Panel: Considerations for Effective Remedy Evaluation

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INTRODUCTION

The remedy evaluation process at contaminated sediment sites encompasses a broad range of policy and technical considerations, both pre-remedy selection and post-remedy selection and implementation. The recent U.S. EPA document *Contaminated Sediment Remediation Guidance For Hazardous Waste Sites* (December 2005) provides a comprehensive risk-based management framework designed to facilitate selection of an appropriate remedy or combination of remedies. However, several issues can impact the expected effectiveness of considered remedial alternatives. These include: evaluating the potential risks associated with continuing sources, including those external to the site, and evaluating anthropogenic background contamination; understanding the risk drivers at the site; establishing realistic/achievable risk-based cleanup goals; identifying the implementation risks associated with each remedy and/or combination of remedies; using models and other data to evaluate which remedies or combination of remedies may effectively address the risk drivers and are most likely to achieve the risk-based cleanup goals; addressing uncertainty associated with the models; and evaluating the feasibility and compatibility of each primary sediment remediation option (on a site-specific basis). Panelists and participants provided federal and industry perspectives on effectively addressing these considerations and applying the national policy and technical lessons learned in a manner that optimizes the selection and evaluation of sediment remediation options and these are reflected below.

KEY REMEDY EVALUATION CONSIDERATIONS AND REMEDY SELECTION PRINCIPLES

Many important issues at contaminated sediment sites, such as source control, implementation risks, residual risks, uncertainty, and monitoring for effectiveness, traditionally have not been considered early enough in the pre-remedy selection phase of sites. As a result, remedy selection decisions have tended to have been made without a thorough understanding of the potential effectiveness of the remedial alternatives. This in turn can lead to stakeholders having unrealistic expectations for what the selected remedy can accomplish and the time frame for achieving success (however it is defined) at the site. The issuance of U.S. EPA's *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (2005), lessons learned at "mature" contaminated sediment sites (i.e., those where remedies have been implemented), and the National Research Council's 2001 report *A Risk-Management Strategy for PCB-Contaminated Sediments* and its 2007 report *Sediment Dredging at Superfund Megasites: Assessing the Effectiveness* have highlighted these issues.

The Panel proposed key remedy evaluation considerations, key remedy selection principles, and steps for remedy evaluation and selection that would address, in part, the issues described above. These consideration and principles should be considered throughout the remedy evaluation and selection process.

TABLE 1. Key Remedy Evaluation Considerations.

- Determine whether sources have been identified and controlled (U.S. EPA 2005). Recontamination is a real and serious concern as evidenced by the number of recently completed sediment sites that have become recontaminated (Nadeau and Skaggs 2007).
- Use and refine a conceptual site model to understand risk drivers and to evaluate which remedial alternative(s) will effectively address risk drivers (U.S. EPA 2005).
- Recognize that mass removal does not necessarily equate to risk reduction (U.S. EPA 2005; NRC 2007).
- Consider implementation risks and residual risks before selecting a remedy (U.S. EPA 2005; Nadeau *et al*. 2009).
- Use a risk-based decision-making approach that includes the 9 National Oil and Hazardous Substances Pollution Contingency Plan (NCP; 40 CFR §300.430(e)(9)(iii)) criteria and complies with the NCP.
- Incorporate lessons learned from experiences at other contaminated sediment sites.

TABLE 2. Key Remedy Selection Principles (adapted from U.S. EPA 2005).

- There is no presumptive remedy for any contaminated sediment site, regardless of the contaminant or level of risk.
- Risk management goals should be developed that can be evaluated within a realistic time period, acknowledging that it may not be practical to achieve all goals in the short term.
- Evaluate uncertainties concerning the predicted effectiveness of various remedial alternatives and the time frames for achieving cleanup levels, remedial goals, and remedial action objectives.
- Use realistic time frames for remedy design, implementation and completion, and incorporate risks associated with remedy implementation when comparing on-going risks.
- The effectiveness of in-situ alternatives (e.g., capping and monitored natural recovery (MNR)) and ex-situ alternatives (e.g., dredging) should be evaluated under conditions present at the site.
- There should not be a presumption that removal of contaminated sediments from a water body will be more effective or permanent than MNR or capping.

