for soil and sediment cleanups at DoD sites. Of the RODs reviewed, 86 had decisions related to sediment management. The primary risk drivers for both human health and ecological risk included metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and chlorinated hydrocarbons. In a more recent review of risk drivers at DoD sites, the same contaminants were identified, but also have been expanded to include volatile organic compounds (VOCs), tributyl tin (and metabolites), dioxin/furans, and munitions constituents.

Contaminated sediment site management requires the management of chemical risks to ecological receptors via the removal, elimination, or reduction of contaminant release and uptake to ecological receptors, as well as the protection of human health principally via consumption of contaminated fish or shellfish. Consistent with the USEPA's *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA, 2005), sediment management at DoD sites must balance the need for ecological and human health protection with factors such as short-term effectiveness, long-term effectiveness, costs, and physical limits to implementation with the fact that often there are still on-going national defense activities occurring at DoD sites. In practice, contaminated site management involves combinations of technologies including dredging, in-place capping, and monitored natural recovery. Increasingly, additional in situ

approaches, such as enhanced monitored natural recovery and the use of contaminant-sequestering agents are being considered. While these in situ remedies have the potential to provide reduction of risk to human health and the environment at DoD sites, questions remain regarding the long term performance and efficacy of these remedies.

1.2 Workshop Objectives

Since 1996, SERDP and ESTCP have funded research and demonstration efforts for sediment characterization, site restoration, and long-term monitoring to support DoD restoration goals. A list of the sediment-related projects funded under SERDP and ESTCP is presented in Appendix A.

In 2004, SERDP and ESTCP recognized the need to hold strategic planning sessions to identify and prioritize research needs that could have the greatest impact on sediment site restoration. The 2004 Expert Panel Workshop resulted in a five-year plan that identified high priority needs for research and development (SERDP & ESTCP, 2004). The objectives of the first workshop have largely been achieved, with successful projects including new tools for characterizing in-place contamination, a guidance document for monitored natural recovery, and demonstrations of in situ amendment remedial alternatives that sequester contaminants. In 2008, a second workshop was held to determine what work was needed to facilitate regulatory acceptance and field implementation of sediment and soil bioavailability concepts and tools to support risk assessments at DoD sites (SERDP & ESTCP, 2008). Bioavailability tools that were developed from the direction of the 2008 workshop included the demonstration of in situ tools for measuring bioavailability of PAHs, PCBs and metals and relating those to uptake and biological effects. In 2011, SERDP and ESTCP held a workshop that focused on optimizing research and demonstration impacts in support of DoD restoration goals (Leeson and Stroo, 2011). While the 2011 workshop focused principally on groundwater, topics germane to this 2012 Sediment Workshop included reducing uncertainty in risk assessments, emerging contaminants (especially munitions compounds), and decision-making support.

A new planning process was needed to address changing DoD sediment site management priorities. DoD Remedial Project Managers (RPMs) identified that over the next five to ten years, they will be completing feasibility studies, designing and implementing remedies, or engaging in the long-term monitoring of the success of those implemented alternatives. SERDP and ESTCP's research and demonstration priorities thus will be largely associated with issues related to identifying methods to establish long-term remedy success, reducing long-term management costs, and achieving site closure. This report, which documents the findings and recommendations of the workshop participants, will serve as a strategic plan to guide investments by SERDP and ESTCP in the area of contaminated aquatic sediments over the next 5 years.

The overarching objective of the workshop was to identify future research and demonstration needs to support DoD sediment management and restoration goals. To that end, this workshop (1) examined the current state of the science and technology for the long-term management of contaminated sediment sites, (2) reviewed the current and projected future status of DoD long-term management activities, (3) identified data gaps that, if addressed, could aid in the long-term

management of contaminated sediments, and (4) prioritized research and demonstration opportunities to help facilitate regulatory and public acceptance of long-term management strategies for contaminated sediment sites.

2.0 METHOD

The SERDP and ESTCP Workshop on Research and Development Needs for Long-Term Management of Contaminated Sediments was held on 25-26 July 2012, in Seattle, Washington. Approximately 40 invited personnel representing DoD RPMs, federal and state regulators, engineers, researchers, industry representatives, and consultants were in attendance. The Agenda for the Workshop may be found in Appendix B; the Attendee list is provided in Appendix C. A steering committee composed of representatives from the various sectors assisted SERDP and ESTCP in defining the meeting's scope and format.

A list of key questions was formulated by SERDP and ESTCP and the steering committee with input from DoD RPMs. These questions, which were provided in advance to the participants, were:

- For remedy selection, what specific information is necessary to support the evaluation and implementation of an alternative? Is there a need to develop or demonstrate specific tools?
- How do source control and potential recontamination issues at a site affect remedy selection, and what tools are needed to support selection and long-term monitoring/optimization (LTM/LTO) of a remedy?
- For amended caps, have the concerns for placement, longevity, and associated long-term costs been sufficiently demonstrated to allow for use in management of contaminated sediment? What barriers remain to utilizing innovative in situ remediation, and how might these barriers be overcome by additional research?
- Are there emerging contaminant sediment cleanup sites that would benefit from additional focus on methods for identification and in situ treatment?
- What are the primary barriers or concerns to utilizing dredging as the sole remedy for contaminant hotspots or site-wide, or in conjunction with in situ alternatives, as part of a mixed remedy? How might these barriers be overcome by additional research?
- Are additional methods or tools needed to more effectively and cost efficiently monitor the progress of remediation during LTM/LTO? How may success be demonstrated using these techniques?

The agenda (Appendix B) was designed to identify the most pressing needs in a focused manner, while ensuring that all participants could express their views. The workshop opened with several presentations (Appendix D) intended to summarize efforts supported to date to address research and demonstration needs at sites with contaminated sediments, as well as provide insight into the status of the Service's restoration goals.

Two breakout sessions, each with three working groups, facilitated discussions of the current state of the science for sediment remediation, review where DoD facilities are in their long-term management implementation of contaminated sediments, and determine what specific tools, demonstration, or information transfer needs exist that would facilitate both long-term management decision making and long-term monitoring of these sites. In the first breakout session, participants reviewed the data gaps and technology needs where additional research and

development or field demonstrations would improve the understanding and assessment of the long-term management of contaminated sediments.

The second breakout session built on the first session by focusing on the research, development, demonstration, and technology transfer needs and opportunities for the long-term management of contaminated sediments. Research paths and demonstrations were prioritized as either critical or high priority, largely based on the sequence of events required to impact DoD sediment site decisions within 3 to 5 years of research and demonstration initiation (Table 1).

Table 1. Definition of Research Need Prioritization

	Critical	High
Research	Research that potentially could have a significant impact on cost-effective long-term management of contaminated sediments at DoD sites.	Research that is of high priority but may not be able to be initiated until critical research needs are addressed or may be more clearly defined after critical research needs are addressed.
Demonstration	Field demonstrations or assessments that can improve on cost-effective long-term management of contaminated sediments at DoD sites.	Field demonstrations or assessments that are of high priority but may not be able to be implemented until critical demonstrations or assessments are completed.

To assist in focusing the meeting discussion, many of the invited participants were contacted by phone and were queried for their understanding of key research and demonstration needs germane to their specific programs. The responses from this survey were summarized prior to the workshop and were used in the first breakout session as a point-of-departure for discussion.

A poster session was held in the evening of the first day of the workshop. This poster session highlighted key SERDP and ESTCP funded efforts that were focused on contaminated sediment issues.

The entire group participated in the final discussions and selection of the key issues and the critical and high-priority research and demonstration needs. Several of the participants contributed to section to this report describing specific issues and needs, and/or edited the draft versions.

3.0 RESEARCH, DEMONSTRATION, AND TECHNOLOGY TRANSFER NEEDS

The research and demonstration needs identified during the workshop are described in the following sections. Research needs, both critical and high priority, are presented first, followed by demonstration needs, then technology transfer needs. Although technology transfer was not identified as a category in the original breakout session charge (Table 1), during the discussion it was apparent that certain issues were predominantly a technology transfer need; no further research or field demonstrations were necessarily associated with the issue. The order in which the needs are listed does not imply any prioritization, although those needs identified as "critical" are identified first within each section.

3.1 Research Needs: Critical

3.1.1. Improved Understanding and Use of Passive Sampling Measures

Reliable and repeatable measures of contaminant bioavailability remain a barrier to using those measures in remedial decision making. Even with the considerable advances in the development of passive sampling devices, regulatory acceptance of these methods is difficult to attain. During the workshop, both DoD RPMs and federal site managers stated that while the state of the science concerning passive sampling devices has advanced, bioavailability is not well understood and thus is not always integrated appropriately into risk assessments and regulatory decisions. Although there is increasing interest in incorporating site-specific bioavailability measurements into site management decisions, there is a general perception that these methods continue to be developed, have not yet been vetted for universal use, and are not approved by the USEPA. Barriers to using these methods include uncertainty regarding the advantages and limitations of the methods, lack of standard methods, the lack of consensus and technical guidance (i.e., regulatory approval) for use in regulatory decision-making, and a general absence of commercial laboratories that are certified and performing passive sampler construction and analysis.

The significant data gap expressed by DoD RPMs and federal site managers at the workshop is the connection between passive sampling measures, and actual measures of contaminants and effects in organisms. For example, participants asked whether passive sampling measures could be used to predict toxicity effects in bioassays. Additional questions included: are passive sampling measures applicable across a wide spectrum of benthic organisms; can passive samplers be used to connect or predict contaminant uptake into fish; and how can passive samplers be used for spatial and temporal interrogation of a contaminated site? Based upon these concerns, the following research needs were formulated by the workshop participants:

- Determine whether in situ passive sampler measurements can be used as surrogates for tissue contaminant measures in benthic and pelagic organisms.
- Determine whether passive sampling measures can be correlated with sediment toxicity measures.
- Determine whether passive samplers can be used to calibrate and validate trophic transfer models.
- Determine how passive samplers can be deployed to yield representative spatial and temporal interrogation of site contaminants.

- Develop field-deployable passive samplers for deeper waters that do not require diver-assisted deployments.
- Compare the use of solid phase microextraction (SPME), polyoxymethylene (POM), polyethylene (PE), and actual porewater (or surface water) measures with biological uptake of hydrophobic organic compounds from sediment.

Research on passive samplers has been conducted by SERDP and ESTCP. Over the last six years, SERDP and ESTCP have sponsored research for characterizing in situ contaminants including SPME, POM, PE for hydrophobic organic contaminants, and diffusive gradient in thin films (DGT) for characterizing metal exposures. Studies funded by SERDP and ESTCP related to measures of hydrophobic organic compounds are listed in Appendix A, and include projects ER-1207, ER-1496, ER-200624, ER-200709, ER-200915, and ER-201216 (Luthy et al., 2004; Gschwend, 2010; Reible and Lotufo, 2012; Geiger, 2010; Gschwend, 2009; Menzie, 2012). ESTCP also funded the only comparative evaluation to date between these methods for PCBs, and compared those measures to bioaccumulation in *Lumbriculus* (Gschwend et al., 2011).

At the 2009 SERDP and ESTCP's *Partners in Environmental Technology Technical Symposium & Workshop*, attending DoD RPMs, USEPA and state regulators recommended development of a "principles of practice" on how to implement and interpret in situ bioavailability measures. ESTCP is now engaged in a technology transfer effort through the ESTCP project ER-201216 (Menzie, 2012), *Sediment Bioavailability Initiative: Development of Standard Methods and Approaches for the Use of Passive Samplers in Assessment and Management of Contaminated Sediment*. In addition, a review of the status and limits of passive sampling measures is being developed by the Society of Environmental Toxicology and Chemistry (SETAC) through its Pelleston Workshop series. The product from the Pelleston effort will be published in 2013. Collectively, these documents should help address the barriers related to the field and laboratory standardization of passive sampler methods.

3.1.2 Improved Understanding of Off-Site Source Assessment and Potential Recontamination of Sites

While the DoD maintains a policy that off-site sources must be identified and controlled prior to implementing cleanup, federal and/or state orders often require cleanup before sources have been or can be controlled. RPMs at the workshop expressed concern that these restored sites may likely become recontaminated by continued input from off-site sources including permitted discharges, transport from upstream un-remediated contaminated sites, or from stormwater discharge.

Recontamination from off-site sources can slow or even reverse recovery. In most urban and industrial harbors and rivers, because it is unlikely that sources will be completely controlled, a fundamental technical challenge is assessing "How controlled is controlled?" This requires better scientific and technical capabilities to understand releases from these sources and how these source levels relate to potential recontamination of the sediment bed. This also drives a more rigorous approach to remedy selection and risk management that incorporates the resilience of remedies in the face of ongoing sources into the criteria for remedy selection (within the existing context of long-term effectiveness). These challenges manifest in the context of both Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sediment

cleanup actions, as well as Clean Water Act (CWA) related Total Maximum Daily Loads (TMDL) actions.

Critical research needs identified by workshop participants were specifically relevant to the assessment of incoming off-site contaminant loads and methods to quantify how those loads might directly change the surface sediment concentrations on a remediated sediment surface. For example, at some sites, the Navy is being required to implement sediment cleanup, but source control has not been achieved and several of the permitted discharges have contaminant particulate loadings that are above sediment cleanup levels. There is a need to be able to establish the linkage between loading and surface sediments recontamination. To this end, research needs include:

- Determine how potential ongoing low-level sources can be accounted for appropriately in remedy selection, design, implementation and monitoring.
- Develop monitoring tools to address discharge loads, physical discharge characteristics, and connect discharge loads to downstream surface sediment concentrations.
- Develop modeling tools to evaluate source impacts and fate and transport including models that address how much source control is required, and understanding the effect of source and non-point contributions to sediment and biological receptors.

3.1.3 Improved Assessment of Parameters that Impact Long-Term Effectiveness of In Situ Amendments and Amended Caps

Long-term effectiveness and permanence is one of the key National Contingency Plan (NCP) balancing criteria that must be addressed when comparing remedial alternatives for sites to be cleaned up under CERCLA (USEPA, 2005). It is generally accepted that remedies relying mainly on dredging or excavation provide long-term effectiveness as long as the remedy addresses generated dredge residuals. Although USEPA guidance (USEPA, 2005) states that dredging, capping and monitored natural recovery (MNR) remedies each "may be capable of reaching acceptable levels of both short-term effectiveness and long-term effectiveness and permanence," many stakeholders have less confidence in the long-term effectiveness of remedies that rely substantially on in situ alternatives such as engineered capping, thin covers (e.g., enhanced natural recovery), or in situ amendments. In order to gain public acceptance of these in situ approaches, additional research is needed to develop laboratory and field tests and models that can more reliably predict the long-term effectiveness and relative permanence of these approaches.

While workshop participants readily acknowledged that much has been learned about the potential utility and applicability of contaminant-sequestering or amended caps, there remain concerns about the long-term efficacy of these remedies. Critical research needs include laboratory technology screening tests/models and pilot scale demonstration field tests to measure or predict the following:

- Develop methodologies or models that allow for the prediction of the long-term efficacy of in situ amendments, applied alone or as part of an engineered cap. Methodologies may include laboratory tests using site sediments, different

amendments in varying mass, and under conditions of exaggerated groundwater advection to predict long-term contaminant flux and contaminant of concern (COC) sequestration potential.
- Evaluate the ability of amendments and amended caps to be effective in the face of continued low-level sources and determine their assimilation capacity.
- Develop an inexpensive and reliable method to measure black carbon in natural sediments, and for post-placement at remediated sites.
- Develop laboratory-based tests to measure shear stress and the potential erosion of placed amendments at remediated sites.
- Develop standardized laboratory treatability tests to determine the most effective type and amount of activated carbon needed based on concentration and type of natural OC in the contaminated site sediment.
- Laboratory and pilot test granular activated carbon (GAC) and various types of more available and inexpensive hard carbon under differing advection regimes to measure short-term and long-term relative effectiveness of sequestration.

Application of contaminant sequestering agents, or "amendments," to minimize or eliminate the bioavailability of hydrophobic organic compounds and metals is well established in the scientific literature. Excellent recent reviews on the topic include Hilber and Bucheli (2010), Ghosh et al. (2011), and Cornelissen et al. (2011). SERDP has promoted several technology development projects (Appendix A), while ESTCP has funded on-going demonstration projects on the efficacy of using activated carbon to sequester contaminants at Hunters Point, CA (ER-1207 [Luthy et al., 2004], ER-1552 [Luthy, 2007] and ER-200510 [Luthy et al., 2009]), at Puget Sound Naval Shipyards, WA (ER-201131; Chadwick, 2011), and the Aberdeen Proving Ground, MA (ER-200825 [Hawkins, 2011], ER-200835 [Menzie, 2008]). Outside of SERDP and ESTCP funded efforts, there are multiple private industry projects on-going including the Grasse River (PCBs), Tondheim Harbor and Grenlands Fjords in Norway (PAHs, pesticides, PCBs, dioxins) (Ghosh et al., 2011).

3.1.4 Evaluation of Confined Aquatic Disposal for Dredged Materials

The primary barrier to using dredging as a remedy remains the high costs of dewatering, handling, and upland disposal of dredged sediment. Dredging has, and remains a principal component of remedial actions at DoD sites. Confined aquatic disposal (CAD) was identified during the pre-workshop survey and again during the workshop discussions as a tool for cost-effective dredge materials management.

CADs have been effective for protecting human and ecological health where industrial waterway activities such as ship passage or berthing are expected to continue. Land use restrictions can be effective in maintaining the integrity of engineered structures such as CADs. In 1984, the USACE disposed PCB and metals-contaminated fine-grained sediment dredged from the Lower Duwamish Waterway in Seattle, Washington in a borrow pit in the adjacent West Waterway, and capped it with clean dredged sediment. Eleven years of monitoring has demonstrated that the capped contaminated sediment remained effectively isolated (SAIC, 1996), and the site is being revisited this year, 18 years following placement. In addition, CAD has been used for contaminated sediments dredged from a combined CERCLA cleanup action and navigation dredge project at the Puget Sound Naval Shipyard Operable Unit B in Bremerton, Washington

(NAVFAC, 2007). Although soft sediments were initially displaced during the capping phase at this site, necessitating a broader thin-layer placement to mitigate the releases, lessons learned can be used to avoid contaminant displacement under similar future conditions. Also, dredging projects in New York Harbor now regularly use pit CADs to manage contaminated sediments, and increasingly CADs are being employed to contain contaminated sediments (Fredette, 2006).

Development of guidance and tools to encourage use of open-water CAD sites for contaminated sediment management offers potentially significant benefits for DoD activities, from logistic, project management, and cost perspectives (Fredette, 2006). For CAD, untreated sediment is placed within a containment structure such as a natural or constructed bottom depression or berm, and capped with clean sediment. The cap must be designed to resist scour and minimize contaminant releases from bioturbation. Despite the availability of materials fate modeling programs such as the Dredged Material Disposal Management Models[1], selecting CAD as a technology and siting CAD sites are often problematic for regulators and stakeholders.

While CAD is an extant technology with a track record of successful implementation and use, Workshop participants identified additional research needs that could aid in the evaluation and engineering of CAD as a component of a dredging alternative. These research needs include the following:

- Research on methods for predicting and measuring whether placed dredged sediments have sufficiently consolidated to have the strength to support CAD cover materials.
- Development of new tools to measure the in situ consolidation as well as to measure cover placement in real time during construction.
- Investigate a range of enhanced natural remedy approaches in conjunction with traditional disposal efforts (i.e., if clean sediments are removed to create a borrow pit, can these sediments be used in effective ways as part of the remedy, or to offset the cost of the remedy by using them for replenishment and restoration efforts).

3.1.5 Evaluation of Food Web Models in Setting Remedial Goals and Long Term Monitoring Requirements

Bioaccumulation is the primary risk driver at many contaminated sediment sites. This process is governed by the relationship between chemical concentrations in media (sediment, water, air and flood plain soil), and the corresponding chemical concentrations in receptors (humans and wildlife). Food web models are used to evaluate in remedy decision making in principally two ways: (1) to assess the risk to humans and wildlife based on contamination levels in sediment and/or water, and (2) to establish risk-based clean up levels that are used to evaluate restoration alternatives.

Currently, bioaccumulation can be assessed with a range of methods from largely empirical simpler models that calculate the bioconcentration factor (BCF), the bioaccumulation factor (BAF) or the biota-sediment accumulation factor (BSAF) to complex mechanistic bioaccumulation food web models that attempt to consider all uptake and elimination processes. Many sediment sites with persistent organic contaminants rely on mass balance bioaccumulation models. The most widely used of these models include those developed by Mackay et al. (1997),

[1] http://el.erdc.usace.army.mil/products.cfm?Topic=model&Type=drgmat, chiefly STFATE

and Gobas et al. (2004) (Arnot and Gobas, 2004). The Army has developed *TrophicTrace*, a bioaccumulation and food web modeling application for aquatic environments that estimates expected concentrations in fish using a sediment-based food web model for organic compounds, via trophic transfer factors from invertebrates to fish for certain metals, and via bioconcentration factors from water to fish for the remaining metals and hydrophilic organic compounds. This model also includes a human health assessment using consumption rates of fish and standard human health risk assessment equations. ESTCP is funding an effort to improve this model in project ER-200917 (Johnson, 2009).

