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Standard Guide for ~~Monitoring~~Contaminated Sediment Site Risk-Based Corrective Action – ~~Monitoring~~Baseline, Remedy Implementation and Post-Remedy Monitoring Programs[1]

This standard is issued under the fixed designation E3164; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide pertains to corrective action monitoring before (baseline monitoring), during (remedy implementation monitoring) and after (post-remedy monitoring) sediment remedial activities. It does not address monitoring performed during remedial investigations, pre-remedial risk assessments, and pre-design investigations.

1.2 ~~This guide pertains to corrective action monitoring before, during and after sediment remediation activities. It does not address monitoring performed during remedial investigations, risk assessments performed before the corrective action, and pre-design investigations. This standard primarily focuses on the approach for remedial actions performed under the~~ Sediment monitoring programs (baseline, remedy implementation and post-remedy) are typically used in contaminated sediment corrective actions performed under various regulatory programs, including the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). ~~Thus,~~Although many of the references cited ~~are CERCLA oriented. The standard is also applicable to remedial~~in this guide are CERCLA-oriented, the guide is applicable to corrective actions performed under ~~state, federal and international cleanup programs, but the standard does not describe requirements~~ local, state, tribal, federal, and international corrective action programs. However, this guide does not provide a detailed description of the monitoring program requirements or existing guidance for each jurisdiction. ~~The requirements for the regulatory entity under which the cleanup is performed should be reviewed to confirm they are met.~~This guide is intended to inform, complement, and support but not supersede the guidelines established by local, state, tribal, federal, or international agencies.

1.3 This guide provides a framework, which includes widely accepted considerations and best practices for monitoring sediment remedy ~~effectiveness. The monitoring sediment standard guide is intended to complement and support the selection of monitoring techniques, not supersede local, state, federal or international community regulations.~~efficacy.

1.4 This guide is related to several other guides. Guide E3240 provides an overview of the sediment risk-based corrective action (RBCA) process, including the role of risk assessment and representative background. Guide E3163 discusses appropriate laboratory methodologies to use for the chemical analysis of potential contaminants of concern (PCOCs) in various media (such as, sediment, porewater, surface water and biota tissue) taken during sediment monitoring programs; it also discusses biological testing and community assessment. Guide E3382 describes the overall framework to determine representative background concentrations (including Conceptual Site Model [CSM] considerations) for a contaminated sediment site; Guides E3344 (methodologies for selecting representative background reference areas) and E3242 (statistical and chemical methodologies used in developing representative background concentrations for a sediment site) complement Guide E3382.

[1] This guide is under the jurisdiction of ASTM Committee E50 on Environmental Assessment, Risk Management and Corrective Action and is the direct responsibility of Subcommittee E50.04 on Corrective Action. Current edition approved ~~May 1, 2018~~Aug. 1, 2023. Published ~~August 2018~~September 2023. Originally approved in 2018. Last previous edition approved in 2018 as E3164–18. DOI: ~~10.1520/E3164-18.~~10.1520/E3164–23.

1.5 *Units*—The values stated in SI or CGS units are to be regarded as the standard. No other units of measurement are included in this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D75 Practice for Sampling Aggregates

D4823 Guide for Core Sampling Submerged, Unconsolidated Sediments

D7363 Test Method for Determination of Parent and Alkyl Polycyclic Aromatics in Sediment Pore Water Using Solid-Phase Microextraction and Gas Chromatography/Mass Spectrometry in Selected Ion Monitoring Mode

E1391 Guide for Collection, Storage, Characterization, and Manipulation of Sediments for Toxicological Testing and for Selection of Samplers Used to Collect Benthic Invertebrates

~~E2616~~E3163 Guide for ~~Remedy Selection Integrating Risk-Based Corrective Action and Non-Risk Considerations~~Selection and Application of Analytical Methods and Procedures Used during Sediment Corrective Action

E3240 Guide for Risk-Based Corrective Action for Contaminated Sediment Sites

E3242 Guide for Determination of Representative Sediment Background Concentrations

E3344 Guide for Selection of Background Reference Areas for Determination of Representative Sediment Background Concentrations

E3382 Guide for Developing Representative Background Concentrations at Sediment Sites — Framework Overview, Including Conceptual Site Model Considerations

~~2.2 *Referenced Documents:*~~

~~Association of State and Territorial Solid Waste Management Officials, Framework for Long-Term Monitoring of Hazardous Substances at Sediment Sites, Sediments Group, January 2009~~

