Monitoring and Adaptive Management Procedures and Guidelines Manual Version 1.0

Originally released in December 2017

Updated August 2019

Suggested Citation: *Deepwater Horizon* (DWH) Natural Resource Damage Assessment Trustees. 2017. Monitoring and Adaptive Management Procedures and Guidelines Manual Version 1.0. Appendix to the Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the DWH Oil Spill. December. Available: http://www.gulfspillrestoration.noaa.gov/.

This document was copy edited and formatted with assistance from Abt Associates.

Table of Contents

Acronyms

BACI	before-after, control-impact
DIVER	Data Integration Visualization Exploration and Reporting
DWH	*Deepwater Horizon*
ESA	Endangered Species Act
FGDC	Federal Geographic Data Committee
GOMA	Gulf of Mexico Alliance
GRTS	Generalized Random Tessellation Stratified
ID	identification
ISO	International Organization for Standardization
MAM	Monitoring and Adaptive Management
MMPA	Marine Mammal Protection Act
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NOAA	National Oceanic and Atmospheric Administration
NRDA	Natural Resource Damage Assessment
OPA	Oil Pollution Act
PDARP	Programmatic Damage Assessment and Restoration Plan
PDF	Portable Document Format
PEIS	Programmatic Environmental Impact Statement
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RESTORE	Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States
SMART	Specific, Measurable, Achievable, Results-Oriented, and Time-Fixed
SOP	Standard Operating Procedure
SOW	scope of work
TIG	Trustee Implementation Group

1. Introduction

In the *Deepwater Horizon* (DWH) Oil Spill Final Programmatic Damage Assessment and Restoration Plan and Final Programmatic Environmental Impact Statement (PDARP/PEIS; DWH NRDA Trustees, 2016a), the DWH Natural Resource Damage Assessment (NRDA) Trustees (Trustees) selected a comprehensive, integrated ecosystem approach to restoration in the Gulf of Mexico. The restoration portfolio allocates up to $8.8 billion (including funds already spent for Early Restoration) paid out over 15 years for natural resources restoration across the five Gulf States and the open ocean. Given the unprecedented temporal, spatial, and funding scales associated with the DWH oil spill restoration effort, the Trustees have recognized the need for robust monitoring and adaptive management (MAM) to support restoration planning and implementation. As such, one of the programmatic goals established in the PDARP/PEIS is to “Provide for Monitoring, Adaptive Management, and Administrative Oversight to Support Restoration Implementation” to ensure that the restoration portfolio of projects provides long-term benefits to the resources and services injured by the spill. Therefore, the Trustees have committed to monitor and evaluate restoration outcomes within an adaptive management framework (Appendix 5.E of PDARP/PEIS; DWH NRDA Trustees, 2016a). An adaptive management framework will allow the Trustees to evaluate restoration effectiveness; address potential uncertainties, as applicable, related to project planning and implementation; and provide feedback to inform future restoration decisions.

In the PDARP/PEIS, the Trustees committed to “develop a set of guidelines for standard monitoring and adaptive management practices” to support the implementation and evaluation of restoration projects over time (Appendix 5.E of PDARP/PEIS; DWH NRDA Trustees, 2016a). The Trustee Council’s Standard Operating Procedures (SOPs; DWH NRDA Trustees, 2016b) state that the Cross-Trustee Implementation Group (Cross-TIG) MAM work group will develop a Monitoring and Adaptive Management Procedures and Guidelines Manual (MAM Manual), which will incorporate recommended MAM procedures and guidelines, building upon the monitoring frameworks and conceptual monitoring plans developed by the Trustees for Early Restoration (Appendix 5.E of PDARP/PEIS; DWH NRDA Trustees, 2016a), to meet the needs of the Restoration Types and approaches laid out in the PDARP/PEIS. This document is Version 1.0 of the MAM Manual. For information on MAM roles and responsibilities at the Trustee Council, TIG, Cross-TIG MAM work group, and Implementing Trustee levels, see the Trustee Council SOPs (DWH NRDA Trustees, 2016b).

1.1 MAM Framework

The Trustees presented a general MAM framework in the PDARP/PEIS to guide DWH restoration efforts, as illustrated in Figure 1. The Trustee Council SOPs and this MAM Manual build upon the PDARP/PEIS MAM framework by providing additional details and guidance to the Trustees in implementing the framework within the new process and structure for restoration planning, administration, and implementation occurring through the respective TIGs. This MAM Manual provides guidance on steps 2 through 8 of the MAM framework, including TIG MAM restoration planning (including the development of MAM Plans), implementation of TIG project

MAM Plans, monitoring of restoration actions, evaluation of restoration effectiveness, feedback of information to future restoration planning and implementation, and reporting on restoration progress toward meeting restoration goals and objectives. Importantly, this adaptive management feedback loop provides the Trustees the opportunity to adjust restoration actions, as needed, based on monitoring and evaluation of restoration outcomes (Williams et al., 2009; Williams, 2011). Once a project is completed, data obtained are used to inform the next set of restoration project decisions. Additional information on implementing adaptive management at the project scale is described in Section 2.3.

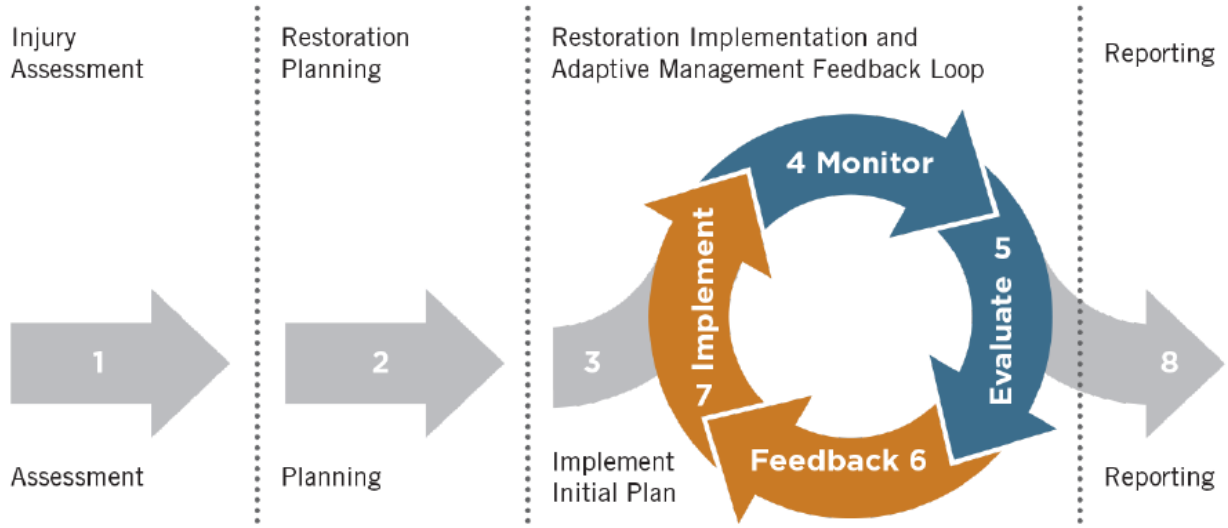

Figure 1. The MAM framework presented by the Trustees in the PDARP/PEIS.

MAM may be applied at multiple scales, including the project, Restoration Type, and programmatic levels. At a broader scale, monitoring information will be synthesized to document progress toward Restoration Type goals and may inform the planning and implementation of future restoration projects (Appendix 5.E.3.3 of PDARP/PEIS; DWH NRDA Trustees, 2016a). At a programmatic level, evaluation of collective progress in restoring the injuries associated with the spill may also inform refinements to the restoration portfolio over time. Future iterations of this MAM Manual will elaborate on these broader-scale concepts.

1.2 MAM Manual Overview

1.2.1 Purpose of the MAM Manual

The purpose of this MAM Manual is to provide the TIGs with detailed information on recommended MAM procedures and guidelines, as well as additional guidance for the development of MAM Plans and the implementation of MAM at the project, Restoration Type, and programmatic levels; further Restoration Type and program-level guidance will be developed in future versions of the MAM Manual. The Manual presents MAM guidelines to execute the broad goals articulated in the PDARP/PEIS, which go beyond the minimum requirements of Oil Pollution Act (OPA) regulations. The guidelines described in this Manual may not be implemented at the same level of effort across all TIGs or for every project. For example, a TIG may have a great deal of experience implementing a specific Restoration Technique and, therefore, would not require the level of adaptive management provided in these guidelines. In addition, the Trustees are conscientious of the limited funds available for restoration and recognize the need to balance restoration on-the-ground with MAM needs. The

Trustees are committed to meeting the monitoring and reporting requirements specified in the OPA regulations, consent decree, and PDARP/PEIS; and to consider the guidelines in the Manual at the appropriate scale. Version 1.0 of this MAM Manual focuses on MAM at the project scale. The TIGs will develop MAM objectives and monitoring parameters that pertain to their restoration activities; and will determine the frequency and duration of monitoring, and the associated budget they deem appropriate.

This MAM Manual includes:

- A template that may be used for project-specific MAM Plans by TIGs
- Guidance for monitoring and data management
- Recommendations and procedures for data quality assurance/quality control (QA/QC), clearance, and release
- Recommended procedures for project-level reporting progress and tracking restoration and recovery
- Guidance for identifying and addressing information gaps.

