Appendix B: Monitoring Tool Matrices

Content: *This appendix provides a detailed description of the ISRAP matrix organization and an explanation of each field of the monitoring tool matrices* ***(www.ISRAP.org)****. Hypothetical examples are given to provide a better understanding of sediment monitoring issues beyond identifying the basic monitoring goals and tools discussed in the previous sections. Ultimately, the matrices can be used to develop sediment monitoring tool comparisons (e.g., ISRAP) for tools used for monitoring for dredging, capping, and monitored natural recovery (MNR), to help remedial project managers (RPMs) focus on key issues associated with site-specific monitoring needs and tools, and to facilitate the design of cost effective and meaningful monitoring plans.*

B.1 Matrix Overview

Though several resources identify general monitoring needs associated with sediment remediation (Apitz et al., 2005; USEPA, 2005b), few provide detailed information on monitoring tools available to address these needs. A compendium of detailed information on monitoring tools is available (USEPA, 2003b), but is not presented in a manner that allows RPMs to readily focus on tools applicable to specific monitoring needs. To date, no formal guidance exists to establish a framework that standardizes monitoring approaches and helps RPMs compare monitoring tools when more than one approach can address a monitoring need.

To bridge the gap between detail-oriented descriptions of monitoring tools and general guidelines that identify monitoring needs, sediment monitoring needs and tools are compiled into remedy-specific matrices for this guidance (Appendix B). The matrices provide a decision-making framework with the following objectives:

- Provide a comprehensive list of monitoring needs.
- Identify monitoring tools associated with each monitoring need.
- Enable a screening-level comparison of monitoring tools when several are available for particular a monitoring need.
- Help RPMs focus on key issues associated with site-specific monitoring needs and tools, to facilitate the design of cost effective, and meaningful monitoring plans.

The matrices build on the first four steps of USEPA's *Monitoring Framework Steps* (USEPA, 2004). By using the matrix to identify monitoring needs and investigate monitoring tools associated with those needs, RPMs can more easily identify monitoring plan objectives and appropriate monitoring tools (Step 1). The matrix also identifies uncertainty associated with individual monitoring tools relative to each monitoring need, a crucial consideration in developing monitoring plan hypotheses (Step 2). Attributes of each monitoring need, such as timing, frequency and formal requirements, and special considerations for assessing monitoring needs specific to remedial approaches are tabulated in the matrices and aid the development of monitoring decision rules (Step 3). Specific tools are identified that aid in design of a monitoring plan (Step 4). The primary fields for each of the matrices (monitored natural recovery, capping, and dredging), for all phases of the monitoring process are arranged in the following hierarchy:

REMEDY

- → **Monitoring Phase**
  - → **Monitoring Need** (Title, Description, Timing Frequency)
    - → **Monitoring Tool** (Title, Description, Type, Commonality of Tool Use, Special Consideration, For More Information)
    - → **Monitoring Design** (Spatial Design Experimental Complexity, Temporal Experimental Design Complexity, Monitoring Tool Logistical Complexity, Difficult in Location Tool in Marketplace, Relative Cost, Level of Expertise Required for Data Interpretation, and Uncertainly in Addressing Monitoring Needs)

The matrices do not include all remedy functions or critical monitoring questions. Conversely, the example tools and needs in the matrices address a wide spectrum of stakeholder concerns and remedial goals that are not likely to be relevant for all (or even most) sites. Examples are included to illustrate the ranges of monitoring tools and needs provided in the Monitoring Tool Matrices. In some cases, little or no ecological monitoring is required, and site-specific monitoring needs and tools strictly focus on chemical concentrations in sediment and water. Ideally, remedial needs should be identified from site-specific remedial action objectives (RAOs) or the record of decision (ROD) prior to using the matrices to investigate the details associated with remedial needs and assist in the identification of appropriate monitoring tools.

B.2 Matrix Arrangement and Description of Matrix Fields

The following sections describe each field of the matrix. Field explanations highlight important issues to consider for cases not explicitly described in the matrix.

Although only three matrices have been developed for this guidance (dredging, capping, and MNR), users can browse information in more than one matrix if more than one remedy is applied or if multi-remedy approaches are used. Multi-remedy approaches include remedies such as thin-layer capping, which uses both capping and MNR, or sites that combine MNR, capping, or dredging.

B.2.1 Monitoring Phase

Within each matrix, monitoring tools are arranged by monitoring needs, which have been divided into three monitoring phases:

- **Construction.** The construction monitoring phase includes monitoring needs for the assessment of adverse conditions associated with the remedial activity, attainment of design criteria, and assessment of construction and operations activities. Assessment of the success of the construction activities in meeting design plans and specifications is also relevant to the construction phase.