TABLE 3. Five Steps for Remedy Evaluation and Selection (adapted from Patmont 2009).

1. Follow U.S. EPA's 2005 *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* because it is filled with good information.
2. Tailor the technical approach to the remedy feasibility and effectiveness evaluation based on experience, lessons learned from case studies, and data.
3. Use tools such as disproportionate cost analysis to communicate the protection versus cost balance.

4. Pre-design/pilot studies and adaptive management can be very helpful in targeting uncertainties at a site and leading to a better understanding of how effective particular remedies may be at the site.
5. Follow U.S. EPA's 2005 *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* because it works.

These key remedy evaluation and remedy selection principles are discussed below in the context of a risk-based decision-making process.

FACTORS IN A RISK-BASED DECISION-MAKING PROCESS

Risk management actions must be specifically designed to reduce significant human health and ecological risks identified in the conceptual site model (CSM) and targeted in the remedial action objectives. To do this, all implementation and residual risks of the remedial alternatives should be identified and considered during remedy evaluation and remedy selection. For CERCLA sites, this decision-making process should be conducted such that the 9 NCP remedy selection criteria can easily be applied when the Record of Decision is written.

Source Control. The first principle for managing risks associated with contaminated sediment sites is to "Control Sources Early" (U.S. EPA 2002). Identifying and controlling sources prior to conducting remediation is critical to the effectiveness of any sediment cleanup (U.S. EPA 2005). Without source control, the site may become recontaminated. Thus, sources, both controlled and continuing, should be identified and evaluated to determine their impact on the effectiveness of potential remedial actions.

The U.S. Navy has a tool to address concerns about continuing sources - the Watershed Contaminated Source Document, which is for evaluating sources (Holmes 2009). As part of the Navy's evaluation of a site, potential Navy and non-Navy sources are investigated through literature searches, watershed visits, and data gap filling activities. Identified sources are plotted on a map and included in the site CSM (U.S. Navy 2003).

Conceptual Site Model. The CSM is a valuable tool that can assist with remedy evaluation and selection by incorporating information on contaminant sources, transport pathways, exposure pathways, and receptors into an understanding of risk drivers at the site. The CSM should be refined and updated as new information is learned and the understanding of the site changes.

The CSM should be used to evaluate the effectiveness of remedial alternatives at addressing identified risk drivers. To be usable, the CSM should not be so long and cumbersome (e.g., a dissertation-length CSM) that the big picture understanding of the site is lost in numerous details (Sturgeon 2009). Moreover, a very lengthy CSM is difficult to update and to follow changes through various versions of the CSM. Thus, to be an effective tool, the CSM should clearly identify and summarize risk drivers at a site.

Adaptive Management and Pre-Design/Pilot Studies. An adaptive management approach, whereby hypotheses in the CSM are tested using pre-design/pilot studies, may be useful at complex sediment sites to address uncertainties in how effective various remedial alternatives may be at achieving remediation goals (Connolly and Logan 2004;

U.S. EPA 2005). Information gained during pre-design/pilot studies should be incorporated into an updated CSM (Connolly and Logan 2004; U.S. EPA 2005). The updated CSM may then be used to further evaluate the potential effectiveness of the remedial alternatives under consideration. A good example of adaptive management and the use of pilot studies is the 2005 Remedial Options Pilot Study at the Grasse River, NY (Connolly et al. 2007).