1.2.2 Audience

The primary audiences of the MAM Manual include:

- The TIGs and Implementing Trustees: The MAM Manual is intended to provide the TIGs and Implementing Trustees with guidance and resources for the development and implementation of MAM, and evaluation and reporting of restoration progress and success.
- The public, the scientific community, and other stakeholders: The MAM Manual is intended to provide transparency to the public, the scientific community, and other stakeholders on recommended MAM processes, procedures, and guidelines related to the DWH NRDA restoration planning effort.

1.3 Organization of the MAM Manual

The MAM Manual includes information on MAM activities at the project and Restoration Type levels. The MAM Manual is organized as follows:

- Section 1 (this section): MAM Manual overview
- Section 2: Guidelines and procedures recommended for restoration project MAM, including MAM Plan development and MAM considerations during project implementation
- Section 3: Guidance for data management
- Section 4: MAM priorities overview and purpose
- References: List of references cited in this MAM Manual
- Attachment A: Agencies that are participating in the Cross-TIG MAM work group
- Attachment B: Glossary of terms frequently used in the MAM Manual
- Attachment C: MAM Plan Template table of contents
- Attachment D: MAM Report Template table of contents
- Attachment E: Monitoring guidance, including core and objective-specific performance monitoring parameters; additional adaptive management or validation monitoring parameters; as well as definitions and data collection methods for core and objective-specific performance monitoring parameters.

2. Restoration Project MAM

2.1 Background

The PDARP/PEIS states that the Trustees will implement monitoring and evaluation to inform decision-making for current projects; and to refine the selection, design, and implementation of future restoration projects (Section 5.5.1 of PDARP/PEIS; DWH NRDA Trustees, 2016a).

In this section, the Cross-TIG MAM work group builds upon the guidance developed in the PDARP/PEIS and the Trustee Council's SOPs (DWH NRDA Trustees, 2016b) for restoration project implementation for the DWH oil spill. The Cross-TIG MAM work group seeks to provide guidance and consistency in MAM-related activities for the Trustee Council, TIGs, and Implementing Trustees, including guidance on the role of MAM in various phases of project-level activities, the development of MAM Plans for restoration projects, and considerations for MAM during planning and restoration implementation. Specifically, this section provides additional guidance to help the Trustees meet the MAM responsibilities described in Chapter 9 of the SOP (DWH NRDA Trustees, 2016b) and Chapters 5 and 6 of the PDARP/PEIS (DWH NRDA Trustees, 2016a).

The remainder of Section 2 is divided into five main sections. Sections 2.2 and 2.3 describe the overarching components of MAM and how they may be applied at the project scale. Section 2.4 provides guidance and resources for the development of MAM Plans (Attachment C). Section 2.5 provides guidance for developing a MAM budget for individual projects. Section 2.6 presents MAM considerations during restoration implementation, including project monitoring, data management, evaluating, reporting, and the incorporation of new information into future decisions. Each of these sections is targeted to be specific and concise with references to additional documents provided for further elaboration or discussion. In instances where the Cross-TIG MAM work group anticipated that more detail may be helpful, topic-specific attachments were developed and referenced throughout in order to keep the content of each of these sections concise.

2.2 Monitoring Components at the Project Scale

Project-level monitoring may include a variety of activities such as pre-implementation monitoring, as-built monitoring (to document successful completion of construction elements, if applicable), performance monitoring, or post-implementation monitoring. Monitoring can be conducted to identify environmental factors that may influence project success, support project compliance, and/or provide data to better understand ecological functions and benefits that would be used to inform decisions related to current or future DWH restoration projects. Pre-implementation monitoring can include monitoring to support project planning, design, location, or implementation; or monitoring to document initial conditions. Post-implementation monitoring can help gauge restoration progress and success. The bulk of project monitoring activities may fall under performance monitoring, which is intended to document whether projects have met their established performance criteria and determine the need for interim corrective actions

(15 CFR § 990.55(b)(1)(vii)). The Implementing Trustee(s) will conduct project-level performance monitoring (including data collection, analysis, and synthesis) and associated adaptive management/corrective actions using project-specific funds, as available, and in accordance with final project-specific MAM Plans (Section 9.5.1.4 of SOP; DWH NRDA Trustees, 2016b).

Project-level monitoring may be conducted at reference and/or control sites, if needed, to determine progress and success. For some projects, the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), and other applicable statutes may require monitoring in addition to performance monitoring described herein to demonstrate compliance. Project monitoring may also include collection of data on environmental conditions that could influence restoration outcomes to better understand drivers of project performance and support project adaptive management, including corrective actions. In an effort to inform implementation of future DWH restoration projects, the Trustees may also choose to conduct additional validation monitoring to better understand the ecosystem functions and services provided by projects.

2.3 Adaptive Management

2.3.1 Adaptive Management in NRDA

Adaptive management is a form of structured decision-making applied to the management of natural resources in the face of uncertainty (Pastorok et al., 1997; Williams, 2011). It is an iterative process that integrates monitoring and evaluation of management actions, where adjustments are made to management approaches based on observed outcomes (NRC, 2004). Within the context of ecological restoration, adaptive management addresses uncertainty hindering restoration decisions by linking science-based approaches to restoration decision-making (Steyer and Llewellyn, 2000; Thom et al., 2005). Within the context of DWH NRDA restoration, adaptive management includes implementing corrective actions, when necessary, to projects that are not trending toward established performance criteria; making adjustments over time to projects that require recurrent or ongoing decision-making; and informing the selection, design, and implementation of restoration projects. The emphasis of adaptive management for DWH NRDA restoration projects is learning from the results of strategic implementation and targeted monitoring as a way to reduce uncertainties concerning restoration decisions.

Adaptive management activities may occur during DWH NRDA restoration project planning and selection. Prior to the selection of a restoration project, the TIGs may review information concerning the effectiveness of past restoration projects and other scientific information, including ecosystem functions and processes. This may also include consultations with experts and review of relevant literature or existing planning documents, feasibility studies, preliminary or final engineering designs, alternative analyses, permitting, environmental reviews, data gathering to support project design, pilot studies, and other similar activities. Creation and completion of these efforts provide information and data that may be used to evaluate uncertainties, prioritize projects based on those uncertainties, and/or modify projects to reduce those uncertainties and improve their likelihood of success. This information is used in the evaluation process required by OPA regulations to select restoration projects (i.e., alternatives) for implementation. Proposed projects are evaluated and compared to other similar projects. The TIGs must evaluate “the extent to which each alternative is expected to meet the Trustees’ goals and objectives” and the “likelihood of success of each alternative” (15 CFR § 990.54(a)).

2.3.2 Project-Level Adaptive Management Components

Adaptive management at the project level includes activities that occur during project planning, implementation, and evaluation. The level of adaptive management needed for a given project (and in turn described in the MAM Plan) will vary based on project specifics. Some DWH NRDA restoration projects may be well-understood and not have uncertainties that warrant adaptive management beyond corrective actions. For elements of the Restoration Plan with higher degrees of uncertainty or where numerous restoration projects are planned within a given geographic area and/or for the benefit of a particular resource, a more robust approach to adaptive management may be described in the MAM Plan (Appendix 5.E.1 of PDARP/PEIS; DWH NRDA Trustees, 2016a). Examples of situations that may require more robust MAM include restoration of resources with limited scientific understanding, the use of novel approaches and/or techniques, and restoration at large spatial scales and/or long time scales.

Implementing restoration projects within an adaptive management framework involves exploring different ways to meet the project's restoration objectives, predicting the outcomes of different restoration actions based on the current state of knowledge, implementing and monitoring one or more restoration actions, and evaluating compliance with performance criteria. It also involves establishing feedback mechanisms to incorporate new information to inform corrective actions or other decision points which may arise during project implementation, where data would be evaluated and used to inform a future management action within the scope of the project. Under OPA and its implementing regulations, restoration provides several mechanisms by which adaptive management is actively addressed.

Examples where adaptive management components could be incorporated into the project planning or implementation process include (see Lyons et al., 2008; Gregory and Long, 2009; Williams et al., 2009; and Runge, 2011 for more information on each of these components):

1. Effective problem framing during restoration planning to identify restoration objectives (see Section 2.4.1).
2. Informed and interactive deliberations among the Trustees and with stakeholders to identify the information needed for project decision-making and implementation to meet project restoration objectives.
3. Incorporation of decision-support tools, such as conceptual models, decision trees, influence diagrams, or population models, to inform project selection and design (see Section 2.4.2.1) and the identification of MAM priorities (see Section 4).
4. Acknowledgement and characterization of uncertainties that could influence restoration outcomes (see Section 2.4.3). Where uncertainties may exist related to the implementation of a particular Restoration Technique, additional project MAM approaches could be developed to mitigate those uncertainties during project implementation. Decision-support tools (e.g., models that describe the linkages between Restoration Approaches, Restoration Techniques, and/or project concepts and expected outcomes) that can predict how the system will respond to the proposed restoration actions may be helpful in identifying uncertainties and developing MAM strategies to manage these uncertainties.
5. Implementation of pilot projects or engineering and design projects to assist in reducing uncertainties and increasing knowledge (e.g., when additional information is needed to evaluate the feasibility or likelihood of success) can be used to inform future restoration projects. Pilot projects should be undertaken when, in the judgment of the Trustees, they are likely to provide the information "needed to evaluate the alternative at a reasonable cost and in a reasonable timeframe" (15 CFR § 990.54(c)).