~~Bridges, T. S., K. E. Gustavson, P.R. Schroeder, S. J. Ells, D. Hayes, S. Nadeau, M. R. Palermo, and C. Patmont, "Dredging Processes and Remedy Effectiveness: Relationship to the 4 Rs of Environmental Dredging," Integrated Environmental Assessment and Management, Vol 6, No. 4, October 2010, pp. 619–630~~

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~~Interstate Technology & Regulatory Council (ITRC), Contaminated Sediments Remediation: Remedy Selection for Contaminated Sediments, Guidance Document, ITRC, Washington, D.C., August 2014~~

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~~Patmont, C. R., U. Ghosh, P. LaRosa, C. A. Menzie, R. G. Luthy, M. S. Greenberg, G. Cornelissen, E. Eek, J. Collins, J. Hull, T. Hjartland, E. Glaza, J. Bleiler, J. Quadrini, "In situ sediment treatment using activated carbon: A demonstrated sediment cleanup technology," Integrated Environmental Assessment and Management, Vol. 11, Issue 2, January 6, 2015, pp. 195-207~~

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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U.S. Navy Space and Naval Warfare (SPAWAR) Systems Center Pacific and ENVIRON International Corporation, Long-Term Monitoring Strategies for Contaminated Sediment Management, February 2010

2.3 *U.S. Army Corps of Engineers:*

Palermo, M. R., J. E. Clausner, M. P. Rollings, G. L. Williams, T. E. Myers, T. J. Fredette, R. E. Randall, Guidance for Subaqueous Dredged Material Capping, Technical Report DOER-1, Dredging Operations and Environmental Research Program, U.S. Army Corps of Engineers, Washington, D.C., June 1998

Palermo, R., P. R. Schroeder, T. J. Estes, and N. R. Francingues, Technical Guidelines for Environmental Dredging of Contaminated Sediments, ERDC/EL TR-08-29, U.S. Army Corps of Engineers, Engineer Research and Development Center, Vicksburg, MS, September 2008

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2.4 *U.S Environmental Protection Agency:*[3]

U.S. Environmental Protection Agency, Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, EPA/540/G-89/004, OSWER Directive 9355.3-01, Office of Emergency and Remedial Response, Washington, D.C., October 1988

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U.S. Environmental Protection Agency, EPA Requirements for Quality Assurance Project Plans, EPA QA/R-5, EPA/240/B-01/003, Office of Environmental Information, Washington, D.C., March 2001a

U.S. Environmental Protection Agency, Comprehensive Five-Year Review Guidance, EPA 540/R-01/007, Office of Emergency and Remedial Response, Washington, D.C., June 2001b

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U.S. Environmental Protection Agency, Handbook: A Compendium of Chemical, Physical and Biological Methods for Assessing and Monitoring the Remediation of Contaminated Sediment Sites, Battelle Memorial Institute, Duxbury, MA, February 2003a

U.S. Environmental Protection Agency, "Five-Year Review Process in the Superfund program," Fact Sheet, EPA 540-F-02-004, OSWER 9355.7-08FS, Office of Solid Waste and Emergency Response, Washington D.C., April 2003b

U.S. Environmental Protection Agency, Guidance for Monitoring at Hazardous Waste Sites: Framework for Monitoring Plan Development and Implementation, OSWER Directive No. 9355.4-28, Office of Superfund Remediation and Technology Innovation, Washington, D.C., January 2004a

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[3] Available from United States Environmental Protection Agency (EPA), William Jefferson Clinton Bldg., 1200 Pennsylvania Ave., NW, Washington, DC 20460, http://www.epa.gov.

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U.S. Environmental Protection Agency, "Operating Procedure: Sediment Sampling, SESDPROC-200-R3," USEPA Region 4, Science and Ecosystem Support Division, Athens, GA, August 2014a
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3. Terminology

3.1 *Definitions:*

3.1.1 *adaptive management, n*—a structured, iterative process of robust decision making in the face of uncertainty, with the goal of ensuring effectiveness during remedial action. **E3240**

3.1.2 *anthropogenic background, n*—human-made substances present in the environment due to human activities, not specifically related to current or historical site-related releases or activities. **E3344**

3.1.3 *background (aka "reference"), n*—substances, conditions, or locations that are not influenced by releases from a sediment site; these are usually a combination of naturally occurring (consistently present in the environment but not influenced by human activity) and anthropogenic (influenced by human activity but not related to specific current or historical activities or releases at the sediment site) components. **E3382**

3.1.4 *bioavailability, n*—the degree to which a contaminant is free to be taken up by an organism. **E3240**

3.1.5 *cleanup level, n*—the prescribed average or point sediment concentration of a chemical that shall not be exceeded at the remediated site. **E3242**

3.1.6 *conceptual site model, n*—the integrated representation of the physical and environmental context, the complete and potentially complete exposure pathways, and the potential fate and transport of potential contaminants of concern at a site. **E3242**

3.1.6.1 *Discussion—*

The CSM should include both the current understanding of the site and an understanding of the potential future conditions and uses for the site. It provides a method to conduct the exposure pathway evaluation; inventory the exposure pathways evaluated; and determine the status of the exposure pathways as incomplete, potentially complete, or complete.