Implementation Risks. Each remedy has its own uncertainties and implementation risks, which should be considered during remedy evaluation and before remedy selection because they impact both the short-term and long-term effectiveness of remedies. For example, the implementation risks associated with MNR are mostly related to continued exposure to contaminants while natural processes work to reduce contaminant bioavailability (U.S. EPA 2005). For capping, implementation risks may include contaminant releases during placement of the cap, impacts on the community (e.g., noise, accidents, residential or commercial disruption), construction-related risks to workers during transport and placement of cap materials, and disruption of the benthic community (U.S. EPA 2005). During dredging, risks to human health and ecological receptors may increase due to increased exposure to contaminants resuspended and released to the surface water (U.S. EPA 2005; NRC 2007; Bridges et al. 2008). In addition to the effects of releases at the site, resuspended and released contaminants may be transported downstream from the site (Steuer 2000). Similar to capping, dredging implementation risks also include impacts to the community (e.g., noise, accidents, residential or commercial disruption), construction-related risks to workers during dredging, handling, dewatering, and transport of dredged sediment, and disruption of the benthic community (U.S. EPA 2005).

Residual Risk. Residual risk is the risk to human health and to ecological receptors from contaminated materials or residuals that remain after remedial action has been concluded. All remedial approaches leave some contaminants in place after remedial actions are complete including dredging (U.S. EPA 2005; Patmont and Palermo 2007; Bridges et al. 2008). Therefore, the residual risks must be realistically evaluated and compared <u>before</u> selecting a remedy. These evaluations and comparisons should be based on site-specific circumstances. Use of case studies and lessons learned from mature contaminated sediment sites may facilitate this realistic evaluation of potential residual risk from each remedial approach under consideration.

TABLE 4. Examples of Case Studies (adapted from Patmont 2009).

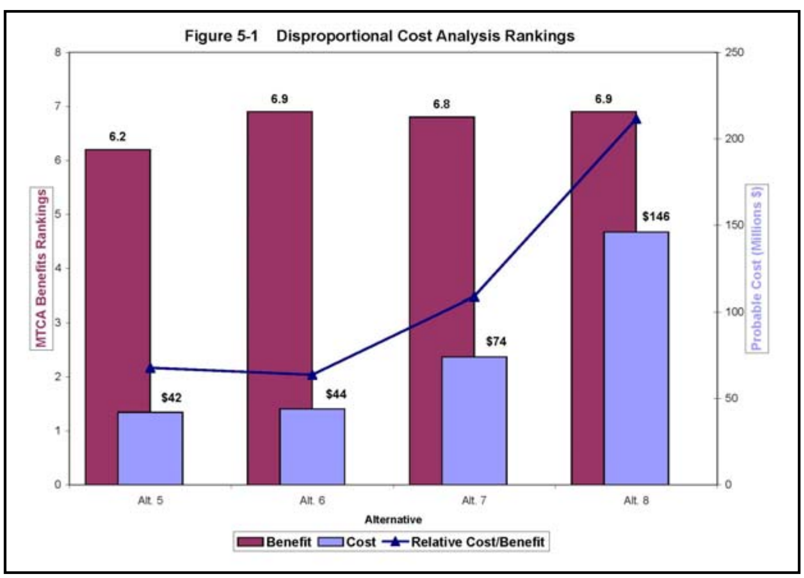
MNR Case Studies – Remedy Effectiveness
Bellingham Bay, WA
Palos Verdes Shelf, CA
Grasse River, NY
Capping Case Studies – Remedy Effectiveness
Simpson Tacoma Kraft Mill, WA
Eagle Harbor, WA
Seattle Waterfront (multiple caps), WA
Whatcom Waterway Log Pond, WA
Ketchikan Paper Company, AK
Spokane River, WA

Dredging Case Studies – Short Term Impacts
Grasse River, NY Fox River SMU 56/57, WI Commencement Bay, WA Duwamish River, WA
Dredging Case Studies – Remedy Effectiveness
NRC 2007 evaluated 26 projects, 3 of which demonstrated risk reduction: Lake Jarnsjon, Sweden Black River, OH Marathon Battery, NY