6. Establishment of feedback loops to facilitate the incorporation of new information gained through monitoring and assessment into subsequent rounds of restoration decision-making (see Section 2.6.2).

Recurrent decisions that occur within the TIGs that may benefit from an adaptive approach include:

- Which projects or techniques to select for a Restoration Plan to meet restoration objectives
- How to implement a project to reduce uncertainties
- Whether and when to implement corrective actions, and what actions to take
- Whether to consider additional data collection and/or analysis to help resolve uncertainties
- Whether to discontinue investments in existing projects
- How to select a portfolio of projects to achieve an overall objective.

TIGs and Implementing Trustees may request Cross-TIG MAM work group support in incorporating these MAM principles into restoration efforts.

2.4 MAM Plan Development

MAM Plans (which are part of the Restoration Plan) will be developed for all projects other than those selected only for engineering and design (Section 10.3.3 of SOP; DWH NRDA Trustees, 2016b). While projects selected only for engineering and design are not required to develop MAM Plans (Section 10.3.3 of SOP; DWH NRDA Trustees, 2016b), considering MAM needs during engineering and design is encouraged. Engineering and design projects may proactively explore ways to resolve or minimize uncertainties, before implementation and construction plans are initiated.

Collectively, the components of the MAM Plan, as described below, document the level of MAM at the project scale. The degree of MAM needed at the project level depends on several factors, including the status of scientific understanding of key species, habitats, or ecosystem dynamics; the novelty of a given approach or technique; the scale at which restoration is implemented; the influence of socioeconomic factors; and the time scale over which restoration will be implemented (Appendix 5.E.3 of PDARP/PEIS; DWH NRDA Trustees, 2016a). Adaptive management at the project level can include employing corrective actions, performance criteria, or other decision points where data would be evaluated in order to direct a future management action within the scope of the project. Some of the information obtained through the adaptive management process, such as information found in planning documents (e.g., feasibility studies, alternative analyses, permitting, preliminary or final engineering designs, environmental reviews) and other previously undertaken planning activities may be used to inform the need for adaptive management and the development of the MAM Plan, but may not necessarily be discussed in the MAM Plan.

MAM Plans will include objectives with associated performance criteria to track progress toward restoration goals; methodologies and parameters for data collection; identification of uncertainties; and potential corrective actions (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). To the extent practical and appropriate, MAM Plans may also include decision points related to the defined uncertainties and the extent to which an adaptive management approach to decision-making will be used for the project.

MAM Plans may follow the MAM Plan Template developed by the Cross-TIG MAM work group, as presented in Attachment C; however, the template may be adapted to fit the needs of each project (e.g., land acquisition projects). The project-specific MAM Plan may be updated as needed. For example, if changes arise during implementation that will alter the planned monitoring activities, the project-specific MAM Plan should be updated to reflect these changes (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b).

A MAM Plan should be reviewed by the TIG, as appropriate, for consistency with the SOP and the MAM Manual (Sections 9.5.1.4 and 10.3.2 of SOP; DWH NRDA Trustees, 2016b). Once approved by the TIG in conjunction with the Restoration Plan, the MAM Plan will be included with the Restoration Plan (Section 9.4.2.1 of SOP; DWH NRDA Trustees, 2016b). In addition, the published project MAM Plan (and any future revisions to the MAM Plan) will be uploaded to the Data Integration Visualization Exploration and Reporting (DIVER) Restoration Portal (Section 10.7.1 of SOP; DWH NRDA Trustees, 2016b). These documents will then be made publicly available through the Trustee Council website (http://gulfspillrestoration.noaa.gov) (Section 10.7.1 of SOP; DWH NRDA Trustees, 2016b).

The remaining subsections in this section of the MAM Manual are intended to provide specific instructions for completing the MAM Plan Template (Attachment C), as well as provide additional guidance and resources for Implementing Trustees developing project-specific MAM Plans. For each section of the MAM Plan Template, we describe the intended purpose of the section and the kinds of information that may be included. We also acknowledge when the content in a project's MAM Plan may deviate from this guidance. For areas where additional guidance was deemed appropriate, we provide an example process for how one would produce the information.

2.4.1 Guidance for Establishing Restoration Objectives for a MAM Plan

Restoration objectives will be developed for each project and included in the Restoration Plan (Section 9.4.2.1 of SOP; DWH NRDA Trustees, 2016b). As specified in the OPA regulations, these restoration objectives should be specific to the injuries (15 CFR § 990.55(b)(2)) and clearly specify the desired outcome of the project, including performance criteria by which successful restoration will be judged (15 CFR § 990.55(b)(2)). The objectives should also be consistent with the goals of the Restoration Type and Restoration Technique and be described in the MAM Plan (Attachment C, Section C.1.2). Although the likelihood of project success is evaluated under the OPA regulations (15 CFR § 990.54(a)(3)), uncertainties may exist regarding how to best implement the selected project(s) to achieve the greatest benefits for the injured resources. Uncertainty about how to best achieve the restoration objectives can motivate the need for adaptive management for some projects and can also drive the collection of supplemental project monitoring data (Williams et al., 2009), as further described in Sections 2.4.3 and 2.4.5. Performance criteria consistent with the restoration objectives should be provided in the MAM Plan, as described in Section 2.4.7.

2.4.1.1 Example Process for Developing Objectives

When developing restoration objectives, it is recommended that the Trustees make them as Specific, Measurable, Achievable, Results-Oriented, and Time-Fixed (SMART) as possible. If this level of specificity is not included in the restoration objectives, this approach could also be applied to the development of performance criteria (Section 2.4.7).

As adapted from Williams et al. (2009), components of SMART objectives include:

- **Specific:** Objectives should be unambiguous, with specific metrics and conditions. Specificity can be encouraged by answering the following questions:
  - What is the outcome you are expecting?
  - Where do you hope to achieve it?
  - When do you expect the outcome to be achieved?

  - Why do you want to achieve this outcome in this way?
  - How do you plan to achieve this outcome?
- **Measurable:** Objectives should contain elements that can be readily measured, in order to evaluate the effectiveness of restoration actions and the benefits they provide to the resources injured by the spill (e.g., support habitat utilization of constructed living shorelines breakwaters by increasing the average infauna and epifauna invertebrate biomass to at least 84 g wet weight/m^2 over 5 to 7 years).
- **Achievable:** Objectives should be realistic given the current condition of the restoration site or resource and any existing stressors that could influence the project.
- **Results-oriented:** Objectives should identify endpoints and/or conditions representing their achievement. For example, an objective might describe the habitat conditions expected at a certain time point following the restoration.
- **Time-fixed:** Objectives should indicate the timeframe for achievement, consistent with the duration of the project. Project implementation may be in stages, but the overall timeframe should be clear.

2.4.2 Guidance for Establishing the Conceptual Setting for a MAM Plan

The purpose of the conceptual setting is to identify, document, and communicate, within the MAM Plan, the interactions and linkages among system components at the project site to understand how the system works and how it might be affected by restoration. If this has already been developed for the Restoration Plan, a reference to the section of the Restoration Plan where the description is located could be provided in lieu of repeating the information in the project-level MAM Plan. In a project-level MAM Plan, the conceptual setting section (see Attachment C, Section C.1.3) aims to serve as a tool to:

- Simplify complex ecological relationships by organizing information and clearly depicting important components, processes, and interactions for a particular project
- Identify outside drivers and stressors that may influence the project
- Document assumptions about how components and processes are related
- Identify gaps in our knowledge and uncertainties where they exist, and identify additional metrics needed to manage these uncertainties
- Supplement numerical models for assessing project benefits and impacts
- Make qualitative predictions of ecosystem response
- Identify which species will show ecosystem response
- Identify appropriate monitoring indicators and metrics in order to detect changes
- Provide a basis for implementing adaptive management strategies
- Identify additional parameters that may need to be monitored to understand the effects of outside drivers on the project outcomes
- Outline further restoration, adaptive management, or monitoring activities, and computational efforts (such as modeling)
- Link planning, monitoring, evaluation, and adaptive management
- Communicate with managers and decision-makers (Barnes and Mazzotti, 2005; Fischenich, 2008; Margoluis et al., 2009, and others cited therein).

2.4.2.1 Example Process for Establishing the Conceptual Setting

Because of the wide array of possible applications, no single format can satisfy the needs for describing and/or illustrating the conceptual setting for all projects (Jorgensen, 1988; Scott et al., 2005). This section should be scaled commensurate with the level of complexity of the conceptual setting; as well as the scope, scale, and Restoration Type of the project. Content can take the form of narratives, tables, matrices of factors, schematics, box-and-arrow diagrams, or some combination of the same (Gucciardo et al., 2004; Table 1). The format and presentation will be project-dependent; for simple or well-understood systems, a short, narrative description of the conceptual setting in restoration planning documents may be referenced or a written summary describing the project site and references to existing literature and/or existing conceptual diagrams may suffice. For complex or poorly understood systems, a project may benefit from the process of developing a diagram with associated documentation describing interactions between components.