Increasingly, remedial goals for sites contaminated with persistent hydrophobic organic compounds are being set using risk-based tissue concentrations in key biota, and the food web models are used to back-calculate sediment concentrations that are thought to be protective (Gustavson et al., 2011). For example, two large Superfund sites on the west coast are considering as cleanup goals fish tissue PCB concentration that are protective of subsistence fishers at an excess life time cancer risk of 1 in one million (1×10^{-6}). The trophic transfer model, which is calibrated and validated using current site conditions, are run "backwards" to yield a sediment concentration that, if implemented, would result in fish tissue concentrations that would result in fish tissue concentrations that would be safe for subsistence fisher consumption.

A major uncertainty discussed by workshop participants is associated with the veracity of the back-calculated sediment concentrations. Are the estimates using transfer coefficients developed for in-bed concentrations that exceed 1,000 µg/kg total PCBs applicable to the back-calculated concentrations which are up to three orders of magnitude lower? Other uncertainties identified include the appropriate spatial representation of contaminant concentrations, appropriate statistical treatment of outlier concentration data, temporal challenges including species area use factors and seasonal changes in species and contaminant availability. The research questions identified include:

- Determine how food web models can be used to improve our ability to select, design, and implement remedies.
- Determine how food web models can provide a framework for design and interpretation of post-remedy monitoring.
- Determine whether the partitioning and trophic transfer assumptions used to develop and calibrate bioaccumulation models for risk assessment are valid for the low-level remedial action levels set for site cleanup.
- Evaluate spatial distribution models, including spatially-weighted average concentrations, geometric means, processes for outlier inclusion/exclusion.
- Evaluate temporal factors in food web models including target species habitat preferences, area use factors, life stage, and seasonal use.

3.2 Research Needs: High Priority

3.2.1 Extension of Passive Samplers to Other Contaminants

Critical research needs concerning passive sampling devices were discussed in Section 3.1.1. Additional high priority research identified at the workshop included developing the tools and

links to biological resources and to other DoD chemicals of concern including dioxins/furans, metals and munitions-related compounds. Accordingly, the following high priority research needs are identified:

- Develop and demonstrate a multi-purpose passive sampling device capable of collecting data on several contaminants of interest.
- Develop and demonstrate passive sampling devices for metals, including arsenic, lead and mercury and zinc.
- Develop and demonstrate passive sampling devices for dioxin/furans.
- Develop and demonstrate of passive sampling methods for munitions compounds.
- Demonstrate the same connectivity to biological measures for these new tools, as discussed in Section 3.1.1.

3.2.2. Tools for Measuring Facilitated Transport in Sediment

In situ remedial technologies for sediments, including capping and in situ treatment with amendments, may not be effective in environments influenced by facilitated transport processes including rapid groundwater upwelling, transport by excessive gas ebullition, or mobile nonaqueous phase liquid (NAPL). Assessing when these conditions might occur and the transport kinetics associated with these processes is thus critical to the selection and design of in situ remedial technologies. SERDP and ESTCP have sponsored work in developing tools to measure these processes, including the Trident Probe and the UltraSeep System (Chadwick and Hawkins, 2008) to provide a direct measurement of groundwater discharge rates and chemical loading rates to surface water.

Current technologies for evaluating groundwater upwelling may not adequately characterize gas ebullition. Gas ebullition is highly variable across a site and the quantification of gas ebullition and contaminant transport kinetics is not readily measurable. The presence or absence of NAPL usually can be assessed; however, the mobility of NAPL under current or potential site conditions is much more difficult to measure. Improved assessment technologies are needed to provide the tools necessary to quantify groundwater, gas, and NAPL transport mechanisms.

3.2.3 New Approaches for Implementing In Situ Amendments or Amended Caps

Two areas of additional research and development needs include: 1) developing new and more effective amendments, and 2) designing new and better ways to deliver amendments as part of caps or in-situ treatment approaches. Much of the recent work on sediment amendments has focused on adsorption by carbon or other substrates (e.g., organoclays, apatite). There remains continued interest from the regulatory community and public in approaches that remove the mass of the contaminants through treatment. Some work is currently underway through SERDP and ESTCP to explore amendments that both adsorb and treat persistent and bioaccumulative organic chemicals (Appendix A).

Workshop participants expressed interest in developing amendments that can meet a number of the following criteria: reduce exposures through a combination of chemical adsorption, degradation and transformation, have low impact on native biota, have long-term effectiveness, be competitively priced from a life cycle perspective that considers all benefits and costs, and addresses complex mixtures of chemicals. This research and development need is directed

toward new technologies that may come from combinations of physical, chemical, and biological research efforts. Research could derive from the fields of nanotechnology, microbiology, enzyme systems, and tissue cultures. High priority research needs include:

- Developing amendments that adsorb and treat persistent bioaccumlative organic chemicals.
- Improved methods for amendments placement in contaminated sediments.
- Develop and assess additional in situ amendments, including those for metals, dioxin/furans, and munitions compounds.

3.3 Demonstration Needs: Critical

3.3.1 Demonstration of the Utility and Application of Passive Samplers

Critical and high priority research for passive samplers was discussed in Sections 3.1.1 and 3.2.1. In addition to those research needs, Workshop participants were consistent in noting that the lack of standardized methods for deployment and analyses—tools and analytical methods are not commercially available—is a barrier to DoD and regulatory acceptance. Furthermore, those same critical and high priority research needs will have to be demonstrated on larger sites in order to gain more confidence with each tool as an adequate predictor/surrogate for ecological and human risks in order to be used for contaminated site management. Specific demonstration needs thus include:

- Standardized protocols for use of SPME, PE, POM, or DGT samplers.
- Promote methods for making and analyzing passive samplers at commercial laboratories.
- Demonstrate how passive sampling measures can be used to set remedial goals and LTM objectives.
- Demonstrate passive samplers as a means for evaluating the performance of remedial technologies

3.3.2 Demonstration of Enhanced Monitored Natural Recovery Design and Operation

Enhanced monitored natural recovery (EMNR) is a hybrid remedy that generally relies on the combined effects of a thin layer cap (enhancement) and natural recovery, and is verified over time through monitoring (Magar et al., 2009; Merritt et al., 2010). ESTCP has funded work on demonstrating EMNR at military sites (Chadwick, 2008), and there have been some sites nationally where EMNR has been implemented (Merritt et al., 2009), Workshop participants identified additional demonstration needs on the placement and long-term efficacy of EMNR as a remedy. Critical needs include:

- Assess the incorporation of different types of natural processes within the EMNR context.
- Demonstration of placement and efficacy measures at a large-scale (> 1 acre) site over a minimum of 5 years, preferably up to 10 years of post-placement monitoring.
- Demonstration of tools to verify and confirm construction specifications are met, and the long-term stability of the placed materials.

- A technology transfer process that would summarize for RPMs the critical processes necessary to select EMNR as a potential remedy, the methods to engineer a stable and effective thin-layer cap, including treatability studies, and a description of the engineering tools used for application.

3.3.3 Demonstration of Long Term Efficacy of In Situ Amendments

Workshop participants, while acknowledging the potential for the application of amendments to sediment remedial projects, identified several barriers to wide-spread acceptance. Projects conducted to date have been relatively small (< 1 acre), and there is little data to support the long term efficacy and costs associated with amendment placement and maintenance. Questions and concerns raised both before and during the workshop included the lack of understanding on the part of DoD RPMs and federal agencies on how to evaluate an amendment remedy during the feasibility study (FS) stage, lack of information on the tests needed to design an amended caps, mechanisms for placing amendments over large areas in deep and/or dynamic environments, short and long term costs, the physical longevity of these amended caps, and whether these caps will operate indefinitely or require active maintenance and amendment augmentation or replacement.

Demonstration projects that could aid acceptance that were identified include:

- Implement an amended cap site larger than 1 acre with a LTM component of up to 10 years (strong leveraging from site owners would be needed).
- Demonstrate the engineering tools for placing amendments over (1) large areas, (2) in deep water, and (3) in dynamic environments.
- Demonstrate long term operation and maintenance needs including continuing sorption, the need for replacement or augmentation of sorbents, and the long term costs associated with maintenance.
- Demonstrate the need for and methods to stabilize amendments in dynamic environments.
- Develop and/or demonstrate models to support design of amended caps/in-situ treatment.
- Develop and demonstrate additional in situ amendments, including those for metals, and dioxin/furans.

3.3.4 Demonstration of Tools to Evaluate Amendment Placement

In situ remediation of contaminated sediments using amendments is an innovative approach to reducing risk and can enhance the functionality and range of uses of conventional caps. One of the challenges is demonstrating effective methods for placing and/or mixing amendments into the base sediments, methods to monitor placement, and methods to identify the amendment over the long term. Amendments can be added to cap materials (e.g., sand), directly applied to contaminated sediment, or encapsulated in other materials (e.g., geotextile fabric or pervious concrete). Demonstration of methods for incorporating amendments into base sediments or with caps can be further evaluated to determine the effectiveness of different techniques relative to reduction in risk, cost, and constructability. Specific demonstration needs in this area include:

- Demonstration of effective tools to confirm both short term placement, as well as long term confirmation that the amendment has remained on site.
- Demonstration to evaluate optimal monitoring strategies and techniques, including techniques to measure and quantify the amendment material placed with the cap and to monitor its performance over time.
- Demonstration of placement and efficacy measures at a large-scale (> 1 acre) site over a minimum of 5 years, preferably up to 10 years of post-placement monitoring.
- Demonstration of tools to verify and confirm construction specifications are met, and the long-term stability of the placed materials.

3.3.5 Development and Demonstration of New Monitoring Tools

A critical demonstration need is how to evaluate the longevity and overall efficacy of remedy performance. There are two key types of monitoring required at contaminated sediment sites: remedy performance monitoring and risk-reduction monitoring. Both of these have short-term and long-term monitoring components. The main research need is to develop easy to perform and inexpensive tests and models that can be used to reliably predict the long-term performance of the remedy and the expected long-term risk reduction.

Many remedies are driven by the need to provide protection from consumption of fish and shellfish contaminated with bioaccumulative contaminants such as PCBs, dioxins, pesticides such as DDT, and methyl mercury. The key monitoring endpoint in these situations is typically tissue concentrations in adult sport fish. Because sediment remedies deal with remediating sediment and often rely on natural recovery processes such as sedimentation to reduce risk to site cleanup levels, there is often a lag between achieving sediment cleanup levels and reductions in fish tissue concentrations.

Additional tools, tests, and models are needed to more quickly predict long-term risk reductions rather than waiting decades to demonstrate reductions in fish tissue levels. Demonstration of these tools includes:

- Demonstrate the use of passive samplers to monitor contaminant flux and transport distance from contaminated sediment layers into the overlying thin cap or amended cap and to calculate Surface Area Weighted Average Concentrations (SWAC).
- Develop laboratory tools that measure and/or predict long-term effectiveness of activated carbon or other cap amendments.
- Develop standardized statistically robust sampling protocols and decision units for baseline and post remediation monitoring in sediment, pore water and fish/biota for a select set of varying site conditions and site sizes. Incremental, composite sampling, as developed for upland soils (Hewitt et al., 2007), also may be applicable to aquatic sediments.

Sediment sampling devices have been developed under both SERDP and ESTCP. In 2007, research was initiated on development of the Sediment Ecotoxicity Assessment Ring (SEA-Ring). This protocol incorporates rapid in situ hydrological, chemical, biological, and toxicological measurements in sediments (Burton et al., 2011). The device is currently undergoing field demonstration to refine the current prototype to be more robust, user friendly,

and cost-effective for commercial application and to standardize test and quality control procedures. The demonstration is anticipated to be complete in 2014 under ESTCP project ER-201130 (Rosen, 2011).

3.4 Demonstration Needs: High Priority

3.4.1 Decision Analysis Support

Several participants expressed an interest in the development and demonstration of decision-analysis support tools that would allow for proactive/interactive decision making that would not only assist RPMs with operational and optimization decisions, but also would be useful as communication aides with regulators, stakeholders, and the general public on the comparative tradeoffs associated with contaminated sediment site management decisions. Three decision analysis support tools were identified:

- Develop methods to improve graphical representations of site information to support decision analyses.
- Develop a gaming tool that simulates sediment characterization and remedy decision making.
- Develop a database of technology performance information derived from case studies of field implementation of various remedial technologies.

Visual presentations using creative graphics and animation can be useful tools for presenting complex scientific concepts, conceptual site models, and remedial alternatives to regulators, stakeholders and the public. Such methods are gaining increasing notice, but have not been used as a common practice for DoD sediment sites. RPMs may not be familiar with how multi-media representations coupled with GIS-generated maps can be used for effective communication and decision making. The recommendation by some workshop participants was to demonstrate these tools using an existing DoD site, and prepare a guidance document on how best to create graphical representations to support decision analyses.

Gaming tools, as participatory simulations, are increasingly being used in research, training and negotiation support in the field of renewable resource management, land use planning, and flood control. Recent well-received examples of informing decision tools include the UVA Bay Game for watershed decisions on the Chesapeake Bay (Learmonth et al., 2011), and flood policy and control decision in the United Kingdom using FloodSim[1]. Research opportunities exist to develop a participatory simulation gaming program, which was referred to by workshop participants as SedSim, to simulate sediment characterization and remedy decision making. Ideally, the research project would use an existing site with an existing remedy decision and a good data record to serve as a baseline against which the results of the simulation can be compared.

Development of a database of technology performance at various contaminated sediment sites could assist RPMs in determining the likely performance of a technology based on site conditions. Such a database was developed for contaminated groundwater sites (Lebrón et al., 2012). The database of technology performance data was used to develop a user-friendly

[1] Available at floodsim.com; accessed 23 October 2012

screening tool that could be used by decision makers during the remedial technology selection or evaluation process to evaluate potential technology performance at a particular site, to evaluate potential technology performance in different geological strata at a complex site, and to aid in the selection of feasible technologies for a particular site based on desired performance metrics. Such a database has not been generated for contaminated sediments sites, although collection and analysis of existing data could be very valuable in determining future technology performance.

3.5 Technology Transfer Needs: Critical

3.5.1 State of the Science for Using Activated Carbon

Workshop participants identified a critical technology transfer need related to the selection, design, placement, and long term monitoring and maintenance requirements for amended caps. Many questions remain among DoD RPMs, and engineers, on how to appropriately incorporate amendments into a remedial strategy at contaminated sediment sites. Of the amendments developed to date, activated carbon is the furthest along in terms of both science and application, so the recommendation from the workshop was to focus on carbon first, and later on other amendments as they become available in the marketplace.

The technology transfer program should include a summary of the state of the science of contaminant sequestering amendments, and methods to select and design amended caps. Important issues that the guidance should address include:

- Protocols for designing a remediation approach that integrate carbon amendments into an overall remedy for a contaminated sediment site.
- Success criteria and performance goals.
- Treatability studies that identify the site-specific activated carbon formulations.
- Methods to measure in situ carbon amendment concentrations and distributions after placement.
- Other engineering design considerations that include not only contaminant sequestration, but also minimizing the need for future maintenance or amendment replacement, and stability of the in-place amendment from natural or human-induced erosion processes.
- Mechanisms available for placing amendments at the desired location, at the desired concentration, with suitable mixing with the native sediments and protection from erosional forces.
- How to estimate the longevity of the carbon amendments when exposed to environmental conditions over time, and plan for the need for future maintenance.
- Hydrodynamic conditions that are conducive or limiting for using carbon amendments as part of a remedial strategy.
- Discuss how to incorporate activated carbon at a site where carbon normalized sediment concentrations were used for risk and cleanup goals.

3.5.2 Munitions Constituents Compendium

Accurately identifying ecological risks has long been a significant issue, especially for military unique compounds. SERDP and ESTCP have been involved in developing methods to improve the assessment of the environmental fate and transport, and ecological risks associated with

existing and new military-unique munition compounds. A summary of the work sponsored may be found on SERDP and ESTCP's Munitions in the Underwater Environment web page[1], and include links to a white paper titled *Munitions in the Underwater Environment: State of the Science and Knowledge Gaps*, a technical report titled *Parameters for the Evaluation of the Fate, Transport, and Environmental Impacts of Chemical Agents in Marine Environments*, and individual specific projects. Additional munitions-related projects may be found in Appendix A.

Workshop participants, while being aware of SERDP and ESTCP's munitions initiative, never-the-less indicated that there is still a need for a succinct single compilation on the fate, effects and ecological risks associated with munitions constituents in aquatic environments.

3.5.3 Confined Aquatic Disposal Guidance and Training

Development of guidance and tools to encourage use of open-water CAD sites for contaminated sediment management offers potentially significant benefits for DoD activities, from logistic, project management, and cost perspectives. For CAD, untreated sediment is placed within a containment structure such as a natural or constructed bottom depression or berm, and capped with clean sediment. The cap must be designed to resist scour, erosion, and bioturbation. Despite the availability of materials fate modeling programs such as the Dredged Material Disposal Management Models,[2] selecting CAD as a technology and siting CAD sites often is problematic for both regulators and stakeholders.

Workshop participants recommended an updated guidance document and technology transfer program. The product would include a guidance document and training with the intended audiences (i.e., DoD and USEPA project managers) and with sufficient background documentation to be publicly-accessible. Important issues that the guidance should address include:

- Summary of the state of the science and engineering of CAD sites.
- Expert guidance that would facilitate siting a CAD (e.g., bottom and current characteristics or biological effects of CAD placement and capping).
- CAD design and construction methods.
- Long term operations, monitoring and maintenance requirements.
- Case studies with "lessons learned" from existing CADs.
- Documentation of social and technical issues needing resolution to gain public and regulatory acceptance.

3.5.4 Incorporation of Vessel-Created Erosion into Remedy Evaluation

With increased use of in situ remedial options (e.g., engineered capping, enhanced natural recovery, utilization of amendments, or monitored natural recovery), human-induced episodic event(s) that risk remedy permanence present engineering design challenges. Erosional forces created by propeller wash (prop wash) or ship wake can cause temporary resuspension and mobilization of existing contaminated sediments or cap materials, and could compromise the stability and long-term effectiveness of implemented in situ remedies. Because many DoD

[1] http://www.serdp.org/Featured-Initiatives/Munitions-Response-Initiatives/Munitions-in-the-Underwater-Environment; accessed 23 October 2012.
[2] http://el.erdc.usace.army.mil/products.cfm?Topic=model&Type=drgmat, chiefly STFATE

contaminated sediment sites are located in ports and harbors, the frequency and duration of prop or jet wash created by small recreational watercraft (e.g., jet skis) to large vessels (e.g., Navy ships, cargo ships, etc.) are an important consideration for remedy selection, design, and long-term monitoring. SERDP and ESTCP have sponsored research to develop better tools and models to address these erosional forces; both from natural erosional forces (ER-1497; Gailani, 2006) and specifically ship wake/prop wash (ER-201031; Wang, 2010).

To evaluate the feasibility and long-term effectiveness of remedial approaches, workshop participants identified the need for technology transfer program. A guidance document and specific training on the topic should include the following:

- Field deployable methods and collection techniques for assessing the erosional forces produced by watercraft/vessels that routinely navigate, or could navigate in the future, across a contaminated sediment site.
- Predictive models capable of producing outputs to help better understand and evaluate the influences of vessel movement at a contaminated sediment site.
- Guidance on how to evaluate the impact of ship wake wash on remedies incorporating sediment amendments.

3.5.5 Uncertainty Analysis Tools and Methodologies

Risk assessment, fate and transport analysis, remedial alternatives analysis, back-calculation of sediment concentrations, and other aspects of the remedial investigation (RI)/FS process often rely on the use of models and model outputs to base conclusions and, ultimately, the selection of remedies. Widespread criticism by both, and of both the regulated and regulator communities is often directed at the lack of a description of the uncertainty associated with the model outputs. For example, one cannot discern if the multiple runs of a bioaccumulation model, that is applied to predict a post-remedial time courses for fish tissue reductions and/or sediment concentrations under many different remedial alternatives, are meaningfully different from one another. Guidance is needed to provide information to project managers and their technical support personnel on how to quantitatively incorporate, present, and weigh model uncertainty in evaluating different scenarios (e.g., exposure types, remedial approaches). This will provide improved transparency within the technical documents and deliverables that are produced throughout the RI/FS process, and ultimately, will improve transparency on the basis of decisions that are made for sites.

4.0 Remedy Consensus Tools to Promote Innovative Technologies at Sites

Remediation risk assessment practitioners include individuals who socialize on the quantification and management of statistical risks as well as individuals who evaluate and consider how people perceive risks. Risk management decisions are influenced by both statistical and perceived risks. The latter becomes particularly important when the risks are unfamiliar and out of an individual's control. Sediment contamination is an example of a source of risk to health and the environment that is unfamiliar to the average person and also outside of a person's immediate control. As a result, risk perceptions become an important aspect of how risk managers and the public view the magnitude of the risk and the reliability of alternative remedial approaches. The most immediate reaction on the part of many is to remove the chemicals from the environment and this may be the most appropriate approach for many cases. However, as discussed in this and previous workshop reports, this is not always the best remedy for the system. Still, site managers and the public may not be willing to accept innovative technologies that address chemicals in place even though environmental scientists and engineers may consider these solutions as effective technologies and perhaps more appropriate than dredging at some sites.