3.1.7 *contaminant of concern (COC), n*—substances identified as posing a risk based on a tiered risk assessment and that warrant corrective action. **E3382**

3.1.7.1 *Discussion—*

Typically, all PCOCs identified for a sediment site are evaluated in the risk assessment process. PCOCs that have sediment concentrations greater than risk-based thresholds identified in the risk assessment process are defined as COCs. Thus, the COCs identified for a sediment site are a subset of the PCOCs identified for that site.

3.1.8 *corrective action, n*—the sequence of actions that may include site assessment and investigation, risk assessment, evaluations of potential remedial action alternatives, interim remedial action, remedial action, operation and maintenance of the remedy, monitoring of progress, making "No Further Action" determinations, and completion of the remedial action. **E3240**

3.1.9 *data quality objectives (DQOs), n*—the systematic process to develop performance and acceptability criteria by defining study objectives and the type, quality, and quantity of data needed for site decisions. **E3240**

3.1.10 *natural background, n*—naturally occurring substances present in the environment in forms (and at concentrations) that have not been influenced by human activity. **E3344**

3.1.11 *potential contaminant of concern (PCOC), n*—a contaminant whose sediment concentrations at the site may exceed applicable screening levels; this includes chemicals of potential environmental concern (COPECs) and chemicals of potential concern (COPCs). **E3242**

3.1.12 *remedial action, n*—activities conducted to reduce or eliminate current or potential future exposures to receptors or relevant ecological receptors and habitats. **E3240**

3.1.12.1 *Discussion—*

These activities include monitoring, implementing activity and use limitations and designing and operating cleanup equipment. Remedial action includes activities that are conducted to reduce sources of exposure to meet RAOs, or sever exposure pathways to meet RAOs.

3.1.13 *remedial action objectives (RAO), n*—stated objectives that describe what the remedial action for a site is expected to accomplish, based on the CSM and the exposure pathways that may pose an unacceptable risk as determined in a risk assessment; RAOs are specific and achievable goals for reducing risk to human health and the environment. **E3240**

3.1.14 *representative background concentrations, n*—chemical concentrations that are inclusive of naturally occurring sources and anthropogenic sources similar to those present at a sediment site but not related to current or historical site releases or activities. **E3382**

3.1.15 *sediment(s), n*—a matrix of porewater and particles including gravel, sand, silt, clay, and other natural and anthropogenic substances that have settled at the bottom of a tidal or nontidal body of water. **E3163**

3.1.16 *sediment site, n*—the area(s) defined by the likely physical distribution of COC(s) from a source area and the adjacent areas required to implement the corrective action. A site could be an entire water body or a defined portion of a water body. **E3240**

3.2 *Definitions of Terms Specific to This Standard:*

~~3.1.1 *adaptive management, n*—a structured, iterative process of robust decision-making uncertainty, with an aim to reducing uncertainty over time via monitoring.~~

3.2.1 *backfill, n*—clean materials placed directly on the post-dredge surface to provide cover ~~and/or~~or bring the post-dredging surface to a targeted ~~elevation. (Also~~ elevation, or both (also see, *cover ~~material.~~material*)).

~~3.1.3 *background conditions (aka reference conditions), n*—substances, conditions, or locations that are not influenced by releases from a site; are usually naturally occurring (consistently present in the environment, but not influenced by human activity) or anthropogenic (influenced by human activity, but not related to specific activities at the site).~~

3.2.2 *baseline monitoring, n*—~~abiotic and biotic~~ monitoring to establish ~~ambient concentrations~~ physical characteristics of the sediment site (such as, sediment mudline elevations), chemical characteristics (such as, COC concentrations in various media) and biological characteristics (such as, sediment toxicity to select organisms) prior to the commencement of ~~remediation.~~remedy implementation.

3.2.3 *benthic community, n*—assemblage of aquatic invertebrates that ~~live/reside~~reside in the sediments.