Evaluating Alternatives. Tools such as comparative net risk evaluation (CNRE) and disproportionate cost analysis can be incorporated into the evaluation of alternatives at a site (NRC 2001; U.S. EPA 2005; Patmont 2009). CNRE compares risks (human health and ecological) posed by site contaminants of concern, implementation risks and residual risks for each remedial alternative prior to remedy selection. CNRE is consistent with the 9 NCP criteria (40 CFR §300.430(e)(9)(iii)), which require evaluation and balancing of short-term and long-term risks and benefits, including residual risk. Failure to account for implementation risks and residual risk during the remedy evaluation stage can skew remedy selection and result in a less effective and less protective remedy than anticipated.

Another tool to evaluate the relative costs and benefits of the remedial alternatives is disproportionate cost analysis (Washington State Department of Ecology 2007; Patmont 2009).

Figure 1. Disproportionate Cost Analysis from the Whatcom Waterway Cleanup Action Plan (Washington State Department of Ecology 2007).



In disproportionate cost analysis, weighting factors are assigned to evaluation criteria in the feasibility study (e.g., the 9 NCP criteria) and the relative protectiveness and benefits for each remedial alternative are ranked for each of the criteria. The overall ranking for each alternative is then compared to the estimated cost of the remedy. Costs are disproportionate to benefits if the incremental costs exceed the incremental benefits achieved by a lower-cost alternative. Please see Figure 1 for an example from the Whatcom Waterway Cleanup Action Plan (Washington State

Department of Ecology 2007; note that Alternative 6, a hybrid dredging, capping, and MNR remedy was selected).

These remedy evaluation tools can be used in conjunction with the NCP to assist in evaluating and comparing remedial alternatives. Their use may also make the decision-making process more transparent for the stakeholders because the risks, expected benefits, and costs associated with each remedial alternative are clearly identified and considered.

ISSUES RELATING TO EFFECTIVE REMEDY EVALUATION AND REMEDY SELECTION

After discussing key considerations and principles in remedy evaluation and selection, panelists and participants discussed issues relating to effective remedy evaluation and remedy selection, which included the following:

- Timing: Often, the discussion on what it means for a remedy to be effective does not occur early enough in the process. Rather, it is left until a remedy must be selected, which short-changes the discussion on effectiveness. This negatively impacts the ability of the project manager and the stakeholders to effectively compare alternatives and select a remedy. Thus, it would be preferable to engage in the discussion on what it means for a remedy to be effective earlier in the life of a contaminated sediment site.

- Targeting the Remedial Investigation/Feasibility Study (RI/FS) to Facilitate Effective Remedy Evaluation: The question, "is the information to be sought in the RI/FS necessary to determine whether one or more of the remedial alternatives will likely satisfy remediation objectives?" is often not asked upfront. This affects the type of data collected, which in turn affects the evaluation of alternatives and can negatively impact remedy selection, especially if the right data are not collected. Thus, an upfront discussion of the types of evidence needed to make a decision is imperative.

- Integrating Contaminated Sediment Site Concepts into CERCLA Remedy Evaluation: The role of CERCLA and the NCP remedy evaluation and selection criteria are often not the primary focus of contaminated sediment practitioners, as they struggle with the many technical complexities posed by these sites. Contaminated sediment practitioners often are focused on the "4Rs" (Bridges et al. 2008), adaptive management, and multi-criteria decision analysis while RPMs are used to focusing on the NCP and its 9 remedy evaluation criteria. While the concepts behind the practitioners' language are important and necessary, practitioners need to integrate these concepts into the context of the NCP in order to assist the RPM in making and documenting decisions that are consistent with CERCLA and the NCP.

- Lengthy Conceptual Site Models: Lengthy CSMs hinder remedy evaluation and selection because the big picture issues (e.g., pathways, receptors, risk drivers) are lost in the details. They are also time consuming to read, difficult to update, and make it hard to understand changes to the CSM over time. Thus, their usefulness to the RPM and other stakeholders may be limited. To improve the CSM's usefulness in understanding risk drivers and as a tool to evaluate remedial alternatives, the CSM should clearly and concisely identify pathways, receptors, and risk drivers at a site.