Workshop participants recognize that better remedy consensus tools are needed to help advance the use of innovative technologies that address chemicals in place either through capping, in-situ treatment, or monitored natural recovery. This might involve providing risk managers and the public with a fuller understanding of the issue within the context of overall water quality goals and implications for health and the environment. This also might involve changes in the way sediment management projects are carried out and communicated. However, workshop participants recognized that the consideration of human perceptions into the sediment management process requires expertise in the social sciences. Therefore, a recommendation from the participants is to convene a workshop that focuses on how best to build consensus that can embrace the appropriate range of remedial technologies. This workshop would include social scientists with an understanding of environmental issues as well as scientists and engineers that work specifically on sediment management issues. A key focus of this meeting is to learn from the social scientists on how best to include perceptions. To that end, work will be needed in preparing for the meeting, and scientists and engineers familiar with sediment management should serve as resources rather than leaders of the workshop. Specific recommendations include:

- ESTCP should consider remedy consensus tools an important issue, but the individuals at this workshop are not appropriately equipped to make research recommendations.
- A separate workshop of suitable experts that could formulate issues associated with remedy consensus tools would better serve SERDP and ESTCP.

Some practitioners at the workshop advocated further research and demonstration of Net Environmental Benefit Analyses framework as a decision support tool. A net environmental benefit analysis (NEBA) framework is an approach that includes the formal quantification of how ecosystem services (ecological and socioeconomic), risks, and costs change given various alternative actions. Advocates of NEBA argued that the methodology allows alternatives to be

compared against each other to find the option that provides the greatest net ecosystem service benefit to the public while effectively managing site risks and remedial costs.

Ecosystem services are the benefits that natural resources provide to humans. These services generally fall into two categories: ecological services and human use services. Human use services can further be categorized as direct human use services (e.g., recreation, aesthetics, timber harvest) or indirect/passive human use services (e.g., climate moderation, flood control, ground water recharge, nutrient uptake, basic ecosystem support services, aesthetic value). In order to compare alternatives, it is important to formally quantify the projected changes in ecological and human use service values that would be associated with the implementation of each alternative. Formal quantification could provide an underlying basis from which decision-makers can make an informed and transparent decision that is necessary for all stakeholders.

The NEBA approach is consistent with USEPA risk management objectives and the development of remedial alternatives in the FS process (Efroymson et al., 2004; USEPA, 2009; Slackman, 2010, Nicolette et al., 2011). Risk assessors must consider the potential environmental injuries that could result from implementation of a remedy.

The USEPA and Department of the Interior (DOI) developed joint guidance on the coordination of site cleanup and natural resource restoration (DOI, 1999). This guidance provides a basis for NEBA and the incorporation of ecosystem service valuation into the site remedial alternative selection process. In addition, the NEBA framework has served to evaluate remedial alternatives associated with oil releases (NOAA, 2010) and the formalized process is outlined in Efroymson et al. (2003). However, it should be pointed out that several of the USEPA RPMs pointed out that NEBA is not a part of the NCP decision process for evaluating restoration alternatives.

The recommendation from these practitioners was that SERDP and ESTCP fund research into the NEBA process, specifically on methods to effectively quantify ecological and human services, and integrating those into the remedy decision process.

5.0 CONCLUSION

Sediment contamination remains a significant liability for DoD. In particular, the Navy has 500 sediment sites, with an estimated cost-to-complete of over $800M. Contaminants at these sites include a wide variety of compounds; PCBs, PAHs, various metals and metalloids, and military-unique compounds such as munitions constituents. Most of these contaminants tend to sorb and remain in the sediment long-term, resulting in a persistent contamination source to environmental receptors. Many conventional remediation approaches, such as dredging, tend to be costly, energy-intensive, and disruptive to the environment. Ex situ approaches can lead to further environmental concerns due to contaminant resuspension or volatilization. In situ approaches, such as natural recovery, amendments, and in situ capping, provide a cost-effective alternative to remediate and monitor contaminated sites, thereby reducing ecological and human health risks. However, in situ technologies are not widely implemented in the field, and concerns exist regarding their long-term effectiveness.

For the past 22 years, SERDP and ESTCP have funded over 50 projects to address the management of contaminated sediments in place and to assess the process that govern environmental risks. In 2004, SERDP and ESTCP recognized the need to hold strategic planning sessions to identify and prioritize research needs that could have the greatest impact on sediment site restoration. An Expert Panel Workshop was held in 2004 that resulted in a five-year plan that identified high priority needs for research and development. A second planning workshop was held in 2008 to determine what work was needed to facilitate regulatory acceptance and field implementation of sediment and soil bioavailability concepts to support risk assessments at DoD sites. Due to the changing DoD sediment site management priorities to achieve site closure, future efforts at contaminated sites will focus on completing feasibility studies, designing and implementing remedies, or be engaged in the long-term monitoring of the success of those implemented alternatives. New investigation work would largely be associated with identifying recontamination sources within the local and regional watersheds, as well as addressing emerging contaminants.

To address these issues, research, development, demonstration, and technology transfer needs were identified and prioritized.

- Critical research and development needs included issues with the long term effectiveness of remedies, passive samplers applications in the field, source quantification and threat to a remedy, capping for CAD-deposited sediment, improved food web conceptual models.
- High priority research and development needs included a broader application of passive samplers, tools for measuring facilitated transport in sediment, and new approaches to amended caps and in situ treatment.
- Critical demonstration needs included tools to evaluate amendment materials placement and construction, improved understanding of passive samplers results in the field as well as steps to gain regulatory acceptance, large-scale demonstrations pairing chemical and biological measurements, integration of technologies for a mixed remedy approach, decision support tool to incorporate trade-off analysis, long-

term monitoring tools, long term efficacy of amended caps, enhanced natural recovery.

- High priority demonstration needs included methodology to evaluate uncertainty quantitatively for remedy selection and decision analysis support. Technology transfer needs identified were related to the design of carbon amendments, munitions constituents compendium, current engineering approaches for CAD methods, and incorporation of prop wash into remedy evaluation.

Overarching issues throughout all breakout sessions included the need to for remedy consensus tools to promote innovative technologies at sites. In order to meet this need, further research is desired by a team of social scientists as well as environmental professionals on how to build consensus among parties with widely varied backgrounds and stakes.

The result of this workshop is a strategic plan to guide SERDP and ESTCP investments in research and demonstration needs to support the acceptance of in situ remediation technologies for the long-term management of contaminated sediments over the next five to ten years, ultimately benefiting environmental restoration efforts at DoD sites.

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APPENDIX A

SERDP and ESTCP Sediment-Related Projects

SERDP and ESTCP Sediment-Related Projects

Project Number (where "–xx" = year of initiation for SERDP projects or ER-xxxxyy = year of initiation for ESTCP projects), Project Title, Lead Investigator, (Program), (Status)

Fate and Transport

ER-2122-11, Tracking the Uptake, Translocation, Cycling, and Metabolism of Munitions Compounds in Coastal Marine Ecosystems Using Stable Isotopic Tracer, Craig Tobias (University of Connecticut) (SERDP) (In Progress)

ER-2123-11, Photochemical Transformation of Munitions Constituents in Marine Waters, Dianne Luning Prak (U.S. Naval Academy) (SERDP) (In Progress)

ER-2124-11, TNT Incorporation and Mineralization by Natural Microbial Assemblages at Frontal Boundaries Between Water Masses and in Underlying Sediments in Coastal Ecosystems, Mike Montgomery (U.S. Naval Research Laboratory) (SERDP) (In Progress)

ER-201031, Evaluation of Resuspension from Propeller Wash, Dredging and Extreme Storm Events in DoD Harbors, PF Wang (U.S. Navy SPAWAR Systems Center) (ESTCP) (In Progress)

ER-1495-06, Modeling and Decision Support Tools Based on the Effects of Sediment Geochemistry and Microbial Populations on Contaminant Reactions in Sediments, Jeanne vanBriesen (Carnegie Mellon University) (SERDP) (Complete)

ER-1453-05, Defining Munitions Constituents (MC) Source Terms in Aquatic Environments on DoD Ranges, Bill Wild (U.S. Navy SPAWAR Systems Center) (SERDP) (Complete)

ER-1431-05, Biotic and Abiotic Attenuation of Nitrogenous Energetic Compounds (NEC) in Coastal Waters and Sediments, Mike Montgomery (U.S. Naval Research Laboratory) (SERDP) (Complete)

ER-1209-01, Pathway Interdiction: A System for Evaluating and Ranking Sediment Contaminant Transport Pathways In Support of In-Place Management, Bart Chadwick (U.S. Navy SPAWAR Systems Center) (SERDP) (Complete)

Site Characterization and Monitoring

ER-201214, Demonstration of Fluorescent Magnetic Particles for Linking Sources to Sediments at DoD Sites. , Jim Leather (U.S. Navy SPAWAR Systems Center) (ESTCP) (In Progress)

ER-201128, Microelectrode Observatory for In Situ Monitoring of Metals Concentration and Mobility in Contaminated Sediments, Nancy Ruiz (NAVFAC ESC) (ESTCP) (In Progress)

ER-200919, Demonstration of an In-Situ Friction-Sound Probe for Mapping Particle Size at Contaminated Sediment Sites, Bart Chadwick (U.S. Navy SPAWAR Systems Center) (ESTCP) (In Progress)

ER-200826, Integrated Forensics Approach to Fingerprint PCB Sources using Rapid Screening Characterization (RSC) and Advanced Chemical Fingerprinting (ACF), Jim Leather (U.S. Navy SPAWAR Systems Center) (ESTCP) (Complete)

ER-1502-06, Application of Tools to Measure PCB Microbial Dechlorination and Flux into Water during In-Situ Treatment of Sediments, Joel Baker (University of Maryland) (SERDP) (Complete)

ER-1497-06, Develop Accurate Methods for Characterizing and Quantifying Cohesive Sediment Erosion under Combined Current-Wave Conditions, Joe Gailani (U.S. Army ERDC-EL) (SERDP) (Complete)

ER-200422, Monitoring of Water and Contaminant Migration at the Groundwater-Surface Water Interface, Bart Chadwick (U.S. Navy SPAWAR Systems Center) (ESTCP) (Complete)

ER-199717, Rapid Sediment Characterization, James M. Leather (U.S. Navy SPAWAR Systems Center) (ESTCP) (Complete)

ER-199712, Quantifying In Situ Contaminant Mobility in Marine Sediments, Brad Davidson (U.S. Navy SPAWAR Systems Center) (ESTCP) (Complete)

Bioavailability of Contaminants

ER-201216, Sediment Bioavailability Initiative (SBI): Development of Standard Methods and Approaches for the Use of Passive Samplers in Assessment and Management of Contaminated Sediment, Charlie Menzie (Exponent) (ESTCP) (In Progress)

ER-1744-10, Bioavailability and Methylation Potential of Mercury Sulfides in Sediments, Heileen Hsu-Kim (Duke University) (SERDP) (In Progress)

ER-1745-10, Coupling between Pore Water Fluxes, Structural Heterogeneity & Biogeochemical Processes Controls Contaminant Mobility, Bioavailability, & Toxicity in Sediments, Aaron Packman (Northwestern University) (SERDP) (In Progress)

ER-1746-10, Predicting the Fate and Effects of Resuspended Metal Contaminated Sediments, Allen Burton (University of Michigan) (SERDP) (In Progress)

ER-1747-10, Robust Means for Estimating Black Carbon-Water Sorption Coefficients of Organic Contaminants in Sediments, Philip Gschwend (MIT) (SERDP) (In Progress)

ER-1748-10, Development of an Electrochemical Surrogate for Copper, Lead, and Zinc Bioaccessibility in Aquatic Sediments, Aaron Slowey (U.S. Geological Survey) (SERDP) (In Progress)

ER-1750-10, The Biology of Bioavailability: The Role of Functional Ecology in Exposure Processes, Todd Bridges (U.S. Army ERDC-EL) (SERDP) (In Progress)

ER-1771-10, Assessing Mercury and Methylmercury Bioavailability in Sediment Porewater Using Mercury-Specific Hydrogels, Victor Magar (Environ) (SERDP) (In Progress)

ER-200915, Passive PE Sampling in Support of In Situ Remediation of Contaminated Sediments, Philip Gschwend (MIT) (ESTCP) (In Progress)

ER-200709, The Determination of Sediment Polycyclic Aromatic Hydrocarbon (PAH) Bioavailability using Supercritical Fluid Extraction (SFE) and Ultra-Trace Porewater (UTP) Analysis, Dave Nakles (RETEC) (ESTCP) (Complete)

ER-200624, Demonstration and Evaluation of Solid Phase Microextraction for the Assessment of Bioavailability and Contaminant Mobility, Danny Reible (University of Texas) (ESTCP) (Complete)

ER-1503-06, Biological Processes Affecting Bioaccumulation, Transfer, and Toxicity of Metal Contaminants in Estuarine Sediments, Celia Chen (Dartmouth College) (SERDP) (Complete)

ER-1496-06, Using Passive Polyethylene Samplers to Evaluate Chemical Activities Controlling Fluxes and Bioaccumulation of Organic Contaminants in Bed Sediments, Philip Gschwend (MIT) (SERDP) (Complete)

ER-1494-06, An Integrated Field and Laboratory Study of the Bioavailability of Metal Contaminants in Sediments, Nick Fisher (Stonybrook University) (SERDP) (Complete)

ER-1095-98, Assessment & Prediction of Biostabilization of PAHs in Sediment, Jeff Talley (U.S. Army ERDC-EL) (SERDP) (Complete)

In Situ Treatment

Amendments

ER-201215, Evaluating the Efficacy of Bioaugmentation for In-Situ Treatment of PCB Impacted Sediments, Kevin Sowers (University of Maryland, Baltimore County) (ESTCP) (In Progress)

ER-201131, Demonstration of In-Situ Treatment with Reactive Amendments for Contaminated Sediments in Active DoD Harbors, Bart Chadwick (U.S. Navy SPAWAR Systems Center) (ESTCP) (In Progress)

ER-2134-11, A Permeable Active Amendment Concrete (PAAC) for Contaminant Remediation and Erosion Control, Anna Knox (Savannah River National Laboratory) (SERDP) (In Progress)

ER-2135-11, Application of Biofilm Covered Activated Carbon Particles as a Microbial Inoculum Delivery System for Enhanced Bioaugmentation of PCBs in Contaminated Sediment, Birthe Kjellerup (Goucher College) (SERDP) (In Progress)

ER-2136-11, Activated Biochars with Iron for In Situ Sequestration of Organics, Metals, and Carbon, Upal Ghosh (University of Maryland, Baltimore County) (SERDP) (Completed)

ER-200835, Evaluating the Efficacy of a Low-Impact Delivery System for In-Situ Treatment of Sediments Contaminated with Methylmercury and Other Hydrophobic Chemicals, Charlie Menzie (Exponent) (ESTCP) (In Progress)

ER-200825, In Situ Wetland Restoration Demonstration, Amy Hawkins (NAVFAC ESC) (ESTCP) (In Progress)

ER-1492-06, Quantifying Enhanced Microbial Dehalogenation Impacting the Fate and Transport of Organohalide Mixtures in Contaminated Sediments, Max Haggblom (Rutgers University) (SERDP) (Complete)

ER-1491-06, Rational Selection of Tailored Amendment Mixtures and Composites for In Situ Remediation of Contaminated Sediments, Upal Ghosh (University of Maryland, Baltimore County) (SERDP) (Complete)

ER-200510, Field Testing of Activated Carbon Mixing and In Situ Stabilization of PCBs in Sediment, Dick Luthy (Stanford University) (ESTCP) (Complete)

ER-1207-01, In Situ Stabilization of Persistent Organic Contaminants in Marine Sediments, Dick Luthy (Stanford University) (SERDP) (Complete)

ER-1208-01, In-Situ Enhancement of Anaerobic Microbial Dechlorination of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Marine and Estuarine Sediments, Max Haggblom (Rutgers University) (SERDP) (Complete)

Active Caps

ER-1501-06, Innovative In-Situ Remediation of Contaminated Sediments for Simultaneous Control of Contamination and Erosion, Anna Knox (Savannah River National Laboratory) (SERDP) (Complete)

ER-1493-06, Reactive Capping Mat Development and Evaluation for Sequestering Contaminants in Sediments, Amy Hawkins (NAVFAC ESC) (SERDP) (Complete)

ER-1370-04, Characterization of Contaminant Migration Potential through In-Place Sediment Caps, Victor Magar (Battelle) (SERDP) (Complete)

ER-1371-04, Integrating Uncertainty Analysis in the Risk Characterization of In-Place Remedial Strategies for Contaminated Sediments, Peter Adriaens (University of Michigan) (SERDP) (Complete)

Monitored Natural Recovery

ER-200622, Development of DoD Guidance for Monitored Natural Recovery at Contaminated Sediment Sites, Victor Magar (Environ) (ESTCP) (Complete)

Ecological Risk Characterization

ER-201130, Demonstration and Commercialization of the Sediment Ecosystem Assessment Protocol (SEAP), Gunther Rosen (U.S. Navy SPAWAR Systems Center) (ESTCP) (In Progress)

ER-2125-11, Ecological Risk Assessment of Munitions Compounds on Coral and Coral Reef Health, Cheryl Woodley (NOAA) (SERDP) (In Progress)

ER-1551-07, Bacterial and Benthic Community Response to Inorganic and Organic Sediment Amendments, Yolanda Arias-Thode (U.S. Navy SPAWAR Systems Center) (SERDP) (Complete)

ER-1552-07, Measurement and Modeling of Ecosystem Risk and Recovery for In Situ Treatment of Contaminated Sediments, Dick Luthy (Stanford University) (SERDP) (In Progress)

ER-1550-07, Sediment Ecosystem Assessment Protocol (SEAP): An Accurate and Integrated Weight-of-Evidence Based System, Allen Burton (University of Michigan) (SERDP) (Complete)

ER-200523, Demonstration of an Integrated Compliance Model for Predicting Copper Fate and Effects in DoD Harbors, Bart Chadwick (U.S. Navy SPAWAR Systems Center) (ESTCP) (Complete)

ER-1156-00, Determining the Fate and Ecological Effects of Copper and Zinc Loading in Estuarine Environments: A Multi-Disciplinary Program, Bart Chadwick (U.S. Navy SPAWAR Systems Center) (SERDP) (Complete)

ER-1157-00, Speciation, Fluxes, and Cycling of Dissolved Copper and Zinc in Estuaries: The Roles of Sediment Exchange and Photochemical Effects, Stephen Skrabal (University of North Carolina) (SERDP) (Complete)

ER-1158-00, Speciation, Sources and Bioavailability of Copper and Zinc in DoD-Impacted Harbors and Estuaries, Martin Shafer (University of Wisconsin) (SERDP) (Complete)

ER-1129-99, Biological Assessment for Characterizing Contaminant Risk of Military Unique Compounds at the Genetic-, Individual-, Population-Level, Todd Bridges (U.S. Army ERDC-EL) (SERDP) (Complete)

Munitions Constituents

ER-2122-11, Tracking the Uptake, Translocation, Cycling, and Metabolism of Munitions Compounds in Coastal Marine Ecosystems Using Stable Isotopic Tracer, Craig Tobias (University of Connecticut) (SERDP) (In Progress)

ER-2123-11, Photochemical Transformation of Munitions Constituents in Marine Waters, Dianne Luning Prak (U.S. Naval Academy) (SERDP) (In Progress)

ER-2124-11, TNT Incorporation and Mineralization by Natural Microbial Assemblages at Frontal Boundaries Between Water Masses and in Underlying Sediments in Coastal Ecosystems, Mike Montgomery (U.S. Naval Research Laboratory) (SERDP) (In Progress)

ER-2125-11, Ecological Risk Assessment of Munitions Compounds on Coral and Coral Reef Health, Cheryl Woodley (NOAA) (SERDP) (In Progress)

ER-1453-05, Defining Munitions Constituents (MC) Source Terms in Aquatic Environments on DoD Ranges, Bill Wild (U.S. Navy SPAWAR Systems Center) (SERDP) (Complete)

ER-1431-05, Biotic and Abiotic Attenuation of Nitrogenous Energetic Compounds (NEC) in Coastal Waters and Sediments, Mike Montgomery (U.S. Naval Research Laboratory) (SERDP) (Complete)

ER-1129-99, Biological Assessment for Characterizing Contaminant Risk of Military Unique Compounds at the Genetic-, Individual-, Population-Level, Todd Bridges (U.S. Army ERDC-EL) (SERDP) (Complete)

APPENDIX B

Agenda

Workshop on Research and Development Needs for Long-Term Management of Contaminated Sediments