Table 1. Comparison of presentation types for conceptual setting section

Presentation type	Description	Strengths	Drawbacks
Narrative	Word descriptions, mathematical or symbolic formulae	Summarizes literature, information rich	No visual presentation of important linkages
Tabular	Table or two-dimensional array	Conveys the most information	May be difficult to comprehend amount of information
Picture models	Plots, diagrams, or drawings	Good for portraying broad-scale patterns	Difficult to model complex ecosystems or interactions
Box and arrow (stressor model)	Diagram of key components and relationships	Intuitively simple, one-way flow, clear link between stressors and vital signs	No feedback, few or no mechanisms, not quantitative
Input/output matrix (control model)	Box and arrow with flow between components	Quantitative, most realistic, feedback and interactions	Complicated, hard to communicate, state dynamics may not be apparent

Source: Adapted from Gucciardo et al., 2004.

Depicting the conceptual setting, regardless of format, involves the following steps (adapted from Grant et al., 1997; Maddox et al., 1999; Ogden et al., 2005; Wood et al., 2000; Barnes and Mazzotti, 2005; Fischenich, 2008; Margoluis et al., 2009):

1. Defining the goals and restoration objectives of the project.
2. Defining the boundary of the system or project site of interest.
3. Identifying the outside drivers and stressors affecting the achievement of the goals and restoration objectives. The conceptual setting should include the main outside drivers and stressors, and indicate which outside drivers and stressors are affecting which goals and restoration objectives.
4. Identifying the components that the restoration project will be designed to influence as well as those that may influence the outcomes of the project, including:
    a. Major external drivers, including natural forces (e.g., sea level rise); anthropogenic (e.g., regional land use changes); or other contributing factors such as political, social, economic, or cultural forces.
    b. Physical, chemical, and biological attributes of the system or project.
    c. Mechanisms by which ecosystem drivers, both internal (e.g., flow rates) and external (e.g., climate), cause change, with particular emphasis on those drivers that the project is intended to change.
    d. Critical thresholds of ecological processes and environmental conditions.
    e. Spatial and temporal scales of critical processes.
    f. Current and potential stressors.
    g. Identification of assumptions and knowledge gaps that limit the predictability of restoration outcomes.
    h. Identification of current characteristics of the system that may limit the achievement of restoration objectives.

   i. Indicators representative of ecosystem attributes and drivers.
   j. Identification of parameters to be monitored to determine project performance in meeting the restoration objectives.
5. Identify the relationships among the components of interest. If portraying in a diagram, use arrows to show the causal links among components.
6. Add the restoration project and describe what part of the model implementation it is designed to influence.
7. Incorporate references, as appropriate.

Due to the dynamic nature of and timelines associated with restoration project planning, implementation, monitoring, evaluation, and adaptive management, it may be necessary to revisit and revise the project-specific conceptual setting as new information is acquired through monitoring or scientific advancement (Fischenich, 2008).

2.4.3 Guidance for Identifying Potential Sources of Uncertainty for a MAM Plan

The project-specific MAM Plan may include any uncertainties identified for the project (Attachment C, Section C.1.3.1). These uncertainties may be referenced, when appropriate, in subsequent sections of the MAM Plan to discuss how decisions will be made in the face of uncertainty in order to maximize project benefits and help ensure that restoration objectives are achieved. The tools described in Section 2.4.2 can be used to help identify uncertainties that directly relate to project decision-making. Furthermore, information obtained in planning documents (e.g., feasibility studies, alternative analyses, permitting, preliminary or final engineering designs, environmental reviews) and other previous planning processes may also assist in identifying uncertainties.

The focus for adaptive management is on identifying and, where possible, reducing those uncertainties that affect the decisions within the scope of a project or groups of projects (adaptive management beyond the single project-scale will be addressed in subsequent sections). These decisions may include how to improve the likelihood of achieving favorable project outcomes or selecting corrective actions in the event a project is not performing as expected and intended (see Section 2.4.7). If not addressed, uncertainties may delay the time it takes to achieve the restoration objectives or hinder the project's ability to fully achieve its objectives.

The Cross-TIG MAM work group has identified potential uncertainties for some of the Restoration Techniques included in the PDARP/PEIS (DWH NRDA Trustees, 2016a; Attachment E). These are not intended to be exhaustive, but instead represent examples that can serve as a starting point for Implementing Trustees when identifying uncertainties for a specific restoration project.

2.4.3.1 Example Process for Identifying Uncertainties

To aid in the identification of project uncertainties, science/data gaps identified in previous documents developed by the Trustees and other regional restoration/management programs can be reviewed to determine their relevance to the restoration project. Example documents could include:

1. DWH NRDA: Restoration Type strategic frameworks, PDARP/PEIS Restoration Type MAM sections, injury assessment technical reports, and other documents.
2. Others: Watershed planning documents, science needs documents, State management plans, Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived

Economies of the Gulf Coast States (RESTORE) Council planning documents, Gulf of Mexico Alliance (GOMA) reports, etc.

In addition, various presentation types (e.g., conceptual models, Table 1) may be used as a tool to identify and communicate assumptions and uncertainties. Specifically, uncertainties related to information gaps relevant to planning, implementation, and evaluation of the restoration project could be considered:

1. Planning: Consider information that would be needed to inform the selection, design, siting, etc., of the project. Examples include:
   a. Information needed to improve the design of the restoration project that, if addressed, would improve the project longevity and likelihood of success.
   b. Information needed to improve project siting, to determine the selection of one project location over another. For example, consider gaps in existing datasets or modeling capabilities that, if addressed, would improve the identification of priority restoration sites.
2. Implementation: Consider information needed to inform implementation of the project, including information needs prior to implementation as well as during implementation. Examples include:
   a. Information needed to determine the best timing for project implementation such as potential uncertainties regarding environmental conditions, and whether any environmental conditions must be met prior to implementation.
   b. Information needed to determine the best implementation strategy to maximize the likelihood of meeting restoration objectives.
3. Evaluation: Consider information that would be needed to evaluate effectiveness of the project or understand potential impacts. Examples include:
   a. Information needed to evaluate outcomes in terms of meeting one or more project objectives.
   b. Information needed to understand and mitigate the potential adverse impacts of a restoration project.

2.4.4 Guidance for Developing Monitoring Design for a MAM Plan

The project-specific MAM Plan (Attachment C, Section C.2) should include information on monitoring, including a list of parameters (with units) that will be measured. For each parameter, the reason(s) for monitoring; the methods for measurement; the timing, frequency, and duration of data collection; the sample size; and the monitoring design should be described. For those parameters intended to evaluate progress toward meeting restoration objectives, performance criteria and corrective actions should also be identified (see Section 2.4.7). The MAM Plan should also include parameters needed to evaluate progress toward Restoration Type goals, as appropriate for each Restoration Approach. When applicable, the MAM Plan should also include the monitoring needed to track compliance with appropriate regulations and adaptive management protocols (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). Further guidance on the development of the monitoring section of the MAM Plan is provided below.

2.4.4.1 Selecting Monitoring Parameters and Identifying their Purposes

Attachment E provides guidance on monitoring parameters for performance monitoring and/or adaptive management and validation monitoring. The monitoring parameters identified in a project MAM Plan should be consistent with the monitoring guidance defined in Attachment E, wherever appropriate. If adjustments from the monitoring guidance in Attachment E are needed, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). Depending on the project, additional parameters may be needed to inform adaptive management or validate the functions and services associated with a project. The monitoring guidance subsections in Attachment E provide a list of other parameters that may be considered, as appropriate, for resolving uncertainties, explaining outside drivers, optimizing project implementation, supporting adaptive management and decisions about corrective actions, and informing the planning of future DWH NRDA restoration projects. Implementing Trustees may also choose to conduct additional monitoring beyond the recommended parameters described in Attachment E (Section 9.5.1.4 of SOP; DWH NRDA Trustees, 2016b).

The Trustees should consider relevant existing information sources (e.g., fisheries observer programs, marine mammal and sea turtle stranding networks, regional monitoring networks) to evaluate project performance, where appropriate (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). When existing relevant datasets are available and will be utilized for restoration decision-making, the Trustees should confirm that the collection methods are well-documented, the data are current and complete, and the data collection methods and the timing and frequency of data collection are appropriate to address the project's monitoring needs.

For each of the identified monitoring parameters, the MAM Plan should include information on the intended purpose of the parameter (e.g., monitor progress toward meeting one or more of the restoration objectives, regulatory compliance, support adaptive management of the project, support evaluation of restoration progress for the Restoration Type), methods, sites, frequency, and duration of monitoring. Potential monitoring methods for each core and objective-specific performance monitoring parameter are provided in Attachment E for a subset of Restoration Approaches.

