Monitoring Remedial Effectiveness

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A wide range of technologies are applicable to the management and remediation of contaminated sediments. The selection of these technologies, either alone or in combination, depends on a wide range of considerations, including:

1. Monitor to assess effectiveness of remedial action in achieving ultimate goal, i.e. protection or recovery of the resource at risk
2. Identify interim goals and monitor to evaluate the effectiveness of the remedial action in achieving those interim goals
3. Monitor implementation of the remedial action to evaluate effectiveness of meeting both engineering and environmental protection goals

Each of these are discussed in more detail below.

Any effort to remediate or manage a site containing contaminated sediments is driven by the risk to one or more environmental resources. Commonly, the resource at risk may be human health related, for example protection of commercial or recreational fishing stocks, or related to ecological health, for example the protection of a migrating fish or bird species or protection of biological diversity in the watershed. Ultimately, the measure of success of the remedial or management option is the degree to which the effort was successful in restoring or protecting that resource. The type of monitoring program required to measure success depends on the resource being protected. The end use of any dredged material must also be considered in that there may be influences on the resource or on other resources that may be put at risk.

It is often difficult to monitor the resource at risk, i.e. measure improvements in human or ecological health resulting from a particular action. There may be sources of exposure other than the sediments being remediated or managed. The water body containing the sediments is likely receiving inputs from nonpoint runoff, sediments in other portions of the surface waters and the atmosphere. In addition, it is even more difficult to measure the success of the chosen management options relative to other options that might have been chosen. Such an effort is critical, however, to learning from the site and improving the decision making process at other sites.

Because of the difficulty and time required to define success in restoring or protecting the primary resource at risk, interim goals are needed to provide more immediate feedback that the remediation or management option is progressing. Often, these interim goals are relatively short-term physico chemical and bioassay measurements. Any remediation or management technology seeks to reduce risk by reducing the contaminants that are or may be introduced to the biologically active zone which includes the upper layers of sediment (which may change with time or due to storm events), the water column, and the air above and surrounding the water body. Monitoring of physical, chemical and biological parameters within this biologically active zone often serve to evaluate effectiveness in meeting interim goals. Examples may include chemical concentration measurements in the water column or in the upper layers of sediment, or density and speciation of benthic organisms. Contaminant uptake in species that respond rapidly to sediment contamination can also be useful as an interim measure. The dynamics of the response of many higher organisms, such as fish or birds, however, may be too slow for these ecological end points to be used as interim measures.

The previous two components of a monitoring program are focused on its long-term effectiveness. A monitoring program is also required for the evaluation of the effectiveness of the implementation of the remedial or management plan. This monitoring effort has three goals:

1) to evaluate the implementation of the particular technology to ensure that it met the engineering construction goals;
2) to evaluate and minimize risks to human and ecological health during implementation;
3) to evaluate the appropriateness of the technology at this and future sites.

The goal of protecting human and ecological health has at least three important components:

- Ensuring the safety and health of the workers implementing the technology;
- Minimizing environmental risks to human and ecological health during implementation.
- Evaluating any natural resource damages that may result from the implementation.

The goal of evaluating the appropriateness of the technology is rarely included in current monitoring plans but is necessary to ensure that the best remedial or management plan was selected and to collect data to help assess the applicability of the technology at other sites. For relative comparisons of sediment management technologies, it may be appropriate to employ contaminant mass flows as a surrogate measure of exposure and, ultimately, risk. That is, a technology may generally be assumed to pose less exposure and risk if it leaves less residual contamination and loses less contaminants to the air and water than an alternative technology. A comparative analysis of mass flows can also identify those components of an overall management strategy that largely control the overall risk and therefore should receive the most resources and effort. As a result it is recommended that the monitoring plan during implementation be directed toward closing the material balance on sediment and contaminant (i.e. identifying the fate of all sediment and contaminants). It is hoped that a similar analysis of mass flows helped lead to the decision to remediate and the selection and design of the remedial option. Thus the monitoring will serve to test assumptions and confirm that the remedial technology is operating as designed.

The primary advantage of employing contaminant mass flows as a surrogate for exposure and risk is to avoid the additional uncertainties associated with detailed exposure modeling and translation of that exposure to human health and ecological risk. The later can not be avoided in the assessment of the risks posed by the unmanaged sediments nor in assessing the adequacy of any particular management approach. It can be useful, however, in the comparative evaluation of potentially applicable technologies. Although uncertainty in the relative comparison is reduced by the use of contaminant mass flows, it cannot be eliminated. In keeping with common practice in such assessments, one approach would be to compare technologies on the basis of both average and 95% upper confidence limit contaminant mass flows.

Summary

This paper has attempted to summarize the three types of monitoring desired to support a sediment remediation program, 1) long term monitoring of resource driving the remediation, 2) short-term monitoring of interim measures of remedial success, and 3) short-term monitoring of implementation of remedial technology. Closure of the material balance on sediment and contaminants during implementation of a remedial technology is recommended as a means of maximizing our understanding of the specific project as well as improve our ability to undertake similar projects in the future. Clear definition of the goals of the remediation and how these goals will be measured help to insure that the effectiveness of the remediation is measured and that this information will improve our ability to select, design and optimize remedial or management approaches at other locations.