Seattle, WA 98101

WEDNESDAY, JULY 25, 2012			
0800	**Registration/Continental Breakfast**		
0830	**Welcome and Introduction** **Workshop Objectives and Structure** *(Plymouth Room)*	Andrea Leeson SERDP and ESTCP	
0845	SERDP and ESTCP Twenty-two Years of Sediment Management Research and Development	Andrea Leeson SERDP/ESTCP	Tim Thompson SEE LLC
0915	Sediment Site Restoration: Current Status and Barriers to Achieving those Goals – Regulatory Perspective	Steve Ells U.S. EPA	
0945	Sediment Site Restoration: Current Status and Barriers to Achieving those Goals – Army Perspective	John Wakeman U.S. Army	
1015	**Break**		
1030	National Perspective on Sediment Restoration Technologies	Paul Schroeder ERDC	
1100	U.S. Navy RPM Perspective on Sediment Restoration • Data Needs to Guide Selection of a Restoration Alternative • Science and Demonstration Needs for In Situ Remedy Selection • Engineering and Cost Considerations for Sediment Restoration • Sediment Site Survey and Related Needs	Michael Pound U.S. Navy	
1130	Long Term Operations (LTO) and Long Term Monitoring (LTM) Considerations	Victor Magar ENVIRON	
1200	**Lunch**		
1230	**Breakout Session I Discussions: Data Gaps** • *Breakout Group 1 – Plymouth Room* • *Breakout Group 2 – Waverly Room* • *Breakout Group 3 – Board Room*	Breakout Groups	
1500	**Break**		
1515	Breakout Groups Continue	Breakout Groups	
1610	**Break**		
1615	Reconvene General Session: Recap of Day/Overview for Next Day *(Plymouth Room)*	Andrea Leeson SERDP and ESTCP	
1630	Reception with Poster Session *(Fireside Area)*		
1800	**Adjourn**		

THURSDAY, JULY 26, 2012		
0800	**Continental Breakfast**	
0830	Report from Breakout Session I *(Plymouth Room)*	Breakout Session Chairs
0915	**Breakout Session II Discussions: Development and Prioritization of Research Needs and Technology Transfer Opportunities** • *Breakout Group A – Board Room* • *Breakout Group B – Plymouth Room* • *Breakout Group C – Waverly Room*	Breakout Groups
1115	**Break**	
1145	Reports from Breakout Session II *(Plymouth Room)*	Breakout Session Chairs
1225	Closing Summary and Remarks	Andrea Leeson SERDP and ESTCP
1230	**Workshop Adjourn**	

APPENDIX C

Attendee List

Workshop Attendees

Kym Anderson
Port of Seattle

David Barclift
NAVFAC Atlantic

Todd Bridges, Ph.D.
U.S. Army Engineer Research & Development Center

Sean Bushart, Ph.D.
Electric Power Research Institute

Bart Chadwick, Ph.D.
SPAWAR SSC

Young Chang
U.S. EPA Region 2

YeoMyoung Cho, Ph.D.
Stanford University

Jeff Clock
Electric Power Research Institute

Chuck Coyle
U.S. Army Corps of Engineers

Stephen Ells
U.S. EPA

Yoko Furukawa, Ph.D.
Naval Research Laboratory

Dina Ginn
NAVFAC Northwest

Marc Greenberg, Ph.D.
U.S. EPA Superfund

Philip Gschwend, Ph.D.
Massachusetts Institute of Technology

Heather Henry, Ph.D.
National Institute of Environmental Health Sciences – Superfund Research Program

Allison Hiltner
U.S. EPA

Robert Johnston, Ph.D.
SPAWAR SSC PAC

Melanie Kito
NAVFAC Southwest

Carmen Lebrón
NAVFAC ESC

Andrea Leeson, Ph.D.
SERDP and ESTCP

Kira Lynch
U.S. EPA

Victor Magar, Ph.D.
ENVIRON International Corporation

Kim Markillie
U.S. Navy

Charles Menzie
Exponent

Mandy Michalsen, Ph.D.
U.S. Army Corps of Engineers

Marc Mills, Ph.D.
U.S. EPA

Mark Murphy
U.S. Army Corps of Engineers

Allison O'Brien
U.S. Army – Aberdeen Proving Ground

Cara Patton
HydroGeoLogic, Inc.

Michael Pound
NAVFAC Southwest

Danny Reible, Ph.D.
University of Texas at Austin

Deanne Rider
HydroGeoLogic, Inc.

Paul Schroeder, Ph.D.
U.S. Army Engineer Research &
Development Center

Jason Speicher
FirstEnergy Corporation

Timothy Thompson
Science and Engineering for the
Environment, LLC

Gregory Tracey, Ph.D.
SAIC

John Wakeman
U.S. Army Corps of Engineers

Patricia White
CH2M HILL

Mark Wicklein
NAVFAC Northwest

APPENDIX D

Presentations

SERDP and ESTCP Twenty-Two Years of Sediment Management Research and Development

Andrea Leeson
SERDP/ESTCP

Tim Thompson
SEE, LLC

25 July 2012

SERDP DOD • EPA • DOE | ESTCP

SERDP DOD • EPA • DOE

ESTCP

Research & Development Program

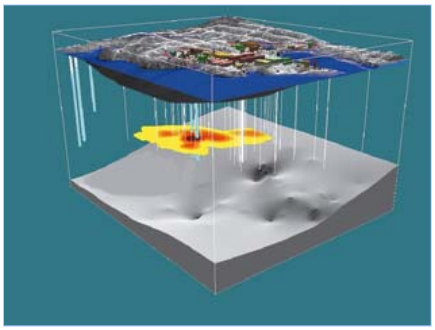
Demonstration & Validation Program

SERDP and ESTCP Program Areas

- Environmental Restoration
- Energy and Water
- Munitions Response
- Resource Conservation and Climate Change
- Weapons Systems and Platforms

Environmental Restoration

Research and technologies for the characterization, risk assessment, remediation, and management of contaminants in soil, sediments, and water.



Contaminated Sediments

Research and demonstrations to advance the in-place management of contaminated sediments and assess the processes that govern ecological and human health risks.

- Fate and Transport
- Site Characterization and Monitoring
- Bioavailability of Contaminants
- In Situ Treatment
- Ecological Risk Characterization

Munitions in the Underwater Environment

- Research focused on understanding fate, transport, ecological effect of munitions constituents in the underwater environment
- Development and demonstration of new capabilities for detecting underwater munitions.
  - Wide area assessment to locate concentrations of munitions
  - Detailed surveys of individual items

Sediment Initiative

SERDP and ESTCP have funded over 50 projects over the past 22 years to address the management of contaminated sediments in place and to assess the processes that govern environmental risks.

SERDP/ESTCP Investment	
SERDP	31.7M
ESTCP	17.6M
Total	**49.3M**

Sediment Initiative

- A Review Panel was created with experts in the field to review the projects and make recommendations to the Program Office.
  - Review Panel Members
    - Michael Pound (U.S. Navy)
    - Steve Ells (U.S. Environmental Protection Agency)
    - Jason Speicher (First Energy Corp.)
    - John Wakeman (U.S. Army)
    - Tim Thompson (SEE, LLC)

Sediment Workshop (2004)

- Objectives:
  - Examine the state of science and engineering associated with the management of contaminated sediments
  - Identify the gaps in knowledge and technology
  - Prioritize those gaps where investments in research and development or field demonstrations could have the greatest impact on sediment remediation
- Summary report available on the SERDP and ESTCP website
  - Workshop Report - *Expert Panel Workshop on Research and Development Needs for the In Situ Management of Contaminated Sediments*
  - www.serdp-estcp.org Located under Program Areas > Environmental Restoration > Contaminated Sediments

Bioavailability Workshop (August 2008)

- Objectives
  - Examine state of the science and technology for understanding and assessing bioavailability processes in sediments
  - Evaluate current and potential future applications of bioavailability concepts and assess barriers to their implementation
  - Identify and prioritize research and demonstration opportunities that could facilitate use of bioavailability in decision making at DoD Sites.
- Summary report available on the SERDP and ESTCP website
  - Workshop Report - *Expert Panel Workshop on Research and Development Needs for Understanding and Assessing the Bioavailability of Contaminants in Soils and Sediments*
  - www.serdp-estcp.org Located under Program Areas > Environmental Restoration > Contaminated Sediments

Active and Recently Completed SERDP and ESTCP Projects

- See handout

Partners in Environmental Technology Technical Symposium & Workshop

November 27 – 29, 2012
Washington Hilton, Washington D.C.
www.serdp-estcp.org/symposium

This annual event assembles researchers and technology developers with the defense user and regulatory communities to showcase cutting edge technologies and ideas, as well as communicate DoD's challenges.

Technical Session & Short Course topics include:

- Long-Term Mgmt of Contaminated Sediments (TS)
- DoD Restoration Goals (TS)
- Vapor Intrusion (TS)
- Emergine Contaminants (TS)
- Passive Samplers for Contaminated Sediments (SC)
- Operational Range BMPs (SC)
- Matrix Diffusion Decision Tool (SC)

R&D Needs for Long Term Management of Contaminated Sediments (2012)

- Strategic planning session to identify and prioritize research needs that could have the greatest impact on sediment site restoration in the next 5 years
- Focuses on site closure, completing feasibility studies, designing and implementing remedies, and/or engaged in the long-term monitoring of the implemented alternatives
- Organized this Workshop to learn
  - What data gaps in addition to technology needs where additional research and development or field demonstrations would improve the understanding and assessment of the long-term management of contaminated sediments

Breakout Session 1: Data Gaps and Technology needs

- Identify additional R&D or field demonstrations that would improve the understanding and assessment of the long-term management of contaminated sediments
- Charge questions Include, but not limited to:
  - Remedy Selection
  - Source Control and Recontamination
  - Active/Amended Caps
  - Emerging Contaminants
  - Barriers to Dredging
  - Long term Monitoring
  - “Other”

Breakout Session 2: Identify and prioritize research, development, demonstration, and technology transfer needs, building on the results of Breakout Session I.

- Identify and prioritize the research and development needs that will have the greatest impact on cost-effective long-term management of contaminated sediments.
- Identify and prioritize the demonstration and technology transfer efforts needed to improve cost-effective long-term management of contaminated sediments.

Pre-meeting Identified "Needs"

- Pre-meeting phone calls
  - Spoke with 2/3 of the attendees
  - Discussed what they saw as problematic issues with their own sites/projects
  - Asked their view of issues related to the charge questions
  - Found common areas, and ranked those in terms of frequency they were mentioned
- This should only be a starting point for discussion
  - Want to learn what are the best investments the Program can make to positively impact the way remedial decisions are made

Remedy Selection – Research Needs

- Developing scientifically defensible methods for developing cleanup values
- Area weighted averaging
- Natural and Anthropogenic Background Levels
- Efficacy of sediment remediation in protecting human health and the environment
- Passive Samplers
- Improving/Standardizing Cap Design.
- Remedy Life Cycle/Risk Management Approach.

Remedy Selection – Technology Transfer

- Guidance on Remedial Alternative Selection.
- Site Remedial Case Studies
- Fate and Transport Model Training

Source Control – Research Needs

- Develop scientifically defensible models for determining TMDL thresholds that are protective of sediments within a specific watershed AND develop methods for allocating those thresholds (Waste Load Allocations).
- Sediment Cleanup and Source Control
- Groundwater Discharge to Sediments
- “How controlled is controlled?”

Source Control – Technology Transfer

- Guidance document comparing and contrasting different models for use with source control.
- Source control identification/Source Tracking (monitoring tools, existing approaches, existing methods)

Amended Caps – Research Needs

- Long Term Efficacy of Active Caps
- Enhanced Natural Recovery and Amended Caps
- Stakeholder Issues
- Active Caps for Munitions Constituents.
- O&M - Long Term Costs.

Amended Caps – Demonstration and Tech Transfer Needs

- Demonstration
  - Mechanisms for putting out carbon over (1) large areas in (2) deep water and (3) dynamic environments
  - Stabilization of amended caps
  - Scale: Demonstration Projects at larger sites (10 acres)
  - Longevity of amended caps; O&M needs)
- Tech Transfer
  - Guidance on in Active Caps - in situ treatments/amendments.

Emerging Contaminants – Research Needs

- Toxicity, fate and transport of emerging contaminants
- Munitions screening/toxicity in sediments.
- Breakdown of Munitions Casings
- In situ Management of Munitions Compounds.
- Science related to dioxin fate and transport from sediment to fish.
- Better and Inexpensive Methods for Speciation of mercury and methylmercury
- Other Existing/Emerging Contaminants

Emerging Contaminants Demonstration Needs

- Underwater detection for munitions.
- Fate and transport of munition compounds from sediments to water to tissue.

Dredging – Research/ Tech Transfer Needs

- Dredge Residual Management
- Confined Aquatic Disposal
- Debris Management
- Pilot studies on dredging discarded military munitions and/or unexploded ordnance.
- Guidance on Dredging Equipment, Performance, Costs

Long Term Monitoring –Research and Tech Transfer Needs

- Tools for characterizing conditions pre- and post-remediation, post-remedial performance, and LTM
- Cap Monitoring
- Monitoring and interpretive criteria for remedy success.
- Reliability and monitoring of armored caps
- LTM Resource Guide and Training

"Other" Research Needs

- Fish windows
- Managing sea level rise
- Scientifically defensible area use factors
- Connecting Ecosystem Services to Restoration
- Reconstruction of habitat post-remediation
- Long term microbial behavior in amended caps
- Improving Tech Transfer
- Decision Support Tools
- Scale for capping or in situ projects

Visit www.serdp-estcp.org for more information about…

- **Funding Opportunities:** View solicitations and deadlines.
- **Program Areas:** Learn more about our investments in Energy & Water, Environmental Restoration, Munitions Response, Resource Conservation & Climate Change, and Weapons Systems & Platforms.
- **Featured Initiatives:** Explore the latest developments in science, engineering, and technology.
- **Tools & Training:** Put innovative research and technology to use.
- **E-mail Distribution Lists** and **RSS:** Sign up to receive notification of updates in your areas of interest.

Sediment Site Remediation: Current Status and Barriers to Achieving Our Goals – An EPA Perspective

SERDP/ESTCP Workshop, Seattle, July 25, 2012

Dredging on the Hudson River

Capping on the Fox River

Stephen Ells, EPA , Office of Site Remediation and Technology Innovation

Briefing Outline

- Historical Perspective
- Risk Management Principles
- Key Policy Issues: EPA, PRPs and Communities
- Upcoming Big Site Decisions
- Key Messages
- Challenges and Future Efforts
- Discussion on Next Steps

A Timeline of Key Contaminated Sediment Remediation Activities

1988 — 2000 — 2012

1988
- First Capping Remedy Implemented: St. Paul Waterway

1992
- First Dredging Remedy Implemented: Outboard Marine

1998
- Federal Workgroup Formed to Write Sediment Guidance

2001
- NRC Report on PCBs Risk Management Strategy
- US EPA Forum on Managing Contaminated Sediments at Hazardous Waste Sites (First Open Dialogue)

2002
- Hudson River ROD signed, Feb. 1
- 11 Sediment Risk Management Principles Memo Issued , CSTAG formed , Feb. 12
- USEPA/USACE/Navy/SMWG Workshop on Sediment Stability (#1)

2003
- EPA Meeting on PCB Sites (EPA-only)
- USEPA/USACE/SMWG Workshop on Environmental Stability of Chemicals in Sediments (#2)

2004
- USEPA/USACE/SMWG Conference on Addressing Uncertainty and Managing Risk at Contaminated Sediment Sites (#3)
- Superfund Sediment Resource Center established in OSRTI

2005
- Contaminated Sediment Remediation Guidance for Hazardous Waste Sites Issued
- Sediment Remediation Course: Technical Considerations for Evaluating and Implementing Dredging and Capping Remedies (Four EPA Regional and two public offerings, from 2005 through 2007)
- Federal Agency Sediment Research Collaboration Workgroup established

2006
- OSWER/OW Manual on Integrating Water and Waste Programs to Restore Watersheds

A Timeline of Contaminated Sediment Remediation at EPA

1988 — 2000 — 2012

2007
- NRC Dredging Report

2008
- The Four R's of Environmental Dredging: Resuspension, Release, Residuals and Risk Workshop and Report
- First Sediment Assessment and Monitoring Sheet (SAMS): Using Fish Tissue Data to Monitor Remedy Effectiveness
- USEPA/USACE/SMWG Conference on Optimizing Decision-Making and Remediation at Complex Sediment Sites (#4)
- Technical Guidelines for Environmental Dredging of Contaminated Sediments

2009
- Second SAMS: Understanding the Use of Models Predicting the Effectiveness of Proposed Remedial Actions at Superfund Sediment Sites

2010
- Hudson River Dredging, Phase 1, Peer Review
- USEPA/USACE/SMWG Conference: The Alpha and The Omega and Points In Between (The Beginning and The End) (#5)

2011
- 3 Regional Training Workshops: Smart from the Start: Addressing Wicked Problems at Contaminated Sediment Sites
- List of Tier 1 Contaminated Sediment Sites and Their Characteristics Completed
- USACE/SMWG Workshop: Working Toward a New Contaminated Sediment Site Paradigm
- Draft Directive: Clarification on Developing Cleanup Levels, Performing Early Actions, and Focusing the RI/FS on Comparing Remedial Alternatives

2012
- Guidance on Conducting a Sediment Erodability and Deposition Assessment
- Third SAMS: Developing and Using SWACs at Sediment Sites
- Fourth SAMS: Using Passive Samplers at Superfund Sites
- Fifth SAMS on CSOs at Superfund Sites
- Fact Sheet on In Situ Remediation for Contaminated Sediments

Tier 1 Sediment Site Data

- 70 sites, 120 areas within sites
- Tier 1 sites
  - Signed decision document
  - 10,000 yd^3 or more dredged, or
  - 5 acres or more capped or MNR
- Key data
  - COCs
  - Volume removed, area capped
  - Costs
  - RAOs and cleanup levels
  - 5-yr review results

2002 Risk Management Principles

1. Control sources early
2. Involve the community early and often
3. Coordinate with States, Local Governments, Tribes and Trustees
4. Develop and refine a conceptual site model that considers sediment stability
5. Use an iterative approach in a risk-based framework
6. Carefully evaluate the assumptions and uncertainties associated with site characterization data and site models

More Principles

7. Select site-specific, project-specific, and sediment-specific risk management approaches that will achieve risk-based goals
8. Ensure that cleanup levels are clearly tied to risk management goals
9. Maximize the effectiveness of ICs and recognize their limitations
10. Design remedies to minimize short-term risks while achieving long-term protection
11. Monitor during and after remediation to assess and document remedy effectiveness

EPA's Overarching Goal

(Principle Uno)

Project managers should develop a conceptual site model that considers key site uncertainties. Such a model can be used within an adaptive management approach to control sources and to implement a cost-effective remedy that will achieve long-term protection while minimizing short-term impacts. (2005 Seds Guidance, P 7-16)

Barriers to Success

- Continued preference for dredging vs. capping, enhanced MNR, amendments
- Lack of confidence in risk reduction predictions from MNR
- Risk-based, protective, cleanup levels are very low and can't be reached in reasonable time frame, and are often below background
- Few early actions taken despite obvious site risks
- Baseline and post-remedy monitoring data often inadequate
- SF and non-SF cleanups and source control efforts; e.g., CSOs, are not well coordinated and often result in recontamination
- Need for remediation is not driven by human health or eco risks but by human need to take action to deal with a perceived problem

PRP Issues

- RPMs don't follow 2005 Seds Guidance
- RI/FS takes too long and costs too much
- Cost effectiveness not given fair consideration
- Mass removal trumps risk reduction
- CSOs often not controlled, so will be recontamination
- No covenant-not-to-sue given for early actions/removals
- Trustees and NGOs want restoration done as part of or in addition to remediation
- Not using local landfills can increase costs 30%

Community Issues

- No disposal in local (or state) landfills
- All contamination should be removed, caps are temporary and MNR = “a wink and a walk”
- Why haven’t scientists developed pixy dust yet
- Should have more say in remedy decision
- Conflicting views and strong opinions among groups, some motivated by economic development and “betterments”

Upcoming Records of Decision

- Centredale Manor, RI – dioxins
- Housatonic River, MA/CT – PCBs
- Lower Duwamish Waterway, WA - PCBs
- Passaic River, NJ – dioxins and PCBs
- Portland Harbor, OR – PCBs, PAHs, metals
- Grasse River, NY – PCBs
- Gowanus Canal, NY – PAHs
- Tittabawassee/Saginaw R., MI – dioxins, PCBs

Key Messages from EPA Sediments Team

- The 2005 Seds Guidance is still sound; may issue new Directive to reinforce need to follow key recommendations
- Technical information on better tools and methods is being provided to RPMs via training and SAMS fact sheets; acceptance and use will take time
- Must collect good monitoring data at all sites to allow us all to evaluate and compare effectiveness of different alternatives
- Other than in-situ amendments, no new sediment treatment technologies ready to use
- In face of current uncertainties, should use structured adaptive management to address complex sites

Challenges to Future Efforts

- How address preference for mass removal when not justified by risk reduction?
- How get RPMs and Regional Attorneys to accept more uncertainty and move forward?
  - Streamline RI/FS by focusing on key exposure scenarios
  - Take early actions in the face of uncertainties; monitor results
  - Use in-situ amendments and reactive caps
  - Push back on stakeholders with unjustified demands
- How get upstream point and non-point sources controls sequenced with active remediation of sediments?
- How resolve technical and policy issues at the staff level before elevating to the political level where science has little role?
- How important is national consistency in a program delegated to 10 individualistic Regions?