2.4.4.2 Determining the Method for Measuring the Parameter for a MAM Plan

To enhance the compatibility of project monitoring data among projects and with other relevant datasets and monitoring efforts, recommended monitoring methods are included as part of the monitoring guidance (Attachment E). This guidance outlines potential methods for measuring each recommended parameter, including any preferred monitoring methods for each parameter. For core performance monitoring parameters, Section E.3 in Attachment E indicates an acceptable method or methods of data collection to ensure compatibility with data collected for similar DWH NRDA restoration projects. The Implementing Trustees may consider, in no particular order, methods recommended by other restoration programs or in regional guidance documents, data collection protocols used on past DWH NRDA projects or other regional restoration projects, data collection protocols used by existing monitoring programs, and data collection protocols used to collect existing baseline data available for the project or reference site. Replication of previous protocols, not described in this MAM Manual, may suit restoration and data collection objectives. The Trustees may consider adopting the data collection methods used in previous projects to allow for comparison with existing data.

2.4.4.3 Determining Timing, Frequency, Duration, and Spatial Scale for a MAM Plan

In designing the monitoring strategy for each parameter, the frequency and spatial scale of monitoring should be relevant to capture variability in the parameter, as well as any temporal cycles in the factors affecting restoration performance (NAS, 2016). Project-level monitoring may include pre-restoration baseline monitoring to document initial conditions, as-built monitoring (sometimes referred to as construction, implementation, or execution monitoring) to verify that the project was successfully implemented as described in the Restoration Plan, compliance monitoring, and post-implementation monitoring to gauge restoration progress and success. The exact period of pre-restoration and post-restoration monitoring should be adequate to evaluate project performance and determine progress toward restoration objectives, as appropriate, and should scale with the size, complexity, and timeframe of the project.

2.4.4.4 Determining the Sample Size for a MAM Plan

Effective monitoring of restoration projects requires the identification of an appropriate sample size. Key points to consider are the relative magnitude of changes in the parameters that might be relevant to decision-making, the level of accuracy needed, the scope and scale of the project, and the cost of data collection. For parameters for which inferential statistical analyses will be conducted (e.g., analyzing the parameter's response to a restoration action, making comparisons from one time period to another, evaluating differences between restoration sites and control sites), sample size selection should consider the amount of change in the parameter that is statistically detectable and is meaningful for the restoration objectives, the confidence in statistically detecting the change (i.e., Type I and II errors), and the unexplained error within the dataset. Power analysis (Cohen, 1992) is a common approach for estimating adequate sample size, as it incorporates the considerations listed above. It can also be used to explore the value of increased sample size, in terms of increased power or more precise effect sizes, relative to the cost of data collection. Exploring the relationships between sample size and improved confidence and effect sizes with a power analysis allows for a strong justification in sample size, and ensures the data being collected result in defensible estimates necessary for decision-making. In instances in which power analyses may not be feasible, previous studies can be used as a guide to estimate appropriate sample sizes, although the relative variability in the dataset and the monitoring objectives for similar studies should be considered. Additionally, experts who have done similar research may be able to provide input on how many samples to collect. Pilot monitoring studies to evaluate the distribution and variability of the data may be implemented when there is no prior knowledge of the distribution for a particular monitoring parameter.

2.4.4.5 Identifying Monitoring Site Locations for a MAM Plan

Probability-based designs involve a randomized component to site selection and are recommended for ecological data as they result in unbiased and defensible parameter measurements (McDonald, 2012). These designs allow for conclusions to be drawn concerning the project's effect on the entire project footprint, rather than just the location for which data was physically obtained. Examples of commonly used monitoring designs are listed in Table 2.

Table 2. Example monitoring designs for project monitoring

Design	Summary
Cluster	Cluster design requires identification of the "cluster" of the element or population being studied and randomly selects sites from within that cluster. Cluster monitoring can have a one-stage (all elements within the selected cluster are sampled) or two-stage (a subset of the elements within the selected cluster are randomly included in the sample) approach (Thompson, 1992). This form of monitoring may be used when the resource being studied has a restricted geographical distribution or is sparse in nature. Multi-stage is similar to cluster monitoring (see Thompson, 1990; and Bried, 2013 for more information).
Generalized Random Tessellation Stratified (GRTS)	GRTS is a spatially balanced survey design that accommodates different spatial scales of monitoring, spreads points "evenly" across the area of interest, and allows replacement of sites (after the fact), if site locations are unsuitable. It thus combines the advantages of being a true probability sample with the spatial balance properties of systematic monitoring (Stevens and Olsen, 2004). The drawback of GRTS design is the site selection procedure can be difficult to understand or implement, although free tools are available (e.g., Kincaid et al., 2016).

Design	Summary
Simple random	Simple random monitoring should meet two criteria: (1) each combination of a specified number of sampling units has the same probability of being selected; and (2) the selection of any one sampling unit is in no way tied to the selection of any other (McCall, 1982). This method is recommended for smaller areas where physical and biological conditions are fairly uniform throughout. Applicability in larger areas may become cumbersome as the distance between plots becomes greater and more time consuming (Murray et al., 2002).
Stratified random	Stratified random monitoring involves dividing the area into two or more subgroups (i.e., strata) prior to monitoring; sites within the same stratum are very similar, while the units between strata are very different. After stratification, simple random samples are taken within each stratum. The inclusion of “strata,” or groups with the same set of characteristics, can improve the precision of estimates for each strata (Elzinga et al., 1998). Stratification may be employed if different performance criteria are identified for different habitat types, for example.
Systematic random	In systematic (or grid) random monitoring, the first site is selected at random and all subsequent sites are then placed equidistant from each other, to form a grid. Projects with a variety of habitats, where truly “even” monitoring across the landscape and precise interspersion of monitoring locations need to be achieved, may consider using a systematic random design (Scott, 1998; Fancy, 2000).
Transect	A transect is a line along which samples are taken. Transects may run parallel or perpendicular to environmental gradients depending on the purpose of the project. Transects may be spaced evenly or randomly, or relative to features of interest. Similarly, samples may be taken evenly or randomly along a transect.

Adding a reference site and/or control site is often desirable to distinguish natural variability from the effects of the project. The BACI (before-after, control-impact) design assesses the performance of a project relative to a reference or control site. Samples are taken at a restoration site and a control or reference site both before and after restoration, which allows project managers to distinguish changes caused by the restoration actions from changes caused by other factors. A single pair of reference and control sites measured before and after restoration will allow the statistical comparison of the monitored locations, while the inclusion of multiple reference and/or control sites will allow for statistically driven conclusions about the effects of the project.

2.4.5 Guidance for Developing the Rationale for Adaptive Management for a MAM Plan

The project-specific MAM Plan should evaluate the extent of adaptive management that is needed for the specific project (Attachment C, Section C.3). The need for adaptive management will vary with the scope, scale, and Restoration Type of the project. For example, higher uncertainty may be associated with certain Restoration Types, novel approaches, larger restoration scales (e.g., number and area of projects), limited scientific understanding of target resources, increasing influence of socioeconomic factors, and longer time scales of restoration implementation (see the PDARP/PEIS for more information; DWH NRDA Trustees, 2016a). MAM Plans should include the identification of potential corrective actions, if appropriate, for the project.

Although all projects are encouraged to consider adaptive management, there may be some projects for which adaptive management beyond corrective action is not necessary. Adaptive management is appropriate when there are consequential decisions to be made, there is an opportunity to apply learning, the value of reducing uncertainty is high, and a targeted monitoring plan can be put in place to reduce uncertainty (Williams et al., 2009). Adaptive management should not be used when the impacts of decisions may be irreversible; when learning is unlikely on a time scale relevant to informing decisions or where no opportunity exists to revise or re-evaluate decisions based on new information (Doremus et al., 2011). Section 2.4.5.1 provides an example of considerations that could be used to determine if adaptive management may be appropriate for a specific project. In cases where it is determined that adaptive management beyond corrective action is not needed, the adaptive management section of the plan may describe why additional adaptive management is unnecessary for the project.

2.4.5.1 Example Process for Evaluating the Extent of Adaptive Management for a MAM Plan

Adaptive management may be an appropriate approach to decision-making for restoration projects or suites of restoration projects with all or most of the following characteristics (adapted from Williams et al., 2009):

- There is more than one potential restoration action and there is an opportunity to re-evaluate restoration decisions in the future.
- Relevant stakeholders are engaged during the project, as appropriate.
- Management objectives have been identified.
- Uncertainties about potential restoration actions are affecting the decision-making process.
- Uncertainties, risks, alternatives, siting factors, and other potential influences on a project or suite of projects have not already been evaluated in a previous feasibility study, alternatives analysis or project planning effort, or the evaluations are no longer relevant or applicable.
- It is possible to describe or predict how resources may respond to restoration actions.
- Monitoring can be conducted to explicitly reduce uncertainties tied to the decision-making process.
- Progress and understanding of restoration actions can be measured.
- Learning can inform decisions and be used to adjust restoration strategies.
- Adaptive management tools (e.g., tradeoff analysis, additional monitoring) have been budgeted in the project.
- Any adaptive management activities are compliant with applicable laws, regulations, and authorities.

2.4.6 Guidance for Describing the Project Evaluation for a MAM Plan

The project-specific MAM Plan should include information on how project performance will be assessed in terms of meeting its restoration objectives and performance criteria, and informing whether corrective actions are needed (Attachment C, Section C.4). For performance criteria without specific numeric targets, the evaluation may be an assessment of whether the performance criteria have been met. However, for quantitative performance criteria, the evaluation may include modeling, analysis, interpretation of results, and estimates of uncertainty (e.g., Type I or Type II errors), as appropriate.