~~3.1.6 *bioavailability, n*—the relationship between external (or applied) dose and internal (or resulting) dose of the chemical(s) being considered for an effect (NRC 2003).~~

3.2.4 *biologically active zone ~~(aka biotic zone),~~ (BAZ), n*—the zone of greatest ~~organism-substrate interaction (Determination of the Biologically Relevant Sampling Depth for Terrestrial and Aquatic Ecological Risk Assessments, Ecological Risk Assessment Support Center [EPA], October 2015).~~organism-sediment interaction.

3.2.4.1 *Discussion—*

Typically, at a sediment site the BAZ is the top 10–15 centimeters (cm) of surficial sediment below the sediment – surface water interface. The BAZ is site-specific and in some cases can be deeper than 15 cm.

3.2.5 *biota, n*—the flora and fauna living in a habitat ~~**(Glossary (1of).**BioassessmentTerms,[3] Wetland Bioassessment Fact Sheet 10 [EPA843-F-98-001e], Office of Water [EPA], July 1998)~~

3.2.6 *capping, n*—the process of placing a material over contaminated sediments to mitigate risk posed by those sediments.

~~3.1.10 *conceptual site model, n*—the integrated representation of the physical and environmental context, the complete and potentially complete exposure pathways and the potential fate and transport of chemicals(s) of concern at a site. The site conceptual model should include both the current understanding of the site and the understanding of the potential future conditions and uses for the site. It provides a method to conduct the exposure pathway evaluation, inventory the exposure pathways evaluated, and determine the status of the exposure pathways as incomplete, potentially complete, or complete. (ASTM E50.04, E2616)~~

~~3.1.11 *corrective action objectives (CAOs), n*—describes what the corrective action is expected to accomplish, based on the conceptual site model and the exposure pathways that pose an unacceptable risk as determined in a risk assessment. CAOs are specific and achievable goals for reducing risk to human health and the environment.~~

3.2.7 *cover material, n*—alternative term for "*backfill*".

3.2.8 *effectiveness monitoring, n*—component of a post-remedy monitoring program to confirm the RAOs are being met or are trending towards being met in an acceptable time frame.

3.2.9 *environmental dredging, n*—the removal of contaminated sediment ~~to reduce risks to human health and the environment.~~at a sediment site; typically during the remedy implementation stage of the corrective action.

3.2.10 *enhanced monitored natural recovery (EMNR), n*—a remediation practice that applies clean material ~~or amendments~~ to the sediment surface to accelerate natural recovery processes.

~~3.1.15 *data quality objectives (DQOs), n*—the monitoring goals for collecting data. DQOs include the performance and acceptance criteria that define whether data meet the monitoring goals.~~

3.2.11 *fish community, n*—an assemblage or association of populations of two or more fish species occupying the same geographical area ~~(for example,~~(such as, stream reach) during a particular ~~time.~~time frame.

~~3.1.17 *freely dissolved contaminants, n*—the concentration of the chemical that is dissipated in water and bioavailable to biota, excluding the portion sorbed onto particulate and dissolved organic carbon (kg of chemical/L of water).~~

~~3.1.18 *groundwater-surface water transport, n*—process by which surface water readily exchanges with groundwater through the subsurface volume of sediment and porous space.~~

3.2.12 *in situ treatment, n*—application of amendment materials to the ~~sediment intended to mix~~ sediment, so they may be mixed (either naturally or mechanically) into the sediments and reduce the bioavailable fraction of ~~contamination~~contaminants in porewater.

3.2.13 *in situ solidification, n*—a remediation approach that mixes solidification agents ~~(for example,~~(such as Portland cement) into impacted ~~sediments that are intended~~ sediments; the intended result is to reduce sediment permeability and the mobility of ~~contamination~~contaminants within the bulk sediment.

3.2.14 *monitoring, n*—the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress towards meeting documented program objectives.

3.2.14.1 *Discussion*—

Monitoring is the collection of data (that is physical, chemical, biological) over a sufficient period of time and frequency, so that data analysis can determine trends in one or more environmental parameters or characteristics and compare their status to remedy objectives.

3.2.15 *monitored natural recovery (MNR), n*—a remediation practice that relies on natural processes (such as, sequestration and biodegradation) to protect the environment and receptors from unacceptable exposures to contaminants.

3.2.16 ~~*post-remedy monitoring, (aka long-term monitoring), performance monitoring, n*—monitoring to determine whether contaminants of potential environmental concern (COPECs) concentrations in affected media met CAOs, or continue to decrease~~

and are expected to meet CAOs in an acceptable time frame.component of a post-remedy monitoring program conducted to determine if the remedy is performing as designed.

3.1.22.1 *performance monitoring, n*—post remedy monitoring conducted to determine if the remedy is performing as designed. It evaluates the remedial technology.