Next Steps for EPA?

Workshop on Research and Development Needs for Long-Term Management of Contaminated Sediments

Army Needs

John Wakeman, Seattle District, US Army Corps of Engineers

July 25, 2012

SERDP DOD • EPA • DOE | ESTCP

Outline

- **Army-managed Contaminated Sediment Sites (CSS)**
  - Are Army's Needs Different from the Navy's?
  - Trends in Types of Sites or Program Emphasis
- **Critical Gaps or Barriers**
  - Characterization/Assessment Methods
  - Remedy Selection, Implementation, Long-term Monitoring

The Players in “Wicked Projects”

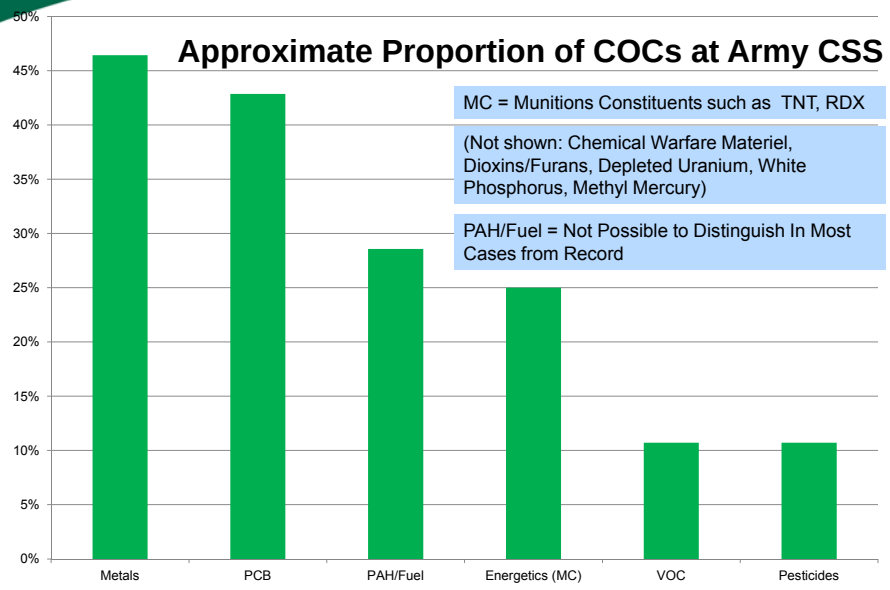
• *Innovation* means getting the good witch on your team to find the right way to do it.
• *Return on investment* means establishing a process that saves a) time for characterizing and remediating a site and b) funds to accomplish it.

Army Program for CSS

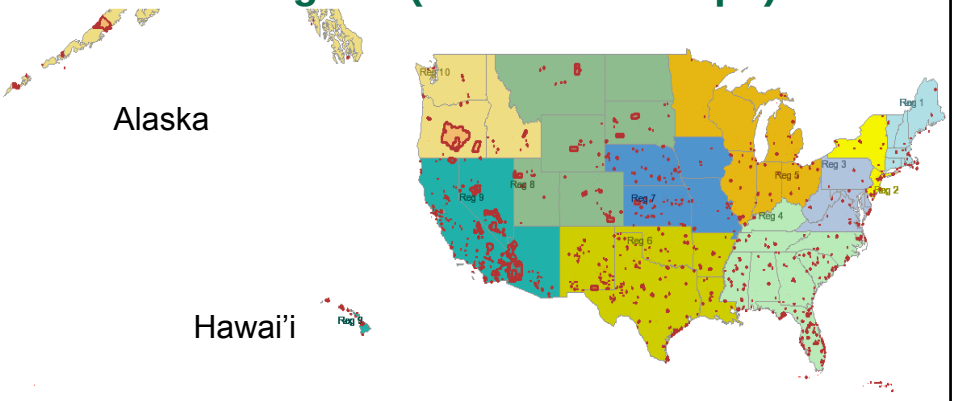
- **Environmental Liability and Stewardship**
- **Military (Defense Environ. Restoration Act)**
  - **Installation Restoration Program (IRP: Owned & Managed or Leased Lands)**
  - **Base Realignment and Closure (BRAC)**
  - **DERP (Defense Environmental Restoration Program)**
    - Formerly Used Sites (FUDS, Often Former Navy Sites)
    - Military Munitions Response Program (MMRP)
- **Civil Works (Congressional Authorizations)**
- **National Priorities List**

Are Army CSS Different from Navy's?

- **Scale:**
  - ♦ Many Sites are Former Navy Sites from WWII or Cold War (Similar)
  - ♦ Few Sites are Port or Harbor Sites (Different)
- **Proportion: Higher Terrestrial (~75%)**
  - ♦ Former Ammunition Manufacturing and Demilitarization Sites
  - ♦ Bombing and Training Ranges
    - Terrestrial Ranges with Marginal Wetlands or Water Bodies, Often Sensitive Sites (Different)
    - However, a Few Marine Ranges (Similar)
- **Contaminants:** Similar List, Different Emphases



FUDS Program (Illustrates Scope)

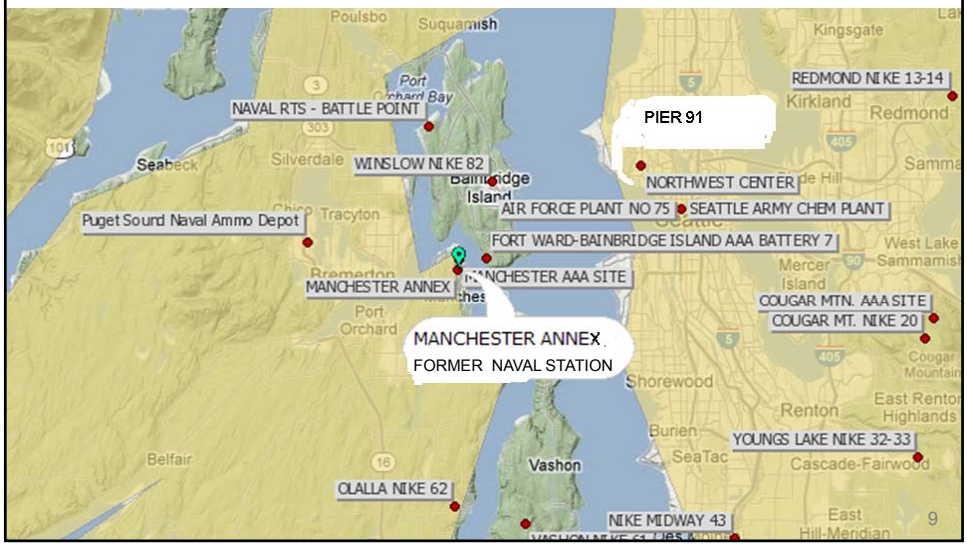


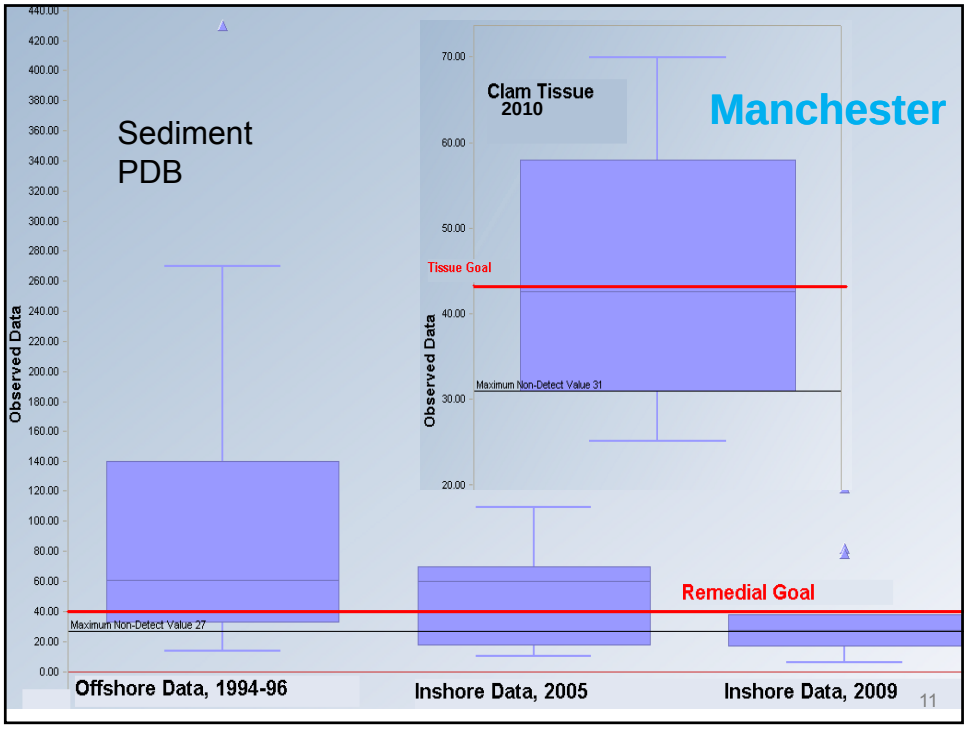
https://rsgisias.crrel.usace.army.mil/publicfuds/

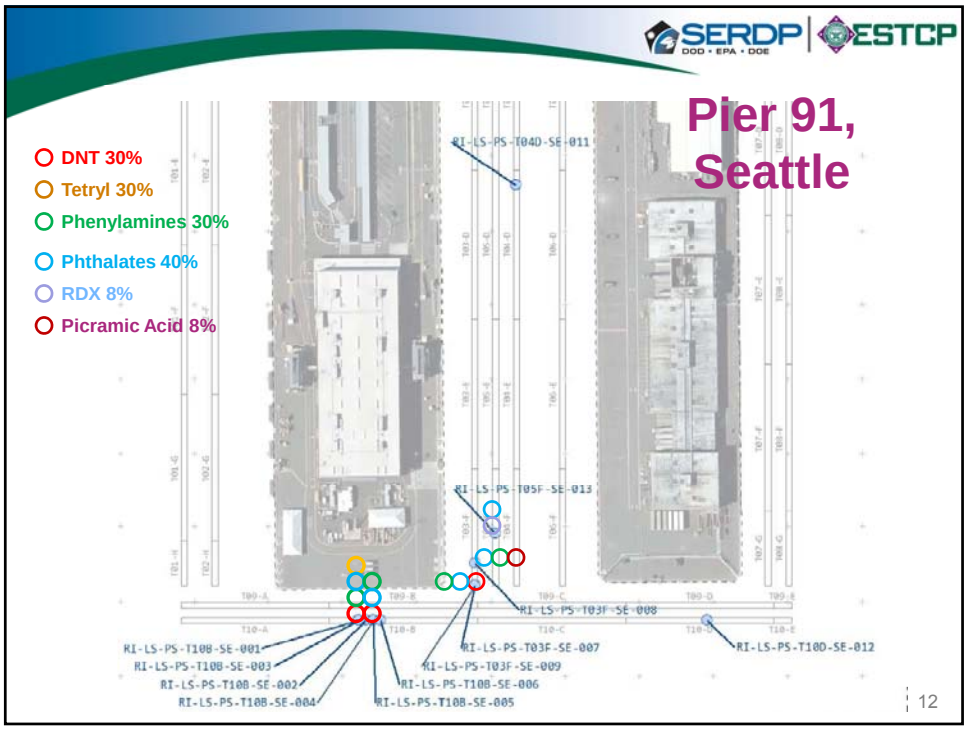
Some FUDS CSS (Informal Survey)

Northeast Cape	Saint Lawrence Island, AK
Sitka Naval Operating Base, Area K	Sitka, AK
Eielson Farm -Piledriver Slough	Eielson AFB, AK
The Presidio Trust	San Francisco
Waikoloa Maneuver Area, HI	Waikoloa, HI
Former Erie Army Depot Weapons Testing	Carroll Township, OH
Tongue Pt Former Naval Air Station	Astoria, OR
Nantucket & Martha's Vineyard	North Kingstown, RI
Nike PR-58	North Kingstown, RI
Rhode Island Camp Avenue Landfill	North Kingstown, RI
Former Nansemond Ordnance Depot	Suffock, VA
Manchester Annex Former NAS	Manchester, WA
Port of Seattle Pier 91	Seattle, WA

Some Local Sites with CSS (Illustrates Legacy)




Manchester
Sediment
PDB
Clam Tissue
2010
Tissue Goal
Maximum Non-Detect Value 31
Maximum Non-Detect Value 27
Remedial Goal
Observed Data
Offshore Data, 1994-96
Inshore Data, 2005
Inshore Data, 2009
11


SERDP
ESTCP
Pier 91,
Seattle
DNT 30%
Tetryl 30%
Phenylamines 30%
Phthalates 40%
RDX 8%
Picramic Acid 8%
RI-LS-PS-T04D-SE-011
RI-LS-PS-T05F-SE-013
RI-LS-PS-T03F-SE-008
RI-LS-PS-T10B-SE-001
RI-LS-PS-T10B-SE-003
RI-LS-PS-T10B-SE-002
RI-LS-PS-T10B-SE-004
RI-LS-PS-T03F-SE-007
RI-LS-PS-T03F-SE-009
RI-LS-PS-T10B-SE-006
RI-LS-PS-T10B-SE-005
RI-LS-PS-T10D-SE-012
12

Some IRP CSS (Informal Survey)

Umiat	North Slope, AK
Fort Devens -Shipley's Hill Landfill	Fort Devens, MA
US Army Systems Center	Natick, MA
Aberdeen Proving Ground	Edgewood, MD
U.S. Army Materials Technology Lab	Natick, MA
Twin Cities Ammo Plant	Arden Hills, MN
Picatinny Arsenal	Morris Co., NJ
Ravenna Army Depot	Kent, OH
Ft Jackson	Fort Jackson, SC
Joint Base Langley-Eustis Skeet Range	Virginia
US Army Reserve Pier 23	Tacoma, WA

Aberdeen Proving Ground

- **Michaelsville Landfill NPL Site**
- **Rivers and Creeks Potentially Impacted**
  - Hg, Pb, DDT, UXO, PAH, PCB
  - RI/FS – fixed price contract for remediation of portions

Gunpowder River, APG

U.S. Army Materials Technology Laboratory

- NPL Listed in 1994 due to munitions storage, arms manufacturing, and materials research, including DU
- Migration into the Charles River was of concern
- Deleted in 2006 because contamination and toxicity found was “anthropogenic urban background conditions that characterize the Lower Charles River Basin”

Joint-Base Langley-Eustis, Virginia (Air Force)

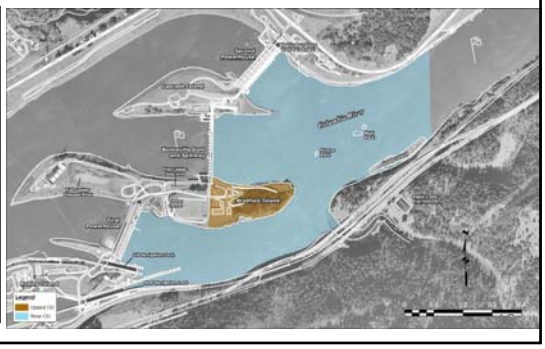
- Brown’s Lake: Pesticides, PCB, PAH
  - ROD in 2007, Remedial Action complete in 2009
  - Long Term Monitoring
- Bailey’s Creek: PCBs
  - ROD 2011, Remedial Action ongoing’
- Former Skeet and Trap Ranges: Lead, PAH, MC under MMRP
  - In RI/FS as of 2009

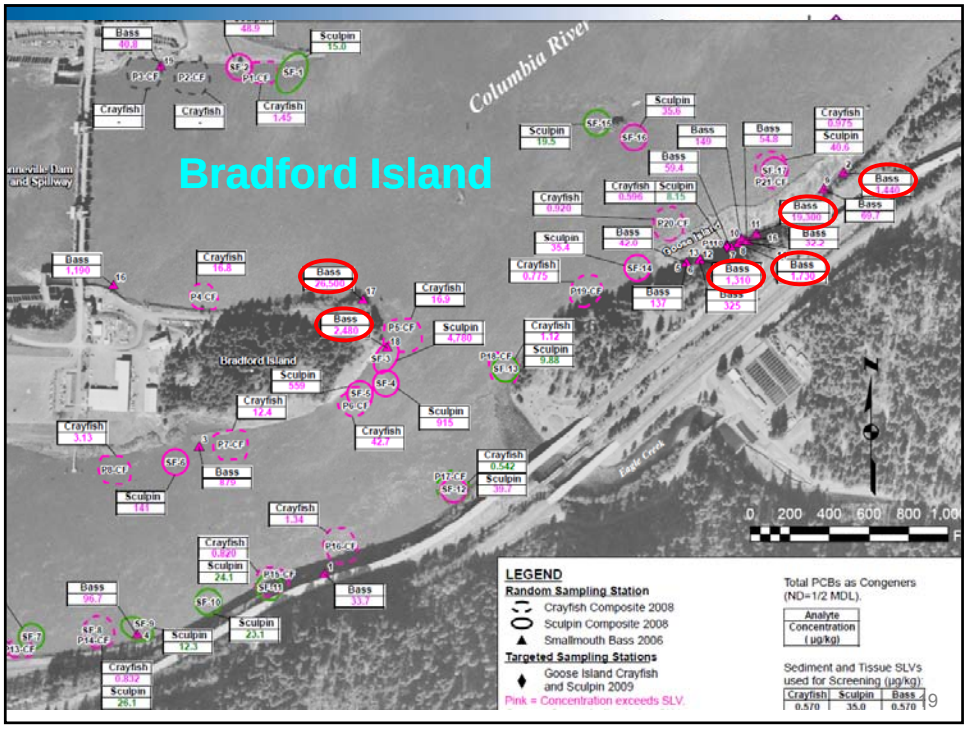
Some Army Civil Works CSS (Based on Regional Knowledge)

Bradford Island	
	Bonneville, OR (Bonneville Dam)
US Moorings (Portland Harbor NPL Site)	Portland, OR
Jemez Canyon Dam	Bernalillo, NM

Bradford Island (Bonneville Lock & Dam

- Non-NPL Operating Project with PCB from disposed capacitors and metals from dam paint-stripping; project is funding constrained
- Interim removal but continued high PCB in bass (may be due to age of bass);
- Beginning FS; candidate for Activated Carbon but very dynamic area





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Trends in Types of Army CSS

- FUDS Program Predicts Increase in Funding to MMRP Sites with Corresponding Reduction to Conventional Chemical Sites
- FUDS, BRAC, IRP Have Sunset Dates for Remedy in Place (Similar to Navy)
- This May Increasingly Emphasize Energetic Compounds and Propellants (MC), and Inorganics
- Special Needs for Civil Works Projects

Gaps and Barriers

- **Characterization & Assessment Methods**
  - ♦ Source Characterization for Bioavailability and DOD Apportionment
  - ♦ Better Conceptual Site Models, Leading to Defensible & Achievable Remedial Goals (*Emphasis on Tissue-based Goals*)
- **Remedy Selection, Implementation, Long Term Monitoring**
  - ♦ Stakeholder and Regulatory Acceptance of Sorbents (e.g., Activated Carbon) in Caps and Enhanced Monitored Natural Recovery
  - ♦ Find Relevant Scale (Depth, Size) for Demonstration Projects
  - ♦ Life Cycle Costing for LTM

Characterization & Assessment
Source Characterization

- ♦ **Source Apportionment – DOD Responsibility**
  - Environmental Forensics - Methods and Acceptance
  - Evaluation of Background/Reference Sites in Setting & Achieving Remedial Goals
  - More Robust CSMs (Decision Support)
- ♦ **Emerging or Emphasis Contaminants**
  - MC: Energetics, Propellants, Metals
  - Characterization at Relevant Scale/Concentration Range to Support Human and Environmental Risk

Characterization & Assessment
Achievable Remedial Goals

- **Increased Emphasis on Tissue-based Goals**
  - Local Lesson Learned – Incomplete CSM Hinders Compliance
  - Particle Tracking on Relevant Scale
- **Integrative Sampling to Determine Bioavailability**
  - Pore-water Passive Samplers and Sampling Arrays
    - Tech Transfer to Gain Acceptance (Scale of Demonstrations Important)
    - Barrier in Some States' "Bulk Sediment" Focus
    - Better Representation of Heterogeneity with Porewater *vs* Bulk
- **Food Web "Decision Support" for Bioaccumulative Compounds to Select Remedial Goal**
  - Food Web Models Over Relevant Range of Concentrations and Scale of Exposure

Remedy Selection, Implementation, and Long-term Monitoring

- **Source Control & Recontamination**
  - Sediment Movement, Dredge Residuals, & Erosion
- **Activated Carbon (& Other Sorbents) Technologies**
  - Related to Selection of Remedial Goals in EMNR – Scope of Usefulness of Sorbents for Particular Compounds
    - EMNR Application Methods by Depth & in Dynamic Environments
    - Stabilization in EMNR and in Caps (Erosion Mitigation)
  - Community Concerns for Collateral Damage to Benthos, Fish
  - Improved Cost Estimates for Sorbent-Dosing and Maintenance Requirements
- **Balance Damage to Sensitive Environments with Remediation Technologies**