> **Examples**
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> Assessing the lateral extent and thickness of the sediment cap or dredge cut lines and bathymetry of the dredged area. Addressing acute environmental impacts associated with remediation, such as sediment suspension and potential off-site transport.

- **Performance**. The performance monitoring phase includes monitoring needs associated with the primary performance of remedy mechanism itself. Performance monitoring is needed for remedies in which contamination is left in place (capping and MNR). The mechanism for capping is isolation of contamination. The mechanism for MNR is usually isolation of contamination, but can also include chemical transformation, reduction in bioavailability and mobility, and dispersion and offsite transport.

> **Example**
>
> For capping, performance monitoring may focus on measuring cap stability and surface sediment chemical concentrations with time. For MNR, performance monitoring may focus on measuring the stability of freshly-deposited surface layers of sediment and surface sediment chemical concentrations with time.

- **Remedial Goal Monitoring.** This monitoring phase provides a definitive assessment of the remedial objectives that are the ultimate goals of sediment management—namely, the reduction of human health and ecological risks (USEPA, 2005b). Feedback provided by remedial goal monitoring is also useful for adaptive management during sediment remediation (NRC, 2003; Linkov et al., 2005), providing cost-effective information to enable more flexible decision-making during and after construction.

> **Examples**
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> Remedial goal monitoring of remedial effectiveness includes simple chemical assessments, such as the monitoring of post-remediation surface sediment, pore water, and surface water concentrations. Remedial goal monitoring tools to assess ecological recovery may include population surveys of fish, birds, or macroinvertebrates.

B.2.2 Monitoring Need

Monitoring need identifies the purpose of monitoring and whether it is enforced through regulatory requirements or based on site-specific ecological recovery goals.

B.2.2.1 Title

This field provides a name for each monitoring need.

B.2.2.2 Description

This field includes a more detailed description of the monitoring need. The monitoring need expresses the monitoring objective and considers the explicit expressions of the environmental values to be protected or restored, referred to in an ecological risk assessment context as "assessment endpoints" (Suter et al., 2000). In many cases, monitoring needs are only relevant for a limited amount of time, such as until exit criteria are satisfied. Relevancy of the monitoring need may not be readily apparent in all cases. Examples durations are provided in the need description field of the matrix, however, one should consult the RAOs on the DQO decision rules or adaptive management framework to identify when the monitoring need is no longer relevant for a site. All monitoring activities should be clearly linked to management and/or exit strategies.

B.2.2.3 Timing

Timing of the monitoring need refers to the point in time at which the monitoring need is likely to be present.

Example

In the construction monitoring phase, attainment of cap design specifications is assessed immediately after capping is completed.

Ranges are provided for some monitoring needs with less distinct timing. For example, performance monitoring needs associated with assessing cap stability over time are present weeks to years after capping, as well as after severe storms, floods, or other events that could affect the cap.

The timing of long-term monitoring needs is determined according to the site conceptual model and results of ongoing monitoring. In some cases, monitoring needs and monitoring tools require that monitoring proceed prior to remediation in order to develop sufficient pre-remedial site characterization data with which to measure remedial effectiveness.

B.2.2.4 Frequency

Frequency of the monitoring need refers to the schedule of monitoring data collection. Monitoring frequencies provided in the matrices are generic recommendations; more or less frequent monitoring may be required according to site-specific conditions and remedial goals.

B.2.3 Monitoring Tool

Monitoring tools are the methods by which data are generated to enable decision-making concerning a given monitoring need.

In this document, the term also applies to planning and data analysis. At best, information provided by monitoring tools is an estimate of the values to be protected or restored by remedial action, similar to "measurement endpoints" or "measures of effects" in an ecological risk assessment context (Suter et al., 2000). Monitoring tools identified within the matrix often serve multiple monitoring needs and may be repeated accordingly.

B.2.3.1 Title

This field includes a concise monitoring tool name.

B.2.3.2 Description

This field includes a description of the monitoring tool.

B.2.3.3 Type

This field lists the general category of the monitoring tool.

- **Physical**. Physical tools rely on measurements of physical parameters, such as depth, size, velocity, or force.
- **Chemical.** Chemical tools focus on measuring chemical parameters, such as pH, salinity, or the presence of particular chemicals.
- **Biological.** Biological tools focus on biological measurements, such as censuses of onsite organisms, toxicity, or tissue residues.

B.2.3.4 Commonality of Tool Use

This field includes a description of the commonality of the tool use for the selected monitoring need.

- Very common. Tools almost always used to evaluate the specific need.
- Common. Commonly used to evaluate the specific need.
- Rare. Occasionally used to evaluate the specific need, often providing additional or backup information for another more-commonly applied tool.
- Very rare. Tools are not usually used for the specific need, but may be applicable in special cases.