3.1.22.2 *effectiveness monitoring, n*—post remedy monitoring to confirm the CAOs are met.

3.2.17 *post-remedy monitoring, n*—programs that typically include performance monitoring (to demonstrate the remedy is performing as designed) and effectiveness monitoring (to determine whether COC concentrations in affected media met RAOs, or are expected to meet RAOs in an acceptable time frame).

3.2.17.1 *Discussion—*

A post-remedy monitoring program may have both short-term and long-term performance and effectiveness monitoring goals (such as, meeting RAOs).

3.2.18 *porewater, n*—water located in the interstitial voids (between solid-phase particles) of bulk sediments.

3.2.19 *remedial investigation, n*—the contaminated site investigation performed prior to remedial alternative selection to determine if the nature and extent of contamination is at unacceptable levels and warrants any potential remedial action.

3.2.20 *remedy implementation monitoring, (aka construction monitoring), n*—monitoring of conditions during remediation remedy execution to determine if design criteria have been achieved. achieved and if regulatory requirements have been met.

3.2.20.1 *Discussion—*

If an active remedy has been chosen, this is often referred to as "construction monitoring". In many cases, there will be permit requirements during the implementation of the remedy and monitoring may be required to ensure compliance with these requirements.

3.1.26 *representative background concentrations, n*—a chemical concentration that is inclusive of naturally occurring sources and anthropogenic sources similar to those present at a site, but not related to site releases and site-related activities.

3.2.21 *residuals, n*—untreated contamination that remains in the surface sediment after dredging sediment.the completion of sediment dredging operations.

3.1.28 *sediment(s), n*—a matrix of pore water and particles including gravel, sand, silt, clay and other natural and anthropogenic substances that have settled at the bottom of a tidal or non-tidal body of water.

4. Significance and Use

NOTE 1—This standard should be used in conjunction with other reference material to guide the user in developing and implementing sediment corrective action monitoring programs.

4.1 Activities described in this guide should be conducted by persons familiar with current sediment site characterization and remediation techniques.

4.1 This guide may be used by various parties involved in sediment corrective action programs, including regulatory agencies, project sponsors, environmental consultants, toxicologists, risk assessors, site remediation professionals, environmental contractors, analytical testing laboratories, data validators, data reviewers and users, and other stakeholders, which may include, but are not limited to, owners, buyers, developers, lenders, insurers, government agencies, and community members and groups.*Intended Users:*

4.1.1 This guide may be used by various parties involved in sediment corrective action programs, including regulatory agencies, project sponsors, environmental consultants, toxicologists, risk assessors, site remediation professionals, environmental contractors, and other stakeholders.

4.2 This guide is not intended to supplant applicable regulations. Instead this guide may be used to complement and support such regulatory requirements.*Reference Material:*

4.2.1 This guide should be used in conjunction with other ASTM guides listed in 2.1 (especially Guides E3163, E3240, E3242, E3344 and E3382), as well as the material in the References section.

~~4.4 This guide provides a decision framework based on over-arching features and elements that should be customized by the user based on site-specific conditions, regulatory context, and sediment corrective action objectives. This guide should not be used alone as a prescriptive checklist.~~

4.3 ~~This guide provides a systematic, but flexible decision framework to accommodate variations in approaches by regulatory agency and by the user based on project objectives, site complexity, unique site features, regulatory requirements, newly developed guidance, newly published scientific research, changes in regulatory criteria, advances in scientific knowledge and technical capability, and unforeseen circumstances.~~*Flexible Site-Specific Implementation:*

4.3.1 This guide provides a systematic but flexible framework to accommodate variations in approaches by regulatory agencies and by the user based on project objectives, site complexity, unique site features, regulatory requirements, newly developed guidance, newly published scientific research, changes in regulatory criteria, advances in scientific knowledge and technical capability, and unforeseen circumstances.

4.3.1.1 This guide provides a monitoring plan development, execution and analysis framework based on over-arching features and elements that should be customized by the user based on site-specific conditions, regulatory context, and sediment corrective action objectives.

4.3.1.2 Implementation of the guide is site-specific. The user may choose to customize the implementation of the guide for a particular site, especially smaller, less complex sites.

4.3.1.3 This guide should not be used alone as a prescriptive checklist.

4.3.2 The users of this guide are encouraged to update and refine (when needed) the conceptual site model, Project Work Plans and Project Reports used to describe the physical properties, chemical composition and occurrence, biologic features, and environmental conditions of the sediment corrective action project.