The results of the analyses may be used to evaluate the following:

- The project's success, as measured by performance criteria and restoration objectives.
- The need for corrective actions and the type of corrective actions.
- Whether the restoration project produced unanticipated effects and, if so, what those effects were.
- Whether any unanticipated events unrelated to the restoration project affected the monitoring results (e.g., hurricanes) and, if so, identification of those events and assessment of how the monitoring results were affected.
- The status of uncertainties identified prior to project implementation.
- New uncertainties.

The TIGs and Cross-TIG MAM work group will also compile project-level monitoring data to evaluate restoration progress for each TIG and Restoration Type, as well as to contribute to the overall evaluation of NRDA restoration outcomes for Trustee Council programmatic reviews. Collectively, project monitoring results will contribute to the Trustees' knowledge base to inform future decisions related to project prioritization and selection, implementation techniques, and the identification of uncertainties. Additional guidance on compiling and evaluating project-level data at broader scales will be included in future versions of this Manual.

2.4.6.1 Example Process for Conducting Evaluation for a MAM Plan

The analytical methods will likely vary for each of the monitoring parameters. However, the following options may serve as a useful guide for considering the options for analyzing, evaluating, and interpreting the data (adapted from Segura et al., 2007):

- Data summarization and characterization
  - Calculation of basic statistics from monitoring data, including measures of location and dispersion. Summarization encompasses measured and derived parameters specified in the monitoring protocol, and forms the basis of more comprehensive analyses, as needed, and communication of results in both graphical and tabular formats, for example.
- Status determination
  - Analysis and interpretation of the status may be used to inform the following:
    - Comparison of observed values to historical levels
    - Observed values compared to the performance criteria (for parameters used to evaluate project performance)
    - Observed values compared to a regulatory threshold (for compliance monitoring parameters)
    - Observed values compared to an ecological threshold (for parameters intended to inform adaptive management or interpretation of project performance)
    - Spatial distribution of observed values for a given point in time
    - Patterns indicating directional relationships with other ecological factors
  - Status determination will involve both expert interpretation and statistical analysis. Statistical assumptions and level of confidence will be ascertained during the analysis.
- Trends evaluation
  - Used to address whether there is directional change over the period of measurements
  - Can inform how this trend compares with trends over broader spatial scales
  - Where appropriate, additional variables, such as natural or random phenomena that may influence the parameter, will be accounted for in the analysis.
- Synthesis and modeling
  - Examination of patterns and trends across multiple parameters to gain broader insights on ecosystem processes. Analyses may include:
    - Qualitative or quantitative comparisons of parameters with known or hypothesized relationships
    - Data exploration and confirmation (e.g., correlation, ordination, classification, multiple regression, structural equation modeling)
    - Development of predictive models.

2.4.7 Guidance for Describing Project-Level Decisions: Performance Criteria and Corrective Actions for a MAM Plan

2.4.7.1 Performance Criteria

Performance criteria will be developed for each project and included in the project-specific MAM Plan (Section 9.4.2.1 SOP; DWH NRDA Trustees, 2016b; Attachment C, Section C.5).

Performance criteria will be used to determine: (i) what constitutes success or (ii) the need for corrective actions (15 CFR § 990.55(b)(2)). If appropriate, performance criteria should be established for at least a subset of the monitoring parameters, as well as potential corrective actions that could be taken if the performance criteria are not met. The selection of performance criteria may be based on desired conditions of the restoration site, conditions at appropriate reference site(s), or derived from the literature (Appendix 5.E.3.1 of PDARP/PEIS; DWH NRDA Trustees 2016a). Because most restoration projects may take many years to reach the project objective, performance criteria may include conditions representative of interim recovery (Appendix 5.E.3.1 of PDARP/PEIS; DWH NRDA Trustees, 2016a). Establishment of interim milestones may help project managers determine if the project will be able to meet restoration objectives at an acceptable pace or if interim corrective actions are needed (Section 9.5.1.4 of SOP; DWH NRDA Trustees, 2016b).

When requested, the Cross-TIG MAM work group can provide support to the TIGs and Implementing Trustees in developing project-specific performance criteria.

Example quantitative performance criteria from Early Restoration projects:

- Objective: Support habitat utilization of constructed living shorelines breakwaters by invertebrate infauna and epifauna
  - Performance criterion: Over 5 or 7 years, the average infauna and epifauna invertebrate biomass is at least 84 g wet weight/m^2 ("Restoring Living Shorelines and Reefs in Mississippi Estuaries" project monitoring plan, Phase IV Early Restoration Plan)
- Objective: Reduce discards in the Gulf of Mexico pelagic longline fishery
  - Performance criterion: Reduce the biomass of dead discards in the Gulf of Mexico pelagic longline fishery by an average of 11,600 dkg per vessel year over 60 vessel years of project participation ("Pelagic Longline Bycatch Reduction Project" monitoring plan, Phase IV Early Restoration Plan)
- Objective: Promote establishment of native brackish marsh vegetation
  - Performance criterion: Average live vegetative cover is equal or greater than 66% at year 5 ("Lake Hermitage Marsh Creation Project" monitoring plan, Phase I Early Restoration Plan)
- Objective: Reduce invasive species plant cover within the project footprint
  - Performance criterion: Invasive plant cover in the project footprint is less than 5% in the marsh creation area by year 5 ("Lake Hermitage Marsh Creation Project" monitoring plan, Phase I Early Restoration Plan).

2.4.7.2 Project-Level Decisions, including Corrective Actions

The project-specific MAM Plan may provide a description of the corrective actions for the project and the process for making decisions about if and when to conduct corrective actions, if appropriate, for the project (Attachment C, Section C.5). Corrective actions aim to address changing circumstances and incorporate new information that indicates a project is not achieving its intended restoration objectives or is causing unintended and undesirable effects. A project may not be achieving its intended restoration objectives because of previously identified uncertainties, unanticipated consequences, unknown conditions, or unanticipated environmental drivers. The decision to implement a corrective action for a project should holistically consider the overall outcomes of the restoration project (i.e., looking at the combined evaluation of multiple performance criteria) in order to understand why project performance deviates from the predicted or anticipated outcome. If pre-defined recurring decisions are anticipated and identified during project planning and design, each decision point should be described along with the set of potential options or corrective actions associated with that decision point.

However, corrective actions are not limited to the pre-defined options identified in the MAM Plan. A table in this section of the MAM Plan could be used to identify potential interim corrective actions for each performance criterion (Table 3), as defined in the OPA regulations (15 CFR § 990.55(b)(1)(vii)), but should not be considered an exhaustive list of all possible corrective actions. Additional corrective actions may be identified post-implementation, as appropriate.

Table 3. Example table that could be used to list project monitoring parameters, interim and final performance criteria, and potential corrective actions

Monitoring parameter	Final performance criteria	Interim performance criteria	Potential corrective actions
Example: Elevation	Example: At year X, marsh elevation ranges between Y and Y for Z area of marsh.	Example: Performance criteria not met for year X.	Example: (1) Add, regrade, or remove sediment; or (2) continue to monitor.
Example: Marsh spatial extent	Example: At year X, the marsh spatial extent is equal to or greater than Y acres.	Example: Performance criteria not met for year X.	Example: (1) Add, regrade, or remove sediment; or (2) continue to monitor.
Example: Tidal inundation	Example: No performance criteria.	Example: If berms are still present at year X.	Example: (1) Gap berms; or (2) continue to monitor.
Example: Survival of plantings	Example: At day X, the percent survival is equal to or greater than Y%.	Example: Performance criteria not met for day X.	Example: (1) Plant/replant vegetation; (2) continue to monitor; or (3) modify monitoring plan.
Example: Vegetation species percent cover	Example: At year X, the percent cover is equal to or greater than Y%.	Example: Performance criteria not met for year X; or if percent cover is less than Y% at years X–Z.	Example: (1) Plant/replant vegetation; (2) add fertilizer; or (3) continue to monitor.
Example: Presence of undesirable plant species (e.g., invasive species)	Example: At year X, undesirable plant species, Y, are not present at the project site.	Example: Performance criteria not met for year X; or if percent of undesirable plant species is greater than Y% at years X–Z.	Example: (1) Remove undesirable plant species; or (2) continue to monitor.

2.4.8 Guidance for Describing the Data Management Strategy for a MAM Plan

The project-specific MAM Plan should include a description of the anticipated data and how those data will be collected, processed, reviewed, stored, and shared (Attachment C, Section C.7). The project-specific MAM Plan should include the following information:

1. Data description
2. Data review
3. Data storage and accessibility
4. Data sharing.

Data management should also be consistent with the guidance in Section 3.

2.4.8.1 Data Description

The project-specific MAM Plan should include information on how the data will be recorded, the type of data that will be collected, the data standards that will be followed, the timing and frequency of data collection and processing, the location of data collection, and the quantity of data that are expected. If data from an existing program will be utilized, a description of the relevance and usability of the data and how it will be obtained and utilized should be included.

2.4.8.2 Data Review

The project-specific MAM Plan should include information on the QA/QC, review, and clearance processes for the data. If needed, the QA/QC procedures may be provided in a separate document, such as a Quality Assurance Project Plan (QAPP) or a scope of work (SOW), and referenced in the MAM Plan. The QA/QC and review processes are outlined in Section 3.1.2.