Commonality ratings are given based on historical tool uses. Many innovative tools are ranked as “Rare” or “Very rare” because their novelty has not afforded the opportunity for widespread use. In some cases, “Rare” or “Very rare” may be the best tools for the situation.

B.2.3.5 Special Considerations

This field lists significant restrictions, caveats, and other important information about the monitoring tool, specifically those that may limit or enhance its application.

B.2.3.6 For More Information

This field provides references to additional information sources about the monitoring tools. Where available, this field includes references to EPA Fact Sheets in the EPA sediment monitoring tools compendium (EPA, 2003b) as well as links to other guidance or information available via the internet.

B.2.4 Monitoring Design

This section provides rankings for seven aspects of monitoring design and characterizes the complexity of the various monitoring approaches.

The monitoring design aspects provide information to enable a screening-level comparison of monitoring tools when several are available for a particular monitoring need. Each monitoring design category is ranked low, medium, or high. Except for Relative Cost, rankings are subjective and include brief justifications. The optimal condition for all seven monitoring design characteristics is "low." However, many rankings are variable according to regulatory interpretation, site-specific conditions, and continued development and refinement of monitoring tools. The decision to select one monitoring tool over another should be made only on further investigation of monitoring tools, site-specific conditions, and specific monitoring needs.

B.2.4.1 Spatial Experimental Design Complexity

This field addresses the complexity regarding the location and number of monitoring points required for successful application of the monitoring tool. Also considered is the level of expertise needed to design a spatial monitoring plan and the complexity of tools needed for spatial sampling plan design, such as geographical or statistical software.

This field is ranked low, medium, or high:

- **Low**. Indicates minimal technical requirements to design an explicit spatial monitoring plan.
- **Medium**. Indicates a complex spatial experimental design may be necessary. The design may need to account for site-specific conditions and characteristics of the tool itself, may be complex, or the tool may require background data and/or specialized expertise to ensure that the sampling plan is cost-effective.
- **High**. Indicates that a complex spatial experimental design is likely required. Complex designs are needed to account for complex and heterogeneous site-specific conditions, and for complex characteristics of the monitoring tool itself. A complex spatial experimental design ranking is likely to require substantial background data and expertise with advanced tools (e.g., modeling or geostatistics) to design a cost-effective spatial sampling plan that meets monitoring needs.

B.2.4.2 Temporal Experimental Design Complexity

This field addresses the complexity regarding decisions on the timing and frequency of monitoring tool use. This category considers the Timing and Frequency associated with the monitoring need, but also addresses time constraints imposed by monitoring tools.

This field is ranked low, medium, or high:

- **Low**. Indicates that the temporal design complexity is simple. Monitoring can be scheduled according to the discretion of project personnel. In addition, the proper timing of the monitoring is readily apparent.
- **Medium**. Indicates that the temporal design complexity is moderate. In many cases, monitoring can be scheduled according to the discretion of project personnel. In addition, the proper timing of the monitoring is usually apparent.
- **High**. Indicates that the temporal design complexity is complicated by possibly more than one day of discrete sampling effort or several days of continuous monitoring. The monitoring schedule may not be at the discretion of project personnel, but may be determined by site conditions or other phenomena, such as monitoring storm events, or biological changes over time. In addition, the proper timing of the monitoring may not be readily apparent, requiring multiple attempts over time to obtain adequate data.

B.2.4.3 Monitoring Tool Logistical Complexity

This field addresses the logistical complexity of monitoring tools, with respect to operation of the tool itself.

> **Examples**
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> Fragile technical apparati, difficult or sensitive monitoring protocols, experimental techniques that may require method development or validation, and methods that require specialized expertise (e.g., taxonomic identifications, scuba diving).

This field is ranked low, medium, or high:

- **Low**. Indicates that the monitoring tool is simple, rugged, and familiar or routinely applied by monitoring professionals. The monitoring tool is not constrained by special conditions and does not require substantial extra efforts (e.g., method development, extensive preparation efforts, etc.) beyond what is required to conduct monitoring at the site. In cases where logistical complexity is low, minimal planning is required to apply the monitoring tool.
- **Medium**. Indicates that the monitoring tool may be moderately more complex, though reasonably familiar to monitoring professionals. The monitoring tool may be constrained by special conditions and may require some non-routine efforts or preparation. In cases where logistical complexity is medium, a greater planning may be required to apply the monitoring tool effectively.
- **High**. Indicates that the monitoring tool is complex, delicate, and may be unfamiliar to monitoring professionals. The monitoring tool is likely to be constrained by special conditions and may require substantial non-routine efforts, significant preparation, or customization. In cases where monitoring tool logistical complexity is high, a significant amount of planning and effort is likely required to apply the monitoring tool effectively, or it may require specialized vendors with appropriate training and experience.