4.4 ~~Implementation of the guide is site-specific. The user may choose to customize the implementation of the guide for particular types of sites, especially smaller, less complex sites.~~*Regulatory Frameworks:*

4.4.1 This guide is intended to be applicable to a broad range of local, state, tribal, federal, or international jurisdictions, each with its own unique regulatory framework. As such, this guide does not provide a detailed discussion of the requirements or guidance associated with any of these regulatory frameworks, nor is it intended to supersede applicable regulations and guidance. The user of this guide will need to be aware of (and comply with) the regulatory requirements and guidance in the jurisdiction where the work is being performed.

4.5 ~~When applying this guide, the user should undertake a systematic project planning and scoping process to collect information to assist in making site-specific, user-defined decisions for a particular project. Planning activities should include the following factors: *(a)* Assemble an experienced team of project professionals; *(b)* Identify the applicable regulatory program(s); *(c)* Engage stakeholders early and often in the planning process; *(d)* Define, agree on, and document clearly stated project objectives and intended outcomes;~~
~~*(e)* Recognize that sediment programs are complex, uncertainty is high, that an appropriate project-specific approach may be developed with the investment of time and effort, and that compromise and uncertainty are inherent in the process;~~
~~*(f)* Compile existing site data; and *(g)* Establish a plan for documenting and reporting key decisions and results. These project planning and scoping activities should be carried forward as the project progresses.~~*Systematic Project Planning and Scoping Process:*

4.5.1 When applying this guide, the user should undertake a systematic project planning and scoping process to collect information to assist in making site-specific, user-defined decisions for a particular project, including assembling an experienced team of project professionals. These practitioners should have the appropriate expertise to scope, plan, and execute a sediment monitoring program. This team may include, but is not limited to, project sponsors, environmental consultants, toxicologists, site remediation professionals, analytical chemists, geochemists, and statisticians.

~~4.8 The users of this guide should consider assembling a team of experienced project professionals with appropriate expertise to scope, plan and execute a sediment data acquisition program. The team may include: regulatory agencies, project sponsors, environmental consultants, toxicologists, risk assessors, site remediation professionals, environmental contractors, analytical testing laboratories, and data reviewers, data validators, data users, and other stakeholders.~~

~~4.6 The users of this guide are encouraged to engage key stakeholders early and often in the project planning and scoping process, especially regulators, project sponsors, and service providers. A concerted ongoing effort should be made by the user to continuously engage stakeholders as the project progresses in order to gain insight, technical support and input for resolving technical issues and challenges that may arise during project implementation.~~*Stakeholder Engagement:*

4.6.1 The users of this guide are encouraged to engage key stakeholders early and often in the project planning and scoping process, especially regulators, project sponsors, and service providers. A concerted ongoing effort should be made by the user to continuously engage stakeholders as the project progresses in order to gain insight, technical support and input for resolving technical issues and challenges that may arise during project implementation.

~~4.7 The users of this guide should establish a plan for documenting and reporting the results of the project planning process, including: key challenges, options considered, decisions taken, analytical approach details, data acquisition results, and project outcomes relative to project objectives.~~*Other Considerations:*

4.7.1 The over-arching process for risk-based corrective action a sediment sites is not covered in detail in this guide. Guide E3240 contains extensive information concerning that process.

4.7.2 Sediment sampling and laboratory analyses is not covered in detail. Guide E3163 contain extensive information concerning sediment sampling and laboratory analysis methodologies.

4.7.3 Developing representative background concentrations for the sediment site is not covered in detail in this guide. Guides E3242, E3344 and E3382 contain extensive information concerning that topic.

4.7.4 In this guide, "sediment" (3.1.15) is defined as a matrix being found at the bottom of a water body. Upland soils of sedimentary origin are excluded from consideration as sediment in this guide.

4.7.5 In this guide, only COC concentrations are considered. Residual background radioactivity is out of scope.

~~4.8 The users of this guide are encouraged to continuously update and refine the conceptual site model and Project Work Plans and Reports used to describe the physical properties, chemical composition and occurrence, biologic features, and environmental conditions of the sediment corrective action project.~~*Structure and Components of This Guide:*

4.8.1 The user of this guide should review the overall structure and components of this guide before proceeding with use, including:

Section 1	Scope
Section 2	Referenced Documents
Section 3	Terminology
Section 4	Significance and Use
Section 5	Components of a Generic Monitoring Program
Section 6	Generic Considerations for Sediment Site Monitoring Programs
Section 7	Types of Sediment Remedial Action Monitoring Programs
Section 8	Baseline Monitoring Programs: General Considerations
Section 9	Remedy Implementation Monitoring Programs: General Considerations
Section 10	Post-Remedy Monitoring Programs: General Considerations and Program Planning Examples
Section 11	Keywords
Appendix X1	Discussion of Monitoring Program Development, Data Quality Objective Development and Statistical Analysis of Data Processes
Appendix X2	Case Study: Monitoring of Sediment Remediation Activities
References	