- Role of the RPM: How RPMs are viewed by stakeholders, by EPA, and by the RPMs themselves affects the decision-making process. One perspective is that RPMs are isolated, solo decision-makers who are solely responsible for the remedy decision and thus, solely responsible for the success or failure of the selected remedy. In contrast, RPMs may be viewed as key voices in the decision-making process, who make a decision based on the weight-of-evidence developed by a large number of people and thus, are part of a team that is responsible for the success or failure of the selected remedy. The panelists and participants discussed the advantages of making existing resources more readily available to RPMs with sediment sites, including information and case studies on completed sediment projects, as well as more consultation and collaboration with the Contaminated Sediments Technical Advisory Group (CSTAG) or others with expertise, either formally or informally.

- My Site is Different: RPMs assigned to sediment sites may not have previous experience with sediment sites and/or they may believe that their site is different from other sediment sites. For example, despite evidence that all dredging leaves residuals (NRC 2007; Patmont and Palermo 2007; Bridges et al. 2008), RPMs and stakeholders may believe that they can do a better job in achieving the remedial goals at their site. This affects how data are collected in the RI/FS, how remedial alternatives are evaluated, and which remedy is selected. Rather than engaging in a theoretical debate over potential remedial limitations, RPMs and stakeholders should compare their site and site conditions to the growing body of case studies to determine what endpoints are realistic for each remedial alternative under consideration at their site. This approach should increase the chances that a realistic expectation will be developed for each of the remedial technologies under consideration, which in turn should increase the chances of meeting the Remedial Action Objectives at the Site.

- Stakeholders' Perceptions: Many stakeholders do not have the benefit of knowledge or an appreciation for the advantages and limitations of dredging, capping, and monitored natural recovery. When another stakeholder, such as a responsible party, raises the issue of dredging residuals and how residuals may affect remedy effectiveness, this valid and important consideration is often dismissed as self-serving and anti-dredging. Follow-up on methods to address this misperception, such as technical dialogues, working groups, or independent experts conveying a balanced overview of the advantages and limitations of the remedial options should be explored.

- Generalization: Often, broad, sweeping generalizations are applied to a large, complicated site rather than breaking down the site into discrete or manageable segments. This may result in inappropriate remedies being selected. For example, a generalization may be "the sediment is unstable and contaminated," which leads to a more intrusive remedy being applied to the entire site rather than to the smaller portion of the site where the more intrusive remedy is appropriate. This could negatively affect habitat at the site, increase implementation and residual risks, and not be cost-effective. While it is important to view the site holistically, it is critical to remedy evaluation and selection to understand the key differences within the overall site. This recognition has led recently to selection of "combination" remedies in which some combination of dredging, capping, and MNR are applied.

- Fear of the Unknown: Fear of the unknown at contaminated sediment sites results can adversely affect the remedy selection process and can impact whether the remedy is effective. For example, fear of the unknown can drive the RI such that substantial data are collected without a clear understanding of how each type of data or study will be used to make decisions. This can lead to long and costly RIs and can delay remedy selection and implementation, which in turn extends the amount of time that risks are uncontrolled at the site. Fear of the unknown may also lead to inappropriate generalizations. For example, rather than acknowledging that it is unclear where the sediment is unstable within a site and developing the information necessary to focus on the areas of potential instability, a generalization is made that all the sediment at the site is unstable. This affects remedy selection, implementation and effectiveness.

CONCLUSIONS

Contaminated sediment sites pose difficult challenges for all stakeholders. These challenges should be acknowledged and confronted as early as possible in the life of a contaminated sediment site so that all stakeholders develop a working understanding of the issues as well as realistic expectations for what can be accomplished at the site and in what time frame those accomplishments may be achieved.

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