If applicable, the project-specific MAM Plan should also provide information on how the transfer of samples or data between parties will be documented. This could include using a standard chain of custody form (as used for the injury assessment), documenting the transfer in a README file or other means.

2.4.8.3 Data Storage, Accessibility, and Sharing

The project-specific MAM Plan should include information on the data storage process and data accessibility.

MAM data should be stored in the DIVER Restoration Portal or a similar outside data platform (Section 10.6.5 of SOP; DWH NRDA Trustees, 2016b). Data should be submitted as soon as possible but no more than one year from when data were collected (Section 10.6.5 of SOP; DWH NRDA Trustees, 2016b). If it will not be possible to add data to the DIVER Restoration Portal within the one-year timeframe, an estimated timeframe for submission should be provided in the MAM Plan (Section 10.6.5 of SOP; DWH NRDA Trustees, 2016b). If project monitoring data will be provided by an outside data platform, the process for the data submission to the DIVER Restoration Portal should be specified in the MAM Plan (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b).

The frequency of data submission should be defined in the MAM Plan and SOW. The frequency should be at least yearly during years when monitoring is being conducted.

Data storage and accessibility should be consistent with the guidelines in the data management section (Section 3.1.3).

The project-specific MAM Plan should include information on the data-sharing mechanisms and frequency.

Monitoring data will be made publically available, in accordance with the Federal Open Data Policy, through the DIVER Restoration Portal or other mechanisms (Sections 10.6.6 and 11.4 of SOP; DWH NRDA Trustees, 2016b). In the event of a public records request related to project data and information that are not already publicly available, the Trustee to whom the request is addressed will provide notice to the other Trustees within the TIG prior to releasing any project data that are the subject of the request.

If MAM data are protected from public disclosure under other statutory or regulatory authorities [personally identifiable information, Magnuson-Stevens Fishery Conservation and Management Act (MSA), ESA, etc.], state law, policies, or security measures, these reasons should also be explained, and any such limitations should be identified in the MAM Plan (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b).

Data sharing should be consistent with guidelines in Section 3.1.4.

2.4.9 Guidance for Describing the Reporting Strategy for a MAM Plan

The project-specific MAM Plan (Attachment C, Section C.8) should include:

1. Information to be reported
2. The frequency of reporting.

Reporting activities include:

- Reporting on general MAM activities in the DIVER Restoration Portal on an annual basis (Sections 10.7.1 and 12.0 of SOP; DWH NRDA Trustees, 2016b).
- Developing MAM Reports at a frequency defined in the MAM Plan (Section 10.7.1 of SOP; DWH NRDA Trustees, 2016b). These MAM Reports should be consistent with the MAM Report Template (Attachment D).
- Developing a Final MAM Report before a project is closed out (Section 10.7.1 of SOP; DWH NRDA Trustees, 2016b). This MAM Report should be consistent with the MAM Report Template (Attachment D).

See Attachment D for the project MAM Report Template.

2.5 Funding: Project MAM Activities

During project development, costs related to MAM should be captured in the overall project budget. MAM costs identified in the budget may cover MAM activities related to planning, implementation, and management; potential corrective actions for a specific project; and Trustee administration, oversight, and decision-making. The costs should be estimated based on currently available data and may be revised as needed if additional information becomes available and/or there are changes to the project or the MAM Plan that affect the MAM budget. In some cases, certain items that will be used for MAM may already be included in the overall project budget (e.g., baseline and as-built costs covered under the construction costs and/or potential corrective actions covered in project contingencies).

MAM budget estimates should be developed based on the scope, scale, and duration of the project; and may include costs for monitoring activities, QA/QC, data management, evaluation and assessment, reporting, and other adaptive management activities. The MAM budget should consider the costs for similar programs, and account for the identified risks and uncertainties described in the MAM Plan, as well as the potential need for corrective actions. The costs of any potential corrective actions should be considered to ensure that any required adaptive management adjustments are captured.

2.6 MAM Considerations during Project Implementation

2.6.1 Monitoring and Data Management

Following the development and approval of the project-specific MAM Plan and the corresponding final Restoration Plan, project-specific monitoring will be conducted in accordance with the MAM Plan and QA/QC procedures. If changes arise during implementation that will alter the planned monitoring activities, such as a change to the monitoring design, the project-specific MAM Plan and/or QA/QC procedures should be updated to reflect these changes, approved by the TIG, and the revised version uploaded to the DIVER Restoration Portal (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). This updating may occur concurrently with the annual project reporting (see Section 2.6.3 below).

The Implementing Trustee(s) may choose to conduct the monitoring themself or contract the monitoring. If an outside party is conducting the monitoring, the Implementing Trustee(s) should coordinate closely with the outside party to ensure monitoring and data collection are being conducted in accordance with the MAM Plan and/or QA/QC procedures. It is recommended that the SOW be as detailed and specific as possible to provide sufficient direction to the party conducting the monitoring. The MAM Plan and QA/QC procedures should also be provided to the party conducting the monitoring. Further, data collection and management should be consistent with the guidelines in Section 3.

To the extent practical, environmental and biological data generated during monitoring activities should be collected using standardized field datasheets (Section 3.2). If standardized datasheets are unavailable or not readily amendable to record project-specific data, then project-specific datasheets should be drafted prior to conducting any project-specific monitoring activities. Photographs and original hardcopy datasheets, and notebooks or electronic datasheets will be retained by the Implementing Trustee(s).

2.6.2 Project Evaluation and Learning from Adaptive Management

An essential component of adaptive management is the feedback of new information to inform future decision-making. Monitoring data collected during project monitoring will be analyzed to evaluate whether the project is trending toward its identified performance criteria, and assess the overall progress toward meeting the project's restoration objectives. The analysis of project monitoring data may also help resolve uncertainties related to the best ways to meet restoration objectives and/or the presence of any external factors that could influence the ability of the project to meet its restoration objectives.

During project evaluation (Section 2.4.6), the Implementing Trustee(s) can use the information gained to inform project-level decisions, such as proposing potential corrective actions to the TIG, if needed (Section 10.4.2.1 of SOP; DWH NRDA Trustees, 2016b). Understanding the specific drivers that influence project performance, such as unanticipated outcomes or events, can help guide the development and implementation of appropriate corrective actions if the Implementing Trustee(s) determines that corrective actions should be implemented for the project. Further, new information learned through project evaluation can also be used to inform the current understanding of the project's environmental setting to help determine how the system may respond to subsequent corrective actions or changes to project operations. If corrective actions will be implemented, the Implementing Trustee(s), in coordination with the TIG, should determine whether:

- Any modifications to the project MAM Plan are required as a result of the corrective action (Section 10.4.2.1 of SOP; DWH NRDA Trustees, 2016b)
- The proposed corrective actions require additional environmental review, including modifications to regulatory permits and consultations; or if the modifications result in a material change to the project as selected in the final Restoration Plans, determine whether public notification is required (Section 9.5.1.4 of SOW; DWH NRDA Trustees, 2016b).

In addition, the Cross-TIG MAM work group may share project-level outcomes across TIGs to identify any lessons learned that can inform the design and implementation of future, similar projects. The Cross-TIG MAM work group will serve as a forum for the TIGs to share knowledge gained through the implementation, monitoring, and evaluation of individual restoration projects. The Cross-TIG MAM work group may elect to hold meetings following the annual reporting period to discuss the monitoring results of existing projects and any lessons learned that may be relevant to the TIGs. The work group members who serve as liaisons to each of the TIGs could provide updates to the TIGs on the outcomes of this discussion. When relevant and appropriate, the Cross-TIG MAM work group will share lessons learned with other DWH restoration programs as part of their external engagement efforts.

2.6.3 Project Reporting

As stewards of public trust resources under OPA, the Trustees acknowledge the importance of informing the public on restoration project progress and performance, as well as on the collective progress toward meeting Restoration Type and programmatic goals (Chapter 7 of PDARP/PEIS; DWH NRDA Trustees, 2016a). Reporting is also a key step of science-based adaptive management (Appendix 5.E of PDARP/PEIS; DWH NRDA Trustees, 2016a). Thus, the Trustees committed themselves to reporting regularly on the progress of restoration projects via the DIVER Restoration Portal (Chapter 7 of PDARP/PEIS; DWH NRDA Trustees, 2016a). Information collected during each reporting cycle will be shared with the public and other interested entities.

Specific reporting activities are described below.

2.6.3.1 Reporting in the DIVER Restoration Portal on MAM Activities

The Implementing Trustee(s) will report on MAM activities through the DIVER Restoration Portal page (Sections 10.7.1 and 12.0 of SOP; DWH NRDA Trustees, 2016b) in the monitoring tab of the “Project Details” page. This monitoring tab currently describes project restoration objectives, monitoring activities, parameters, and performance criteria (Section 12.0 of SOP; DWH NRDA Trustees, 2016b); and will be expanded with the input and approval of the Trustees to include adaptive management activities, such as lessons learned and new reporting templates, as they are developed. These components should be filled out once the project has a published MAM Plan; and these sections should be reviewed and updated, if needed, in the DIVER Restoration Portal annually to reflect the status of MAM activities.