~~4.12 This guide supports users in the identification of key considerations for designing and implementing sediment program data acquisition plans, including the applicability and use limitations and considerations that may be necessary to achieve project data usability objectives.~~

5. Components of a Generic Monitoring Program

5.1 *Framework Overview:*

5.1.1 This section presents the six key steps recommended in U.S. Environmental Protection Agency (USEPA) guidance for developing various types of monitoring plans (**2**); this process (as applied to sediment sites) is used in sediment-specific guidance prepared by USEPA (**3**). The steps in this process are:

5.1.1.1 *Step 1*—Identify Monitoring Plan Objectives

5.1.1.2 *Step 2*—Develop the Monitoring Plan Hypothesis

5.1.1.3 *Step 3*—Formulate Decision Making Rules

5.1.1.4 *Step 4*—Design the Monitoring Plan

5.1.1.5 *Step 5*—Conduct Monitoring, Analysis and Characterize Results

5.1.1.6 *Step 6*—Establish the Management Decision

5.1.2 In the absence of any regulatory requirements or guidance regarding monitoring program development in a jurisdiction, it is recommended that this USEPA process be used to develop various monitoring programs at sediment sites.

5.1.3 The six-step USEPA monitoring program development process relies heavily upon the USEPAs seven-step data quality objective (DQO) process (**4**). The DQO process defines the type, quality and quantity of data necessary to make rational monitoring decisions. Application of the DQO process leads to an optimized data collection plan for a monitoring program.

5.1.4 A detailed discussion of the six-step USEPA monitoring program development process is provided in X1.1. The relationship between the six-step USEPA monitoring program development process and the seven-step USEPA DQO process is also discussed X1.1.

6. Generic Considerations for Sediment Site Monitoring Programs

6.1 *Scope:*

6.1.1 At contaminated sediment sites, monitoring is conducted to accomplish various goals. These may include (**3**):

(1) Assess compliance with remedy design and performance standards (that is, remedy implementation monitoring and post-remedy performance monitoring).

(2) Assess short-term remedy performance and effectiveness in meeting sediment cleanup levels (that is, post-remedy performance and effectiveness monitoring).

(3) Evaluate long-term remedy effectiveness in achieving Remedial Action Objectives (RAOs) and reducing risk to human health and the environment (that is, a combination of baseline and post-remedy effectiveness monitoring).

6.1.2 The considerations discussed in this section can be applied to all types of monitoring programs typically associated with sediment remedial actions.

6.2 *DQO Development:*

6.2.1 DQOs describe the performance and acceptance criteria for the data collected. DQOs are established for each type of monitoring conducted. USEPA has a systematic process for developing DQOs (**4**).

6.2.2 The relationship between DQOs and the six-step monitoring program development process are discussed in more detail in X1.1.1.

6.2.3 Interstate Technology & Regulatory Council (**5**) and USEPA (**3, 6**) discuss applying the USEPA DQO process to sediment monitoring programs.

6.3 *Decision Rules:*

6.3.1 A decision rule describes how the data will be evaluated and how decisions will be made. A decision rule describes what action will be taken for a given monitoring result. Decision rules are often expressed as "if/then" statements.

6.3.2 Decision rules form the basis for decisions to continue, modify, or stop the monitoring, or recommend taking additional corrective action.

6.3.3 Decision rules are discussed in detail in X1.1.4.

6.4 *Types of Sediment Monitoring Measurements:*

6.4.1 Sediment monitoring typically includes three types of measurements:

6.4.1.1 Physical measurements (that is, physical properties of sediment and surface water).

6.4.1.2 Chemical measurements (that is, chemical properties of sediment, porewater, surface water, and biota).

6.4.1.3 Biological measurements (that is, biological characteristics of organisms and communities of organisms).

6.4.2 Methods for collecting physical, chemical, and biological measurements are described in Battelle (**7**), EPRI (**8**), ITRC (**5**), National Research Council (**9**), Space and Naval Warfare (SPAWAR) Systems Center (**10**), USACE (**11, 12, 13**), and USEPA (**3, 14, 15**).Table 1 presents common monitoring methods and provides references to guidance documents on how to perform various physical, chemical, and biological measurements.