Summary

- Army and Navy Needs are Similar, but with Different Emphases: Scale, Wetlands, Freshwater Sites
- Contaminant Spectra may be Similar; Different Emphases
- MC Response an Increasing Program Trend
- Demonstrations at Scales Relevant to Setting Remedial Goals and Estimating Costs
- Tech Transfer an Ongoing Need, Especially for Passive Pore-water Characterization and Sorbent Technologies
- Balance Remediation Benefits Against Habitat Disruption

National Perspective on Sediment Restoration Technologies

Dr. Paul R. Schroeder
Research Civil Engineer
Sediment Management Team Leader

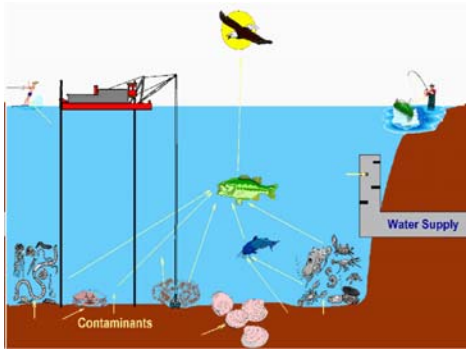
U.S. Army Engineer Research and Development Center
Vicksburg, MS

Background

- Contaminated sediment sites are often challenging
- Comprehensive solutions often use multiple technologies
- Remedies are risk-based
- Goal is risk reduction
- Phased, adaptive approaches often lead to the most effective remedy

Remedy Development

- Requires understanding contaminant sources, exposure routes and their contribution to risk
- Development of a conceptual site model
- Remedies reduce risk by reducing exposure to ecological resources and humans



Risk Drivers

- Exposure is driven predominantly by the contaminant availability in the sediment bioactive zone. Typically,
  - the top 2 inches of sediment in freshwater systems
  - the top 4 inches of sediment in marine systems
- Ingestion of sediment is the dominant pathway contributing to contaminants in the food chain, bioconcentration of water and suspended solids is secondary, and direct contact is least significant pathway

Remedy Priorities

- Reduce the mass of contaminants being consumed in bioactive zone; for organic contaminants
  - Reduce the contaminant concentration on the organic matter being consumed in the bioactive zone
  - Reduce the bioavailability of the contaminants being consumed so that the contaminants will not bioaccumulate and move up the food chain
  - Prevent the spreading of contaminants to a larger area or increasing concentrations in nearby areas

Remedy Priorities

- Reduce the dissolved contaminant concentration in the bioactive zone
- Reduce contaminant concentration in the water column
  - Resuspension of sediment from bioactive zone: erosion, prop wash and organisms
  - Diffusion and pumping from bioactive zone
- Limit recontamination from below the bioactive zone or off-site (source control)

Monitored Natural Recovery

- Works by diluting the bioactive zone and burying the surficial sediment with new sediment settling on the area, good for low levels of risk
- Aided by breakdown of contaminants
- Risk reduction is slow where
  - mixing is deep,
  - suspended solids concentrations are low,
  - contaminants are persistent or
  - groundwater recontaminates the sediment surface
- All sites rely on MNR in some capacity
- Need guidance for developing lines-of-evidence, more case studies, understanding of bioavailability, more comprehensive modeling of impacts of episodic events, and better monitoring protocols to verify performance

A New Wrinkle
(Enhanced Natural Recovery)

- Kick-starts recovery with 2 to 6 inches of material
  - Preferably, the same material as present or richer
  - May include amendment to reduce bioavailability
  - Limit mixing/resuspension using sand
- Preserves ecosystem
- Preserves water depth
- Cuts recovery time in half or more
- Welch Creek, Fox River

In Situ Treatment

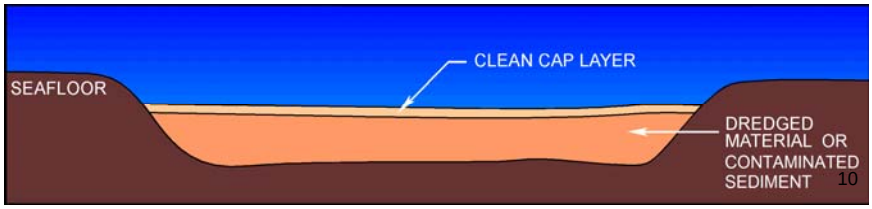
- Adding amendments directly to the bioactive zone
  - Binds contaminants so that organisms will not bioaccumulate contaminants when ingested
  - Reduces contaminant concentration in the pore water to reduce uptake and transport to the water column
  - Competes with natural organic matter (food sources) for contaminants, lowering availability
  - Works with low to moderate levels of risk
  - Limits recontamination effects
- Contaminants still present in bioactive zone
- Better if combined with enhanced natural recovery or thin layer capping
- Need more case studies, better implementation methods, techniques to verify placement, evaluation protocols including effects of sediment carbon characteristics and demonstration of surrogates for bioavailability under non-equilibrium conditions

Amendments
- Activated Carbon
- Organoclay

Why Cap?

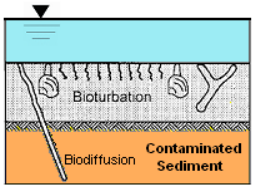
Manage short-term and long-term risks from contaminated sediment by:

- Provide physical isolation of contaminants
- Reduce contaminant flux and bioavailability
- Increase physical and chemical stability
  - Reduce dispersion by erosion
  - Reduce mobilization by sorption

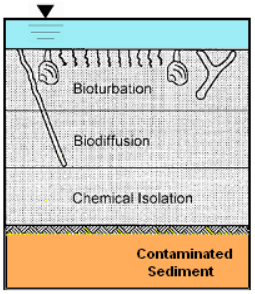


Design of Caps Still Evolving

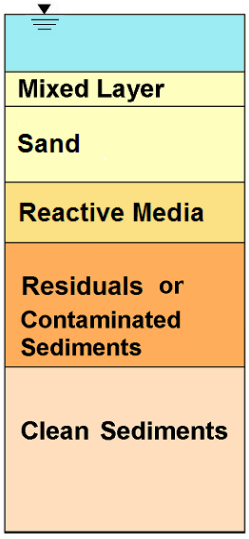
Thin Caps
Isolation Caps
Reactive and Specialty Caps
Residuals Caps (following dredging)



THIN CAP



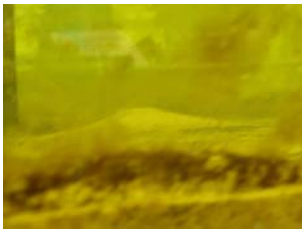
ISOLATION CAP



REACTIVE OR SPECIALTY CAP

How do caps work?

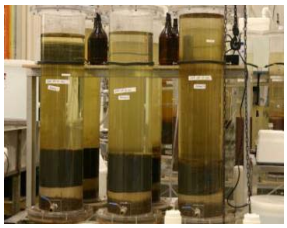
- Moves the bioactive zone out of the contaminated sediment, limiting all exposure routes to the benthos
- Provides a clean surface to cut off contaminant migration to the water column
- Thin caps has greater potential for recontamination by deep bioturbators, good for low to moderate risk
- Isolation caps limit the migration of contaminated sediment by burrowing organisms that may recontaminate the bioactive zone, good for high risk
- Need quantification of permanence and the potential for recontamination by deep bioturbators (burrowers), advection, and uncontrolled sources



Why Reactive Capping?

Adding amendments to manage short-term and long-term risks by:

- Reducing contaminant flux and bioavailability, particularly with groundwater flow, oils, and deep bioturbators (potential for recontamination from below)
- Increasing physical and chemical stability of caps for high risk
  - Reduce mobilization by sorption
  - Degrade contaminant
  - Reduce dispersion by erosion
- Maintaining isolation of contaminants with thinner caps
- Need case studies, better implementation, techniques to verify placement, and demonstration of surrogates for bioavailability for non-equilibrium conditions

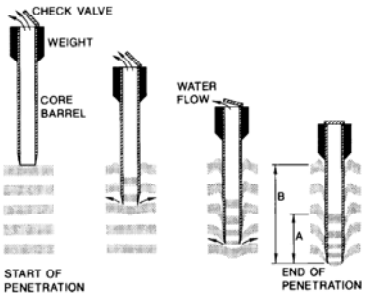


Dredging

- Dredging is unlike other remediation technologies because it removes contaminant mass from the waterway; however, by itself, it may not reduce risk
- Must remove everything above clean-up level
  - Easier said than done
  - Hard to determine depth of contamination
  - Creates residuals

Characterization Errors

- Average error in depth of contamination in the Hudson River was routinely more than 6 inches and averaged more than a foot.
- Error in cores result due to core compression, gas pockets, poor core recovery, displacement, refusal, etc. Errors of 20 to 30% are common.
- Errors cause major problems in cost overruns, production, processing, and disposal. Dredge prism designed to limit sediment volume dredged.
- Need alternative/supplement to coring such as SPME



NOTE—Dark bands represent stiff sediments; light bands represent plastic sediments. As coring proceeds, sediment below the barrel moves laterally away from the cutting edge and plastic sediments inside the barrel are compressed. "A" is the core's length and "B" is the barrel's penetration depth.

FIG. 1 Deformations Caused by Open-Barrel Core Samplers (1)[1]

Risk Reduction by Dredging

- Risk is reduced only if the overall bioactive zone is cleaner than before dredging
- Dredging leaves undisturbed or generated residuals that may be more contaminated than the original bioactive zone
- Dredging also loses contaminants by resuspending sediments during removal

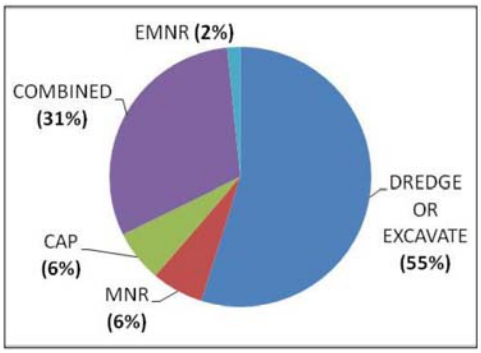
- Residuals management provides risk reduction
- Residuals management may include any of the typical remediation technologies
- Need contaminant release control technologies, and quantification of effectiveness of control technologies such as silt curtains

Source Control

- Dredging should be considered primarily for
  - source control actions and early actions to remove hot spots (greater than ~1000 times the clean-up level)
  - areas where losses from failures would result in significant spreading of the contamination; that is, areas acting as sources to increase the risk in other areas
  - in navigation channels where prop wash may distribute several feet of surface sediment or placed material and depth is not available for other actions
  - elevation control for other technologies
  - small sites

The Need for Innovation

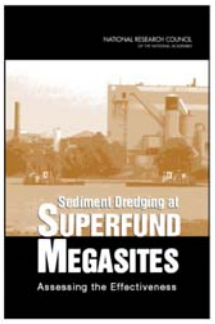
- EPA-OSWER database catalogues actions taken at 124 areas within 69 sites from 1987 to present
- 55% of the areas relied exclusively on removal
- All but 1 of the combined remedies involved removal
- About 85% of sites relied heavily on removal



The Need for Innovation

National Research Council Review

- 26 cleanup dredging projects reviewed
- Dredging alone achieved desired contaminant-specific cleanup levels (CULs) at only a few of the reviewed sites
- Longer-term benefits of dredging are not well understood or documented
  - Sparse or incomplete monitoring data were collected
  - Selected organisms not linked to remediation at the site
  - Pre-remediation monitoring approaches were not consistent with those used post-remediation
  - Pre-remediation trends were not of sufficient duration to enable judging the effect of the remedial action
- The committee was generally unable to establish whether dredging alone is capable of achieving long-term risk reduction



THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

Gustavson et al. 2008. Evaluating the Effectiveness of Contaminated-Sediment Dredging. *Environmental Science and Technology* 42:5042-5047.

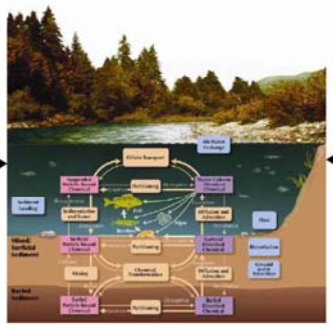
The overarching need is…

A Resilient Remedy

- Includes components which enable the remedy to recover from insults
- Incorporates a combination of approaches and technologies that complement and reinforce each other
- Is designed to be optimized and adapted over the long-term

How do we efficiently develop and implement a remedy using a combination of technologies?

Dredging



MNR/ENR

Capping

Logical Progression

Dredging for Hot Spots and Source Control → **MNR** → **In Situ Treatment or ENR** → **Capping or Reactive Capping** → **Dredging for Permanence**

- Natural recovery processes represent the baseline after source control
- If more than MNR is required, additional engineering can be incrementally added
- The progression should preserve opportunities to learn and adapt, while minimizing future regret

Adapted from:

TS Bridges, SC Nadeau, MC McCulloch. 2012. Accelerating Progress at Contaminated Sediment Sites: Moving from Guidance to Practice. *Integrated Environmental Assessment and Management* 8: 331-338.

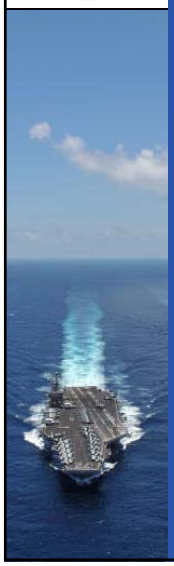
Additional Needs

- Tools to aid formulation of alternatives
- Tools to aid use of adaptive management
- Tools to aid remedy selection
- Comprehensive performance model
  - Comprehensive in situ sediment remediation model, current models have limitations
  - For many sites all remediation technologies tend to predict similar risk reduction in the long term
    - Reasons poorly understood
    - Uncertainties not addressed
    - Confidence not provided
    - Anthropogenic and catastrophic impacts may be neglected
- More long term monitoring and case studies

Take Home Message

- All remediation technologies have their advantages and their disadvantages
- There are no silver bullets
- Selection should consider the nature of the risk and threats to the remedy from site characteristics
- Selection should also consider impacts of remedy failure, maintenance, monitoring opportunities for phased implementation and adaptive management

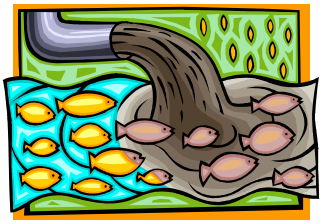
Department of the Navy
Sediments Program Policy, Guidance, R&D Efforts, and Challenges



Naval Facilities Engineering Command Southwest
Michael Pound
July 25, 2012

Program Background

- Navy has 200+ contaminated sediment sites
- Projected remediation cost of $1.3 billion, MRP sites add another $1 billion
- 35% of the Environmental Restoration, Navy (ER,N) budget is for sediment sites
- Sediment has been a focus area for Navy policy and technical guidance for the past 10+ years

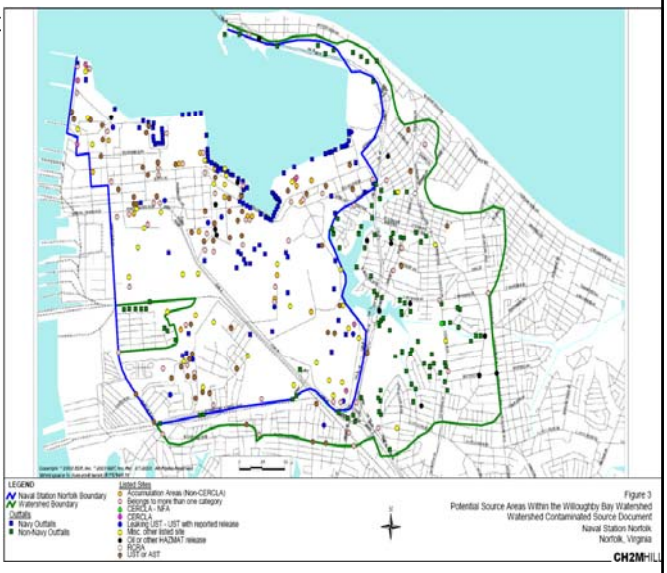


DON Policy on Sediment Site Investigation and Response Action

- DON Policy on Sediment Site Investigation and Response Action issued February 8, 2002
- The policy generally specifies:
  - Sources must be identified and controlled before cleanup
  - All investigations shall primarily be linked to a specific Navy CERCLA/RCRA site
  - Cleanup must be risk-based and have site-specific cleanup goals
  - Monitoring criteria for any monitoring plan must be established before the first sample is collected

Sediment Policy – Watershed Contaminated Source Document (WCSD)

- Summary report describing potential Navy and non-Navy sources that may have contaminated sediment in the water body adjacent to Navy property.
- Should include and be a component of the Conceptual Site Model (CSM).

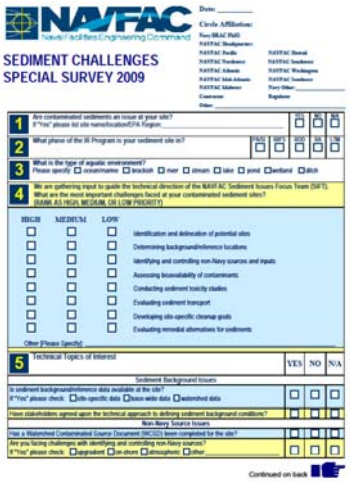


2009 Sediment Survey Responses

RESPONSE: 20 Sites (28 Surveys)

- NAVFAC SE
  3 Sites (4 surveys)
- NAVFAC SW & PMO BRAC
  6 Sites (9 surveys)
- NAVFAC LANT & Midlant
  6 Sites (6 surveys)
- NAVFAC PAC & Hawaii
  2 Sites (2 surveys)
- NAVFAC NW
  2 Sites (2 surveys)
- NAVFAC WASHINGTON
  1 Site (1 survey)

4 Surveys with no site identified


NAVFAC
Naval Facilities Engineering Command

SEDIMENT CHALLENGES
SPECIAL SURVEY 2009

Date: _____
Circle Affiliation:

1 Are contaminated sediments an issue at your site? If "Yes" please list site name/location/EPA Region. YES NO N/A

2 What phase of the IR Program is your sediment site in? RI/FS PA/SI RAO LTM

3 What is the type of aquatic environment? Please specify: ocean/marine, brackish, river, stream, lake, pond, wetland, ditch

4 We are gathering input to guide the technical direction of the NAVFAC Sediment Issues Focus Team (SIFT). What are the most important challenges faced at your contaminated sediment sites? (RANK AS HIGH, MEDIUM, OR LOW PRIORITY)

	HIGH	MEDIUM	LOW
Identification and delineation of potential sites			
Determining background/reference locations			
Identifying and controlling non-Navy sources and inputs			
Assessing bioavailability of contaminants			
Conducting sediment toxicity studies			
Evaluating sediment transport			
Developing site-specific cleanup goals			
Evaluating remedial alternatives for sediments			

Other (Please Specify) _____

5 Technical Topics of Interest — YES NO N/A

Sediment Background Issues

Is sediment background/reference data available at the site? If "Yes" please check: site-specific data, base-wide data, watershed data

Have stakeholders agreed upon the technical approach to defining sediment background conditions?

Non-Navy Source Issues

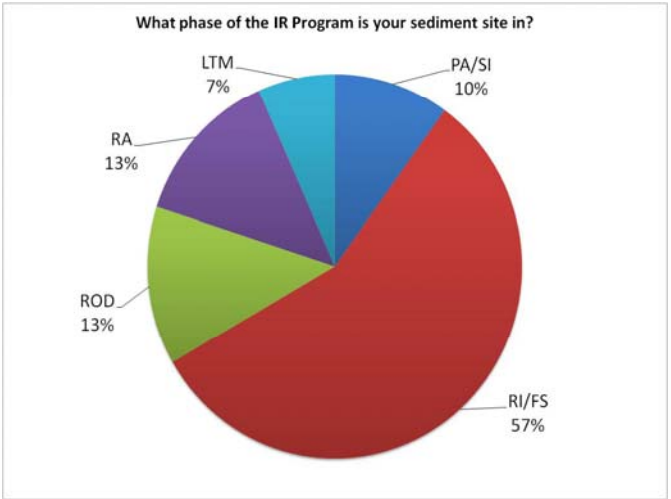
Has a Watershed Contaminated Source Document (WCSD) been completed for the site?

Are you facing challenges with identifying and controlling non-Navy sources? If "Yes" please check: upgradient, on-shore, atmospheric, other _____

Continued on back

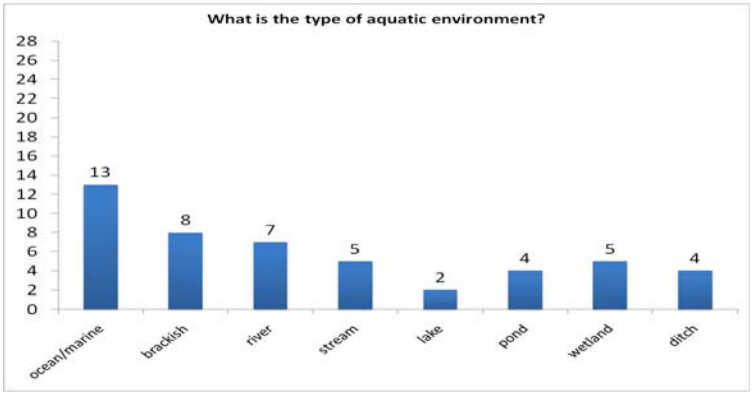
Phase of Installation Restoration Program

- Investigation
  - 67%
- Remediation
  - 33%



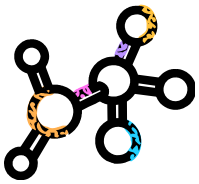
Type of Aquatic Environment

- 44% of responses ocean/marine/brackish environment
- 56% of responses fresh water environment



What COCs are present in sediment?