B.2.4.4 Difficulty in Locating Tool in Marketplace

This field addresses the difficulty of locating a commercial monitoring professional to apply a monitoring tool. It is ranked low, medium, or high:

- **Low**. Indicates that the monitoring tool is widely available from traditional commercial sources that supply sediment monitoring services. In most cases, commercial arrangements with monitoring professionals are not complicated by availability or geographic proximity to the site.
- **Medium**. Indicates that the monitoring tool may not be available from traditional commercial sources. In most cases, this category includes more complex tools that may only be available from a limited number of specialized commercial monitoring sources. These tools can be novel, proprietary, or require a high level of technical expertise that is not yet widely available in the monitoring marketplace. Commercial arrangements with monitoring professionals may be complicated by availability or geographic proximity to the site.
- **High**. Indicates that the monitoring tool is likely unavailable from commercial sources. In most cases, this category includes extremely complex or experimental tools. The tool may only be available from non-commercial sources, such as university, non-profit, or government laboratories. In some cases, it may not be possible to obtain access to the monitoring tool.

B.2.4.5 Relative Cost

The cost of sediment monitoring is difficult to estimate and highly variable, depending on the site, the monitoring plan, and other factors. This field ranks costs for tools that fulfill the same monitoring need. The value of the field is dependent on the cost range of a given set of tools. When monitoring needs are associated with only one tool, the relative cost is ranked "medium." Tools assigned the same ranking for the same monitoring need are roughly equivalent in cost.

Note: Because rankings are relative, this field cannot be used to compare costs across different monitoring needs.

Example

Multiple short-term and long-term monitoring tools are potentially appropriate for investigating human health risks associated with consumption of fish, including simple chemical methods, laboratory or highly-controlled biological investigations, and field surveys of native fish. Of these approaches, the least expensive are ranked "low." The most expensive are ranked "high."

B.2.4.6 Level of Expertise Required for Data Interpretation

This field addresses the level of expertise required to interpret data and to use the interpreted data to address the monitoring need within a decision framework. This field is ranked low, medium, or high:

- **Low**. Indicates that little specialized expertise is required to interpret and apply monitoring data for decision making. In many cases, data produced are readily applied to decision making and interpretation.
- **Medium**. Indicates that experience may be required to interpret and apply monitoring data for decision making. In some cases, data may not be in a readily usable form for decision making and may require interpretation relative to other studies, modeling, or outside expertise.
- **High**. Indicates that significant specialized expertise is required to interpret and apply monitoring data for decision making. Data may not exist in a readily-usable form for decision making. Interpretation may require comparison with other studies, modeling, or the assistance of specialized expertise. May require specialized vendors.

B.2.4.7 Uncertainty in Addressing Monitoring Need

This field addresses the level of uncertainty associated with using data to satisfy the monitoring need. This aspect of monitoring design is critical to a successful monitoring program.

Uncertainty associated with monitoring can originate from multiple sources. Uncertainty tends to be lower for long-term monitoring than for short-term monitoring due to differences in the temporal representativeness and predictive abilities of long-term monitoring designs. In some cases, monitoring uncertainty is a function of the relationship between the type of data provided by the tool and the information required to definitively assess the monitoring need. Data provided by basic monitoring tools may require extrapolation to link the monitoring results to complex monitoring needs. When applied to simple monitoring needs, the same monitoring tools produce results with greater certainty. In cases where basic and advanced tools are both available, there is a tradeoff between levels of effort and certainty. In some cases, information required for the monitoring need may be unquantifiable.

This field is ranked low, medium, or high:

- **Low**. Indicates high confidence in the ability of the monitoring tool to satisfy monitoring needs. Data produced using the monitoring tool are directly relevant to assessment endpoints associated with the monitoring need and are directly applicable in the decision-making process.
- **Medium**. Indicates moderate confidence in the ability of the monitoring tool to satisfy monitoring needs. Data produced using the monitoring tool are relevant to assessment endpoints associated with the monitoring need, but may require extrapolation or may not be sufficient to address more complex monitoring needs if the monitoring tool is used as a single line of evidence.
- **High**. Indicates low confidence in the ability of the monitoring tool to provide useful information to satisfy monitoring needs. Data produced using the monitoring tool are only partially relevant to assessment endpoints associated with the monitoring need, and may require significant extrapolation for use in decision-making. The monitoring data are likely insufficient to address more complex monitoring needs when the monitoring tool information is used as a single line of evidence. In many cases, monitoring tools with high uncertainty serve as screening tools for refining the monitoring program using more complex monitoring tools with greater certainty.