6.4.3 All data collection efforts need to adhere to the DQOs, quality assurance plans, field sampling and analysis plans (FSAPs), and standard operating procedures (SOPs). Data analysis, including appropriate statistical procedures, is used to evaluate various aspects (such as achieving RAOs, trend analysis of data) of remedial activities (**4, 53**).

6.5 *Periodic Review of the Monitoring Plan:*

6.5.1 Periodic review of the monitoring program is an important aspect of the program. For example, at CERCLA sites USEPA performs formal reviews every 5 years. Periodic review facilitates a scheduled interaction with the regulator, so decision making can be coordinated. Modifications to the monitoring plan (such as, reduced frequency of monitoring) may be appropriate to optimize the monitoring plan, based on the periodic review of the data collected.

7. ~~Components of a Monitoring Program~~Types of Sediment Remedial Action Monitoring Programs

7.1 ~~This section discusses developing data quality objectives (DQOs), decision rules, and monitoring plans and the stages of sediment remediation monitoring. United States Environmental Protection Agency (USEPA; 2004a, 2005b) presents six key steps in developing a monitoring plan, including how to identify the monitoring objectives, develop the monitoring hypothesis, formulate the decision rules, design the monitoring plan, conduct the monitoring analysis and characterize the results, and establish management decisions. The monitoring plan development process described in this section follows the USEPA guidance.~~*Stages of Monitoring:*

7.1.1 Monitoring associated with sediment remediation is divided into three stages: baseline, remedy implementation, and post-remedy (Fig. 1).

~~5.2 *DQO Development*—The first step in developing a monitoring plan is to define the DQOs, which describe the questions being answered by the monitoring, and the performance and acceptance criteria for the data collected. DQOs are established for each type of monitoring conducted. The monitoring DQOs are usually based on the corrective action objectives (CAOs) for the remedial action. Typically, the monitoring DQOs serve to confirm that the CAOs are met. There may be additional monitoring DQOs beyond the CAOs. USEPA has a systematic process for developing DQOs (USEPA, 2006). Interstate Technology & Regulatory Council~~

TABLE 1 Sampling Methods

Reference	Bathymetric Survey	Side Scan Sonar	Acoustic Subbottom Profiling	Current Velocity	Hydrodynamic Analysis	Sediment Settlement Plate	Sediment Trap	Sediment Profile Imaging	Sediment Profile Photography	Sediment Shear Stress	Sediment Erosion	Surface Water Samples	Suspended Sediment Monitoring	Semi-Permeable Membrane Device	Core Samples	Grab Samples	Rapid Sediment Characterization Tools	Seepage Meter/Flux Sampler	Porewater Sampling	Benthic Survey/Community Analysis	Benthic Organism Samplers	Artificial Substrate Samplers	Drift Net Sampling	Fish Community Census/Terrestrial Wildlife Census	Vegetation Survey	Tissue Sampling	Toxicity	Caging	Air Sampling
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TABLE 1 *Continued*

Reference	Bathymetric Survey	Side Scan Sonar	Acoustic Subbottom Profiling	Current Velocity	Hydrodynamic Analysis	Sediment Settlement Plate	Sediment Profile Imaging	Sediment Profile Photography	Sediment Shear Stress	Sediment Erosion	Suspended Sediment Monitoring	Surface Water Samples	Core Samples	Grab Samples	Sediment Characterization Tools	Seepage Meter/Flux Sampler	Porewater Sampling	Benthic Surveys/Community Analysis	Tagged Organisms	Artificial Substrate Samplers	Fish Population Census/Terrestrial Wildlife Census	Fish Consumption Survey	Fish Tissue Sampling	Toxicity	Capping	Air Sampling
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TABLE 1 *Continued*

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TABLE 1 *Continued*

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TABLE 1 *Continued*

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TABLE 1 *Continued*

Column headings: Reference; Acoustic Subbottom Profiling; Current Velocity; Hydrodynamic Analysis; Sediment Settlement Plate; Sediment Trap; Sediment Profile Imaging; Sediment Profile Photography; Sediment Shear Stress; Sediment Erosion; Suspended Sediment Monitoring; Surface Water Samples; Semi-Permeable Membrane Device; Core Samples; Grab Samples; Rapid Sediment Characterization Tools; Seepage Meter/Flux Sampler; Porewater Sampling; Benthic Surveys/Community Analysis; Caged Organisms; Artificial Substrate Samplers; Drift Net Sampling; Fish Community Census/Terrestrial Wildlife Census; Vegetation Survey; Tissue Sampling; Toxicity; Capping; Air Sampling; Bathymetric Survey; Side Scan Sonar; Acoustic Subbottom Profiling; Current Velocity; Hydrodynamic Analysis

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