- Metals [11]
  - Cu [4], Cd [1], Cr[1], Hg [4], Mg [1], Ni [2], Pb and Lead Shot [4], Zn[3]
- PCBs [9]
- Pesticides [7]
  - Chlordane [1], Dieldrin [1], DDT [3], Endosulfan [1]
- PAHs [7]
- VOCs [6]
- Tin [1] and Tri-n-butyltin (TBT) [1]
- BTEX [1]
- Dioxin/Furans [1]
- Munitions Constituents [1]



Most Important Challenges Identified by RPMs at IR Sediment Sites (Fall RITS Sediment Survey 2009)

Policy Issues

- Determining background/ reference locations (#2)
- Identifying and controlling non-Navy sources/inputs (#3)
- Evaluating remedial alternatives for sediments (#4)
- Identification and delineation of potential sites (#6)

Technical Issues

- Developing site-specific cleanup goals (#1)
- Assessing bioavailability of contaminants (#5)
- Evaluating sediment transport (#7)
- Conducting sediment toxicity studies (#8)

Additional Supporting Guidance, Tools and Training

Guidance

- **Contaminated Sediments Web Portal**
  http://www.ert2.org/t2sedimentportal/?id=home
- **NAVFAC Guide: Sediment: Implementation Guide For Assessing and Managing Contaminated Sediment at Navy Facilities (January, 2005)**
- **Chemical Fingerprinting User's Guide (Sept. 2003)**
  http://www.spawar.navy.mil/sti/publications/pubs/tr/1907/tr1907cond.pdf
- **Rapid Sediment Characterization Tools (Sept. 2008)**
  http://www.spawar.navy.mil/sti/publications/pubs/tr/1970/tr1970cond.pdf
- **User's Guide for Assessing Sediment Transport at Navy Facilities (September 2007)**

Training

- Periodic presentation during RITS

Sediment Transport User's Guide

- Guide is available at http://www.spawar.navy.mil/sti/publications/pubs/tr/1960/tr1960cond.pdf
- Final guide has lessons learned from field demonstrations (as case studies)

- TECHNICAL REPORT 1960
  September 2007
- **User's Guide for Assessing Sediment Transport at Navy Facilities**
- A.C. Blake
  D. B. Chadwick
  SSC San Diego

  P. J. White
  CH2M HILL

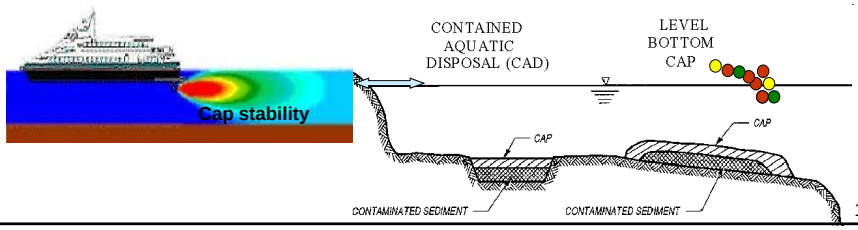
  C. A. Jones
  Sea Engineering, Inc.
- Approved for public release; distribution is unlimited.
- SSC San Diego

ISRAP Technology Description

- Interactive Sediment Remedy Assessment Portal (ISRAP) – An Online Resource for Sediment Remedy Monitoring Approaches
  - Online, interactive web-tool - help RPMs focus on key issues associated with site-specific monitoring needs and facilitate a comparison of effective monitoring tools.
  - Guidance - provide remedy-specific recommendations for sediment monitoring programs.
  - Case Studies
    - PSNS OUB (Bremerton, WA)
    - Wykoff/Eagle Harbor
- Site Demonstration
  - MCB Quantico, VA (Site 99, embayment)
  - Enhanced Monitored Natural Recovery (thin-layer capping)

Research & Development (R&D) Efforts

- Evaluation of Resuspension from propeller wash
  - Effectiveness and stability of sediment caps under propeller wash over short or long terms are not known.
  - Current practice may be neither practical as more sediment caps are installed, nor efficient as no ship activity may be overly conservative.
  - Science-based (risk-based) knowledge is needed to define parameters and quantify the processes that pose risks to the cap stability.



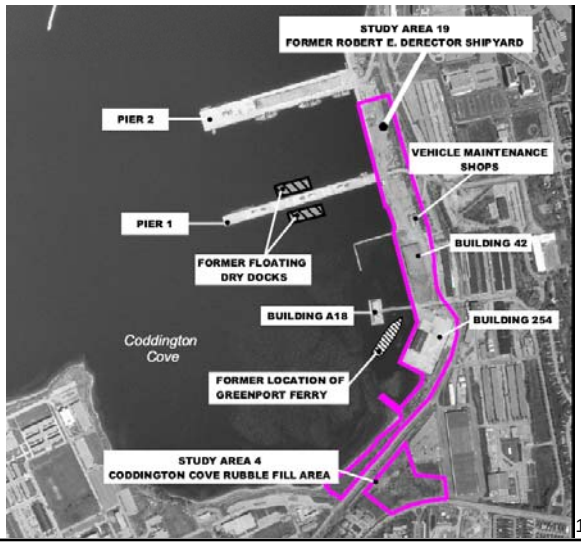
NAVSTA Newport IR Site 19 - Derecktor Shipyard

Located in Narragansett Bay at Naval Station Newport, RI

Several former activities lead to sediment contamination
- PCBs, PAHs, lead, benzo(a)pyrene

Current activities may serve as a source for anthropogenic input.

Piers are still actively used

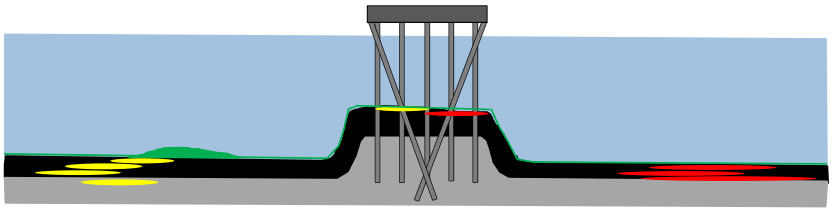


Former Derecktor Shipyard Conceptual Site Model 2012

New sedimentation, trapped by the presence of long term dockage of large vessels, does not appear to contain contaminants. Additional sedimentation is occurring, particularly in near-shore areas where there is restricted water flow.

Lead, Total PAHs and PCBs in sediment exceed preliminary clean-up goals to ecological receptors.

Benzo(a)pyrene in sediment poses risk to humans through shellfish ingestion.



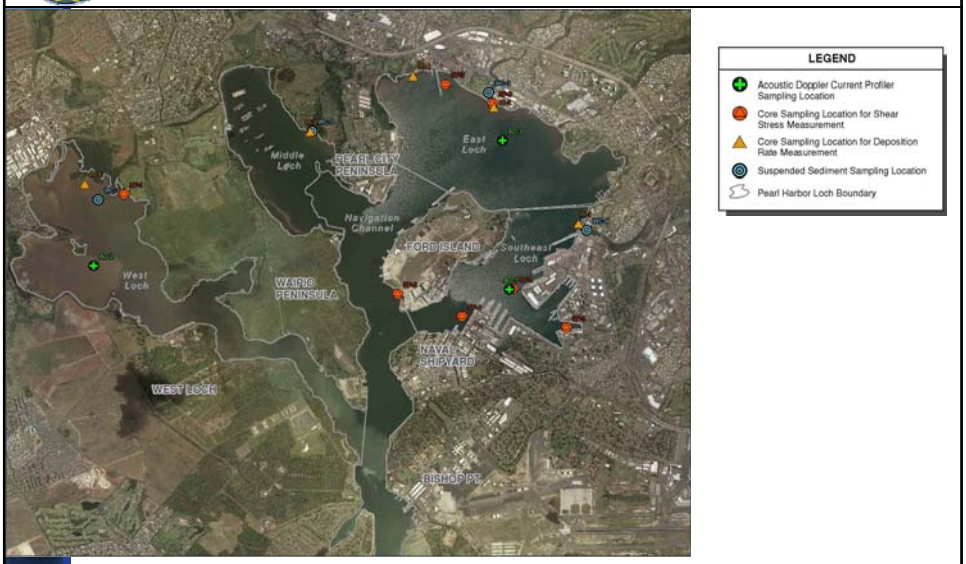
Derecktor Shipyard Technical Issues

- Multiple lenses of contamination and multiple preliminary clean-up goals for human health and ecological endpoints.
- Compiling chemical, physical, and toxicological data to identify “best fit” combination of remedial alternatives
- Identifying remedial timeframes for non-removal alternatives without having several rounds of sediment characteristic data

Derecktor Shipyard Non-technical Issues

- Unwillingness of project team to accept a combination of remedial alternatives
- Unwillingness of project team to accept that natural recovery mechanisms may be occurring without several rounds of data
- Uncertain future of piers and departure date for inactive carrier

Pearl Harbor Sediment



How to manage sediments under the piers?

- Potential recontamination source to adjacent area
- Storm drain outfall under piers potential ongoing source
- Difficult to characterize
- Sediment removal hindered by structural obstructions
- In-situ cap emplacement feasible but still challenging
- In-situ treatment may be the best solution to be further explored

How to integrate navigation dredging with remedy?

- Majority of areas of concern is dredged periodically for navigation
- Natural recovery unlikely due to removal of overlying recent sediments
- In-situ cap required initial dredging and armored caps
- Dredging – how to integrate navigation dredging program with IR program when different requirements exist.

How to manage biota-only areas of concern?

- Fish tissue exceedance with no associated sediment exceedance identified at Walker Bay
- Likely to be identified in other areas moving forward
- Proposed long-term monitoring of fish tissue challenges:
  - Exit strategy – agreement on target level?
  - Whole fish vs. fillet?
  - Identify source and evaluate source control?

How to manage non-point sources?

- 5 major streams, drainage canals/ditches, numerous Navy/Non-Navy storm drain conveyance outfalls
- Quantifying non-point source loading is a challenge
- Developing clean-up levels that take into account non-point source contributions
- Existing NPDES permit limits above project action levels
- Implementing source control on non-Navy property

Hunters Point Naval Shipyard – Parcel F

Site Issues:

- Sediments are designated as radiologically "impacted"
  - Process for removing designation unclear
  - Designation increases remediation costs and impacts transfer negotiations
- Sediments also have chemical (non-radiological) contamination including PCBs and metals (copper, lead, and mercury)
- Currently in the Feasibility Study Stage. Chemical FS is completed; radiological studies in progress.

Hunters Point Naval Shipyard – Parcel F

Site Issues (cont.):

- End-use conditions changed after Feasibility Study addressing chemicals was finalized in 2008
  - Wetland creation project by CA State Parks underway
- To follow the Navy's sediment policy, an adjoining non-Navy site must be cleaned by PRPs, prior to the commencement of the remediation of Parcel F, to avoid recontamination.
- New regulatory team since 2008 Feasibility Study was finalized

Hunters Point Naval Shipyard – Parcel F

Technologies in 2008 Feasibility Study:

- Pilot Study performed at Parcel F by Dr. Richard Luthy and Stanford Team
  - In-Situ Stabilization using activated carbon added to the sediment
  - Bioaccumulation studies performed in the lab using three organisms and two sorbents (coke and activated carbon)
  - Sediment erosion tests conducted to test shear stress
  - Field demonstration conducted to test ability of two types of injection systems for mixing activated carbon into the sediments

Rake Injector Mixing Activated Carbon Slurry

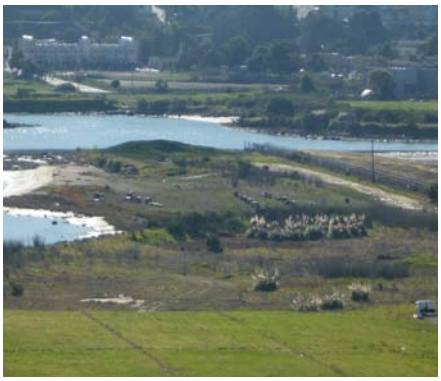
Aquamog Mixing Activated Carbon Slurry

Hunters Point Naval Shipyard – Parcel F

Technologies in 2008 Feasibility Study (cont.):

As a result of the Pilot Study, In-Situ treatment incorporated into three Remedial Alternatives

Highest ranked alternative included a combination of sediment removal, monitored natural recovery, backfill of dredged areas with sediment or backfill of dredged areas with sediment amended with activated carbon

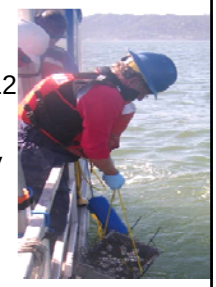


Because backfill will be placed in dredged areas, by amending the backfill with activated carbon, it would further bind any residual PCBs at the site, thereby further reducing the bioavailability

Hunters Point Naval Shipyard – Parcel F

Site Actions:

- Radiological Data Gap Investigation underway
  - Phase I complete, Phase II scheduled for Fall 2012
  - Radiological Feasibility Study Addendum in 2013
  - Navy evaluating ways for de-designating category of radiologically "impacted"
- Engineering/Sediment Transport studies underway to evaluate new end-use
- Interactive GIS tool showing average chemical concentrations may be used to facilitate negotiations with agencies



Alameda Point Seaplane Lagoon

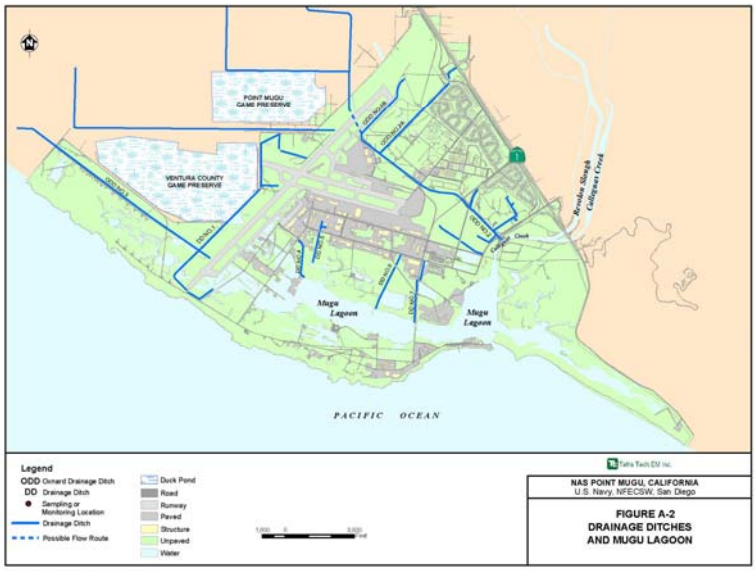
Alameda Point Technical Challenges

- Radium-226 component in addition to PCBs, metals, and pesticides in the sediment added complexity to removal, handling, waste characterization, and disposal processes
- Large quantity of debris including anchors and much wire made use of planned environmental bucket not feasible and slowed the dredging process
- Petroleum contamination from former shoreline bulk fuel operations resulted in petroleum release from the sediment during dredging and the need for a skimmer working in the dredge area throughout the northeast sediment removal
- Water management in large dewatering pads was challenging due to the quantity of dredge water and rainfall since dredging needed to be conducted during the rainy season

Alameda Point Non-Technical Challenges

- Scheduling:
  - Required scheduling of dredging to avoid impact to the endangered Least Terns that forage in the lagoon; no dredging between March and September; and
  - required scheduling/completion of sediment processing during the dry season for sediments to be dry enough for the required radiological processing
- Noise concerns during 24/7 dredging due to nearby residences
- Limited space for radiological screening pads due to nearby businesses
- A high visibility project requiring additional BCT, RAB, and public outreach efforts

NAWS Pt. Mugu Site 11



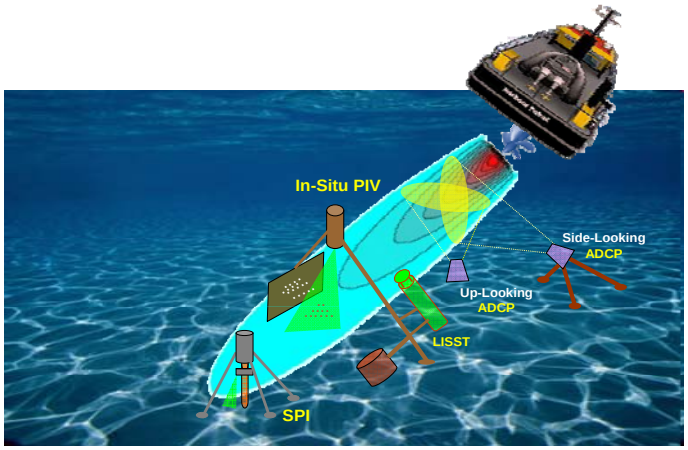
NAWS Pt. Mugu Site 11 Technical Issues

- Both the upstream and Navy source areas are potentially responsible for sediment contamination in Mugu Lagoon.
- The Navy has identified chromium as a risk to ecological receptors that in part originated from IRP Site 5. However, chromium was also found at elevated concentrations upstream of Mugu Lagoon.
- Other metals, pesticides and PCBs appear to originate from upstream source areas.
- Navy source areas will be remediated as needed but will not reduce the significant flux of DDTs, PCBs, or metals to Mugu Lagoon that originate from the watershed upstream of Point Mugu.
- Draft Final FS concluded that no further action is required under CERCLA because adequate monitoring and controls are in place to monitor the site under the Clean Water Act.

Final Thoughts for Workshop Consideration

- Navy has developed a significant body of sediment policy, guidance, and technology tools to manage sediment sites
- Navy sediment sites share commonalities but each has their unique issues which fragments the market for environmental technologies
- Technology transfer support from the technology developers to RPMs and regulatory agencies needs improvement; the barriers are not exactly the same

Questions????



Long-Term Operations and Long-Term Monitoring Considerations

Workshop on Research and Development Needs for Long-Term Management of Contaminated Sediments

July 25-26, 2012

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ENVIRON

Workshop Goals

1. Examine the current state of the science for the long-term management of contaminated sediment sites
2. Review the current and projected future status of DoD long-term management activities
3. Identify data gaps that, if addressed, could aid in the long-term management of contaminated sediments
4. Prioritize research and demonstration opportunities to help facilitate regulatory and public acceptance of long-term management strategies for contaminated sediment sites

State of the Practice

USEPA (2005) Sediment Guidance

1. Assess compliance with design and performance standards
2. Assess short-term remedy performance and effectiveness in meeting sediment cleanup levels
3. Evaluate long-term remedy effectiveness in achieving remedial action objectives (RAOs) and in reducing human health and/or environmental risk

Manage Uncertainty – Uncertainty is inherent to any cleanup activity (USDOE 1997, 1999)….If all uncertainties could be eliminated prior to remedy implementation, there would be no need for post-implementation monitoring (U.S. DOE 1999).

Remedy-Specific Monitoring Primary Remedy Functions

MNR

- Sedimentation and burial
- Chemical transformation
- Chemical sequestration

Capping

- Contaminant isolation
- Armoring
- Creation of a clean sediment surface

Dredging

- Contaminant removal
- Often combined with MNR or backfill to achieve Remedial Action Objectives (RAOs)

Remedy-Specific Monitoring Goals

MNR

- Confirm ongoing processes
- Sediment stability
- Ecological recovery
- Demonstrate achievement of remedial objectives (long-term recovery)

Capping

- Validate construction and achievement of remedial objectives (immediate recovery)
- Cap stability
- Cap surface recontamination
- Ecological recovery

Dredging

- Validate construction and achievement of remedial objectives (mass removal / elevation)
- Validate backfill placement
- Surface sediment concentrations
- Natural recovery (see MNR)
- Ecological recovery

Long-Term Monitoring Measures of Success

i. Achieving ecological (or risk-based) goals and not requiring more active remediation

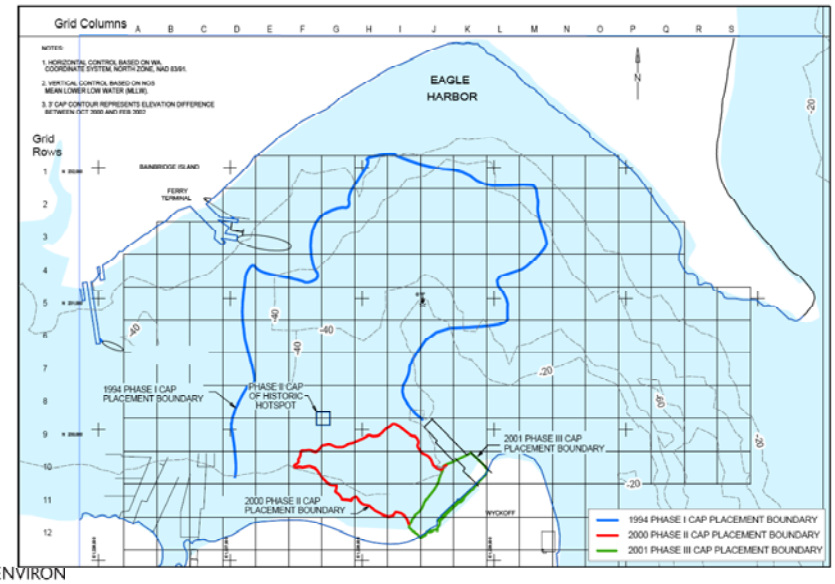
ii. Establishing confidence in the remedy and reducing monitoring requirements with time

iii. Transitioning to a long-term, low-level maintenance program (e.g., only monitoring in the event of a change of site conditions)

iv. Closing the site (e.g., no further action), and spending no more money on the site

Monitoring Examples

Eagle Harbor Cap (Washington) Example

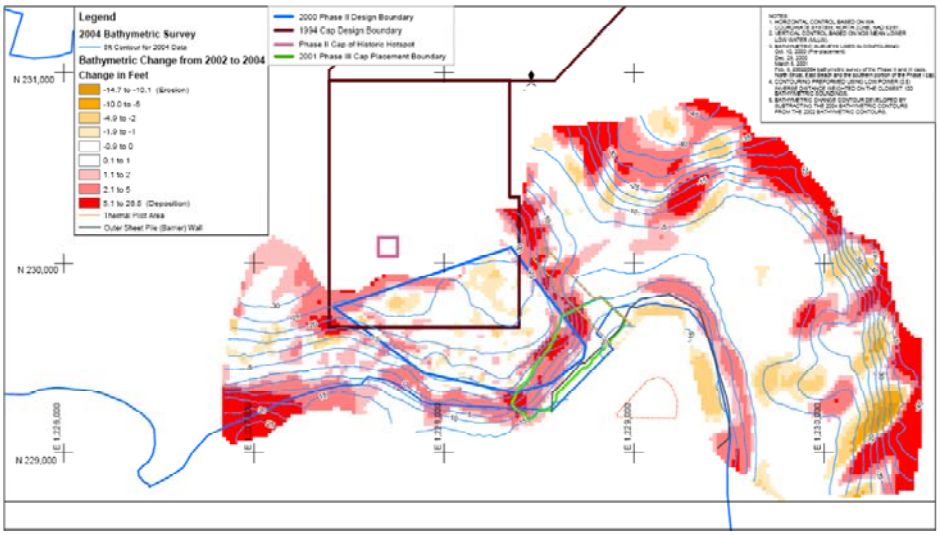


Wyckoff/Eagle Harbor Monitoring Objectives

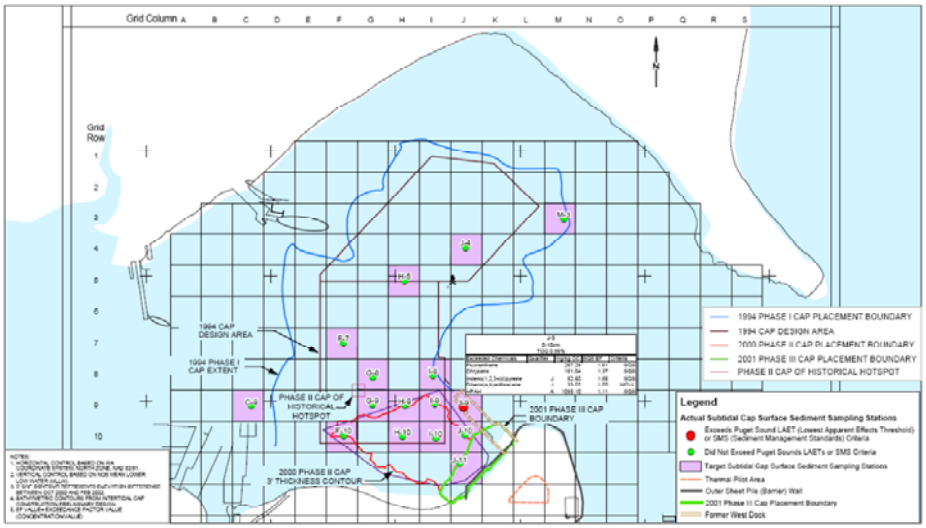
1. Is the cap physically stable, remaining in place at a desired thickness?
2. Is the cap effectively isolating the underlying contaminated sediments?
3. Are sediments in the biologically active zone (0-10 cm) remaining clean relative to the Washington State Sediment Management Standards (SMS)?

Monitoring Tool	Cap Performance Objective Addressed
Bathymetry	Objective 1
Surface sediment chemistry	Objective 3
Through-cap coring and chemistry	Objective 1, Objective 2

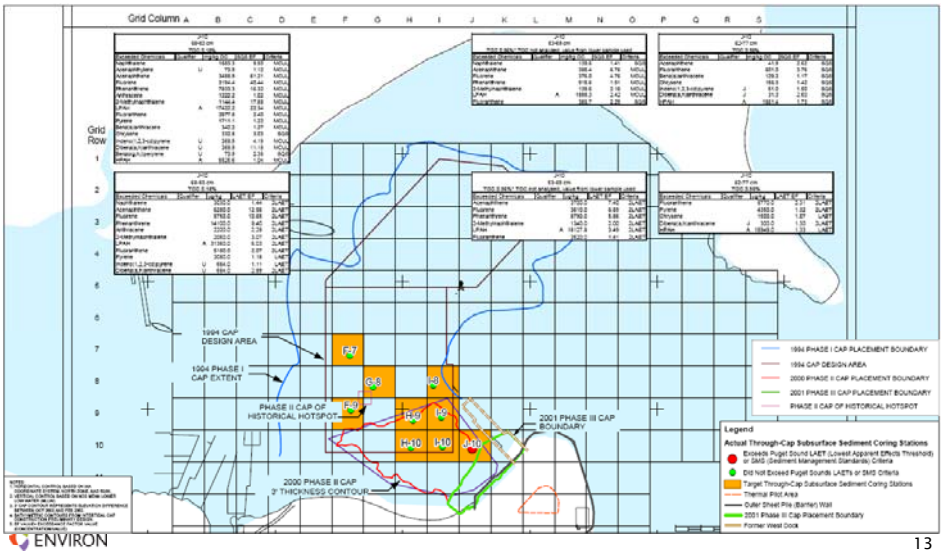
Bathymetric Change: 2002 to 2004



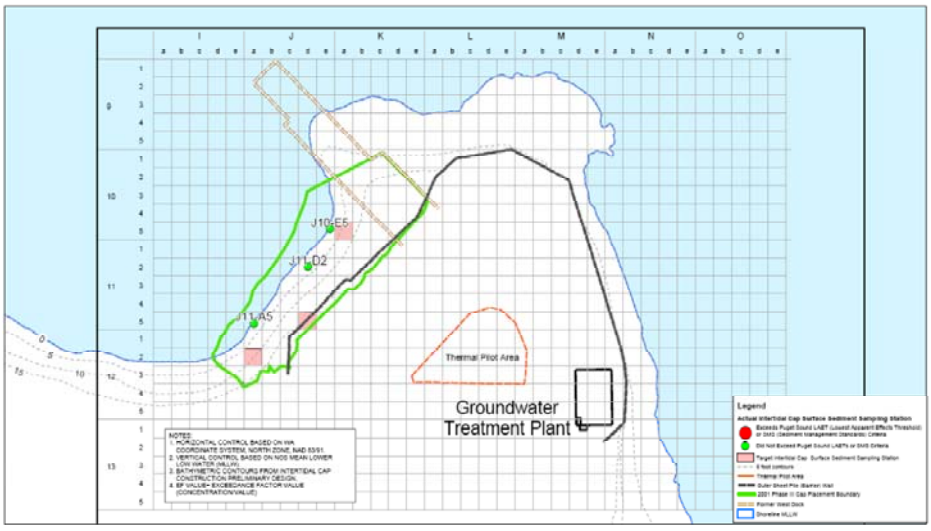
Subtidal Cap Surface Sampling



Through-Cap Subtidal Sediment Coring Results



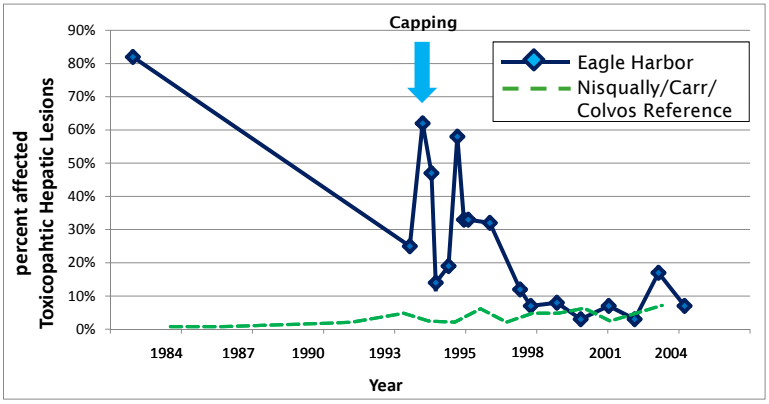
Intertidal Sediment Surface Sampling



Eagle Harbor Biological Monitoring
English Sole (*Pleuronectes vetulus*)

- Bottom dwelling, feeding
- High site fidelity
- Used as a sentinel species

Cap Performance Biological Endpoint:
Eagle Harbor Flatfish Liver Lesions

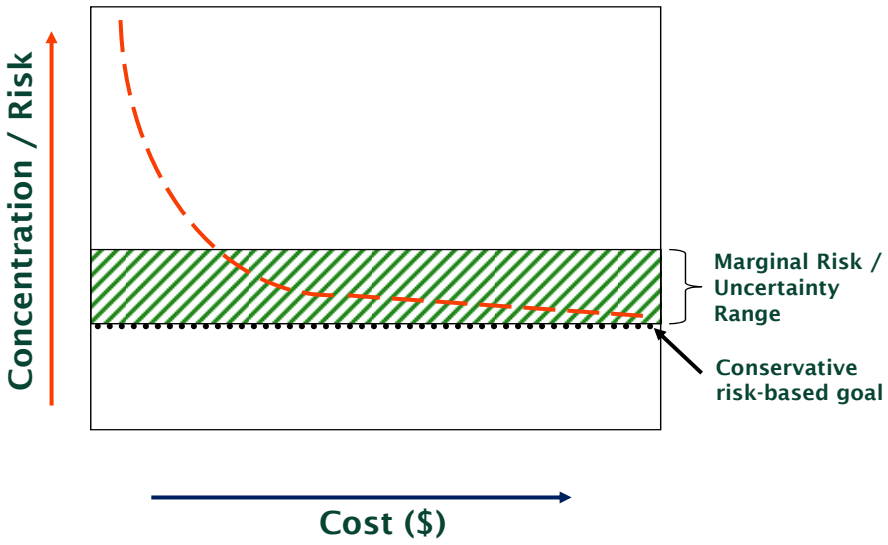


Data source: Myers et al. (2008) & WDFW (2010)

Wyckoff Conclusions

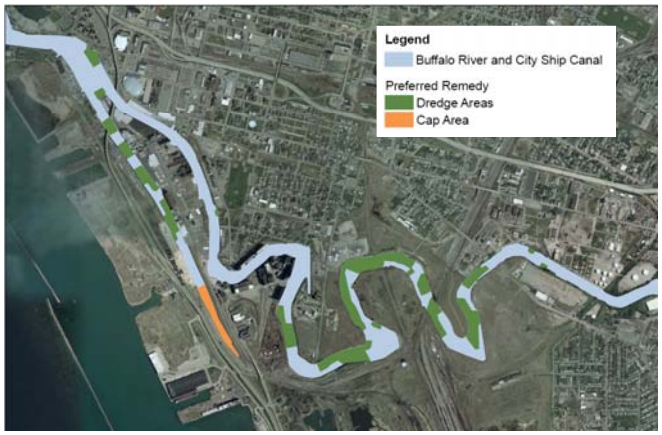
- Bathymetry and coring verified cap placement
- Onshore source control and capping reduced surface sediment concentrations
  - Surface sediment monitoring verified reduced sediment concentrations
  - Sediment coring showed absence of vertical PAH migration
- Liver lesion risk dropped significantly in English sole since capping (monitored by NOAA)
  - Risk reduction most evident 3 years post-capping
  - Risks remained low and stable for the last five years

Monitoring Should Be Commensurate with Remediation



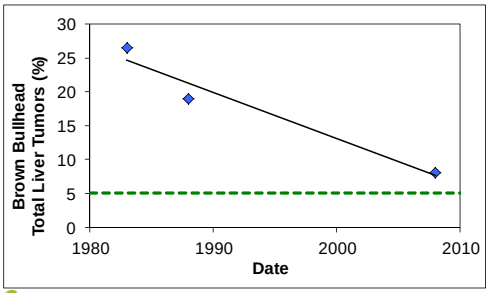
Buffalo River Area of Concern, Buffalo, New York

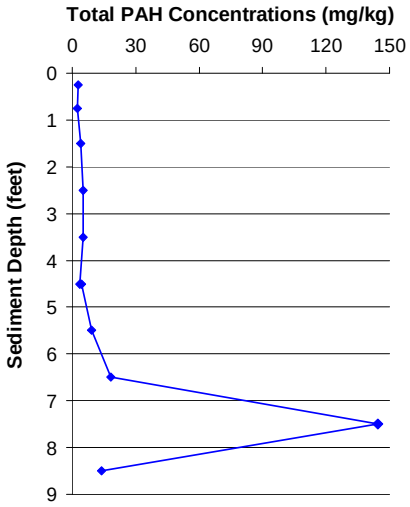
- Buffalo River: lower 6.2 miles of
- City Ship Canal: 1.4 miles
- Primary chemicals of concern
  - PAHs
  - PCBs
  - Lead
  - Mercury



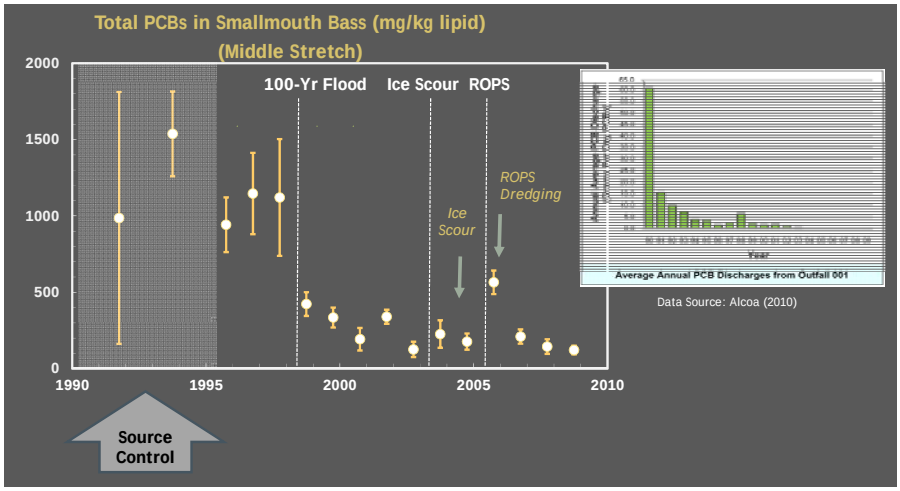
Buffalo River Area of Concern, Buffalo, New York

- Buffalo River is depositional
- ~70,000 CY dredged / year
- 3-9 cm/yr sedimentation
- Natural deposition has led to chemical isolation and reduced surface sediment concentrations



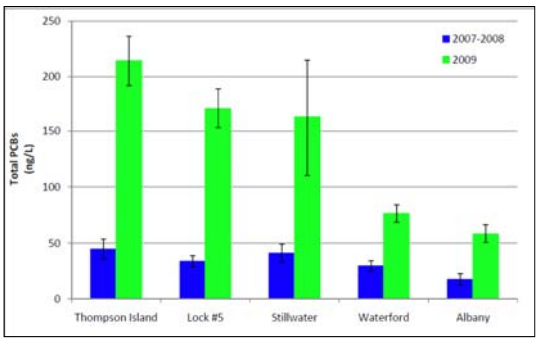


Monitoring Biological Endpoint: Grasse River Natural Recovery – Fish Tissue PCB Levels



Data Source: Alcoa (2010)

Hudson River PCB Dredging Releases Future Dredging Costs > $1 Billion



Data Source: Anchor QEA and Arcadis (2010)

- 2009 dredging sent ~3% of dredged mass downstream
- Controls were largely ineffective and caused other problems
- Debris exacerbated resuspension and residual impacts

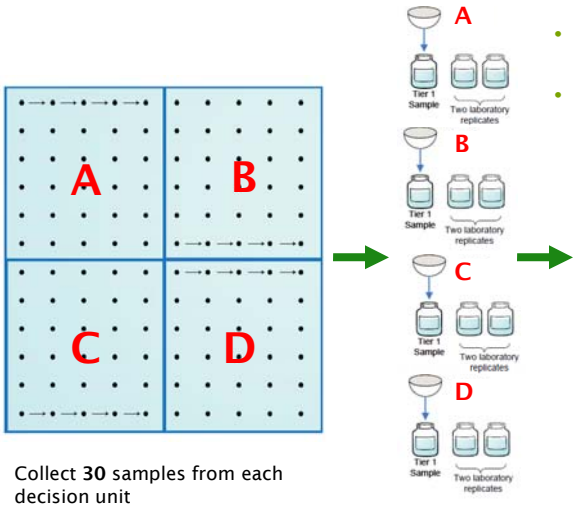
More than 18,000 environmental samples collected during Phase 1

Opportunities for Improvement

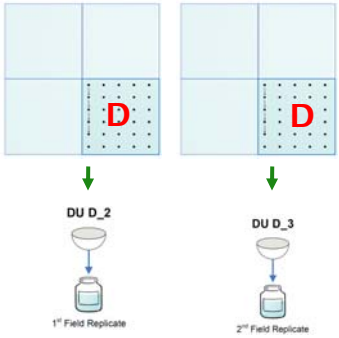
- Leverage monitoring to promote adaptive management
- Use composite sampling to steer away from point-by-point assessment of habitat and exposure
- Changing the paradigm for remedy success
  - Recognize that risk assessment tends to be conservative and does not necessarily predict injury
  - Focus monitoring on community metrics (habitat, ecology, ecosystem services)
  - Distinguishing chemical measurements and risk from injury
- Returning to remediated sites to measure performance—how have we done so far?
- Sampling / field analytical methods

Supplemental Slides

Composite Template



- Suitable for sites where focus is on an exposure area
- Composite samples from a single Decision Unit



Collect **30** samples from each decision unit

Combine, homogenize and subsample increments

Replicate Decision Units or composite samples

Physical Measurements

Sediment erosion/deposition, surface water flow rates, and sediment physical characteristics

- **Sediment Properties**
  - Particle size, heterogeneity, bulk density
- **Water Column Properties**
  - Turbidity and suspended solids
  - Sediment suspension during remedy implementation
- **Geophysical measurements**
  - Bathymetry, side scan sonar, subbottom profiling
- **Settlement Plate Data**
  - Changes in cap thickness, cap consolidation
- **Sediment Profile Camera Data**
  - Visual surface sediment characteristics, bioturbation/oxidation depths, presence of gas bubbles

Chemical Measurements

Surface sediment chemical concentrations, surface water and pore water chemical concentrations, chemical transformation

- **Sediment Sampling**
  - Grab and Composite Samples: Surface sediment chemistry
  - Sediment Coring: Vertical chemical profiles, or contaminant migration through a cap or through naturally deposited clean sediment
- **Surface Water Sampling**
  - Direct Water Column Measurements: Dissolved oxygen, pH
  - Surface Water Samples: Chemical concentrations (dissolved and particulate), water-column releases during remedy construction
- **Pore Water Sampling**
  - Direct Pore Water Sampling: Trident probe to measure contaminants
  - Passive Samplers (Peepers): Establish pore water equilibrium to measure contaminants
  - Passive Samplers (SPMD/SPME): Semi-Permeable Membrane Devices, and solid-phase microextraction measure dissolved contaminants
  - Seepage Meters: Contaminant flux into the water column

Biological Measurements

Biological testing can include toxicity assays, assessment of changes in the biological assemblages at sites, or toxicant bioaccumulation and food chain effects.

- **Benthic Community Analysis**: Evaluate population size, density, and diversity, and monitor recovery
- **Toxicity Testing**: Measure acute and long-term lethal or sub-lethal contaminant effects on organisms
- **Tissue Sampling**: Measure bioaccumulation, model trophic transfer potential, and estimate food web effects
- **Caged Fish/Invertebrate Studies**: Monitor changes in contaminant uptake (bioaccumulation rates) by biota in sediment or water column
- **Sediment Profile Camera Studies**: Characterize macroinvertebrate recolonization, polychaete population density, redox zones, and benthic mixing