In addition to the annual reporting process described above, if changes arise during implementation that will alter the planned MAM activities, the MAM details in the DIVER Restoration Portal should be updated accordingly, as needed, and the revised MAM Plan should be uploaded to the DIVER Restoration Portal as a new file.

2.6.3.2 Interim and Final MAM Reports

Interim (if applicable) and Final MAM Reports should be developed at the frequency defined in the final MAM Plan (Section 10.7.1 of SOP; DWH NRDA Trustees, 2016b). The report template provided in Attachment D should be used, to the extent practicable, when developing the Interim and Final MAM Reports:

- Interim MAM Reports should contain results of the evaluation, summary statistics for MAM data, an overview of progress toward project restoration objectives, a determination of the need for corrective actions, an adequate description of the methods used to obtain the project MAM results, and any additional information deemed relevant by the Implementing Trustee(s) or TIG.
- Final MAM Report should contain a final evaluation of project monitoring data; a report on the final project outcomes, including lessons learned or uncertainties addressed; considerations for planning and implementing future projects; and any additional information deemed relevant by the Implementing Trustee(s) or TIG.
- The Final MAM Report should be developed once the project is complete and no additional NRDA monitoring is planned. A Final MAM Report is required before a project is considered complete (Section 10.7.1 of SOP; DWH NRDA Trustees, 2016b).

Once reviewed by the TIG, the Interim (if applicable) and Final MAM Reports should be uploaded to the DIVER Restoration Portal to be shared with the Trustee Council and the Cross-TIG MAM work group (Section 10.7.1 of SOP; DWH NRDA Trustees, 2016b). The review and clearance of monitoring reports should follow the same clearance and release process as the monitoring data, as outlined in Section 3.1.2. Once the reports are cleared for release, the documents will be made publicly available.

3. Guidance for Data Management

3.1 Data Procedures

3.1.1 MAM Data Recording

Following data collection, data should be recorded in accordance with the MAM Plan, QA/QC procedures (if a separate document), QAPP, and/or SOW (if applicable). The steps are as follows:

1. Enter or download the data into established digital formats, consistent with the data standards (Section 3.2). For example, relevant project data that are handwritten on hardcopy datasheets or notebooks should be transcribed (i.e., entered) into Excel spreadsheets (or a similar digital format).
2. Develop the metadata. Geospatial metadata should follow the International Organization for Standardization (ISO) metadata standards (ISO, 2014; see data standards described in Section 3.2) to the extent practicable and in accordance with individual agency requirements.
3. Store and manage documents and electronic data files in a secure location in such a way that the Implementing Trustee is guaranteed to have access to all versions of the data at least as long as agency retention requires.

It is recommended that all hardcopy field datasheets and notebook entries be scanned to Portable Document Format (PDF) files, and the files archived along with the hardcopy datasheets. Changes to electronic data files should be tracked. All photographs, original hardcopy datasheets, notebooks, and revised data files should be retained.

3.1.2 MAM Data Review and QA/QC

Before being added to the DIVER Restoration Portal, all data will go through the appropriate QA/QC process in accordance with the data management section of the MAM Plan and QA/QC procedures (if contained in a separate document), QAPP, and/or SOW (if applicable), and be consistent with the process outlined below.

Step 1. Data Verification

1. Verify that the data are correctly entered and convert into a format that may be imported into DIVER (transcription verification, see details below), consistent with the data standards (Section 3.2).
2. Perform an initial validation check for suspected errors other than data entry/transcription errors (e.g., units, expected value range).
3. Address any suspected errors, and document the changes made to correct actual errors and suspected errors that were found to be valid data.
4. Verify the metadata are in standard ISO format (see data standards described in Section 3.2) to the extent practicable and in accordance with individual agency requirements.

Corrections to errors should be made before the data are used for any analyses or distributed outside the agency. As needed, the initial data analysis may be conducted at this time in accordance with the SOW, QAPP, and/or MAM Plan.

Additional Information

Transcription verification is a process where the entered data are checked to ensure they are transcribed accurately. There are two common approaches to transcription verification:

- Visual check – Have the entered/converted data visually inspected, preferably by a person who did not enter the data. This could be performed on the entire dataset or a portion of the dataset (e.g., 10%).
- Double data entry – Have two people independently enter the data, and check for agreement.

Any errors/corrections may be double-checked by the original data entry/conversion personnel or an independent reviewer. The robustness of the verification review may depend on the type of data, how the data were collected and recorded, the quantity of the data, and the required data quality (e.g., data quality objectives).

Step 2. Data Procurement

Data should be made available to the TIG at least yearly during years when monitoring is being conducted. Data submitted to DIVER or another data repository should be verified. Submissions may also include scanned datasheets, raw data, and/or analyzed data.

The Implementing Trustee(s) is responsible for ensuring that the data submitted are consistent with the data standards (Section 3.2), and that the data transfer is documented (e.g., chain of custody form, README file).

Step 3. Data Validation and Final QA/QC

In accordance with the MAM Plan and/or QA/QC procedures, the Implementing Trustee(s) is responsible for reviewing submitted verified data and verified processed data, and checking for suspected non-data entry errors (e.g., units, expected value range, date/time, latitude/longitude). After any and all suspected errors are addressed, the data are considered to have gone through the QA/QC process.

Additional Information

Depending on the type of data, there are a number of checks that can be done when reviewing the transcription-verified data to ensure the data are accurate and complete. Some examples include (adapted from https://www2.usgs.gov/datamanagement/qaqc.php):

- Check units.
- Compare values to expected value ranges (e.g., existing datasets, reports).
- Check date and time.
- Perform geospatial checks (e.g., coordinates).
- Ensure data columns and rows line up properly.
- Look for missing or irregular data entries.
- Look for blank entries.
- Note any data qualifiers.
- Perform statistical summaries.

- Check for outliers. This can be done by creating graphs (e.g., normal probability plots, regression, scatterplots), creating maps, or performing additional data analysis (e.g., subtract values from the mean).

Step 4. Information Package Creation

The Implementing Trustee(s) is responsible for creating an information package for public release, which should include the following documents if applicable:

- Monitoring data
- Metadata
  - Geospatial metadata following ISO standards (see data standards, Section 3.2, Step 6)
  - Data dictionary (defines codes and fields used in the dataset; see data standards, Section 3.2, Step 6)
  - README file (e.g., how data were collected; QA/QC procedures; other information about data such as meaning, relationships to other data, origin, usage, and format – can reference other documents; see data standards, Section 3.2).

Prior to upload and release of the monitoring data and associated metadata, the Implementing Trustee(s) should confirm with the relevant TIG(s) that the package is ready for release.

3.1.3 MAM Data Storage and Accessibility

The Implementing Trustee(s) is responsible for ensuring that documents and electronic data files are stored in a secure location in such a way that accessibility is guaranteed for as long as the agency requires.

The DIVER Restoration Portal offers a centralized storage option for each Trustee that will meet data storage and accessibility (internal and public) requirements; however, the Trustees may maintain records on other platforms. If data are stored on another platform, an explanation of where the data are stored, as well as a description of the long-term management and archiving procedures of that database, will be provided in the DIVER Restoration Portal (Section 10.6.5 of SOP; DWH NRDA Trustees, 2016b). Options to link data from a source database to the DIVER Restoration Portal are available as well.

The Implementing Trustee(s) will provide MAM data and information to the DIVER Restoration Portal or similar outside data platforms as soon as possible and no more than one year from when data are collected, unless otherwise specified in the MAM Plan (Section 10.6.5 of SOP; DWH NRDA Trustees, 2016b).

More detailed data entry steps and workflows for restoration data management can be found in the DIVER Restoration Portal Manual (NOAA DWH Data Management Team, Undated).

3.1.4 MAM Data Sharing

The Trustees will ensure that data sharing follows standards and protocols set forth in the Open Data Policy (Section 10.6.6 of SOP; DWH NRDA Trustees, 2016b). However, some MAM data may be exempt from the Open Data Policy due to protection from public disclosure under other regulatory authorities (e.g., Privacy Act, ESA, MSA). No data release can occur if it is contrary to Federal or State laws (Section 10.6.4 of SOP; DWH NRDA Trustees, 2016b).Trustees will provide notification to the Cross-TIG MAM work group when new data and information packages have been uploaded to DIVER or another similar data platform. In the event of a public records request related to project data and information that are not already publicly available, the Trustee to whom the request is addressed will provide notice to the other TIG Trustees prior to releasing any project data that are the subject of the request.

Trustees will provide DWH NRDA MAM data and information to the DIVER Restoration Portal or another similar data platform as soon as possible and no more than one year from when data are collected. If it will not be possible to add data within that timeframe, an estimated timeframe of when to expect the data after they have been collected should be provided in the data management component of the MAM Plan (Section 10.6.5 of SOP; DWH NRDA Trustees, 2016b). If the data are stored in the DIVER Restoration Portal, it can be shared to the public by publishing the data to the Trustee Council website (Section 10.6.6 of SOP; DWH NRDA Trustees, 2016b). For further instructions on this process, see the DIVER Restoration Portal Manual.

3.2 Data Standards

These data standards reflect the guidelines developed during Early Restoration and will continue to serve as interim monitoring reference materials for the TIGs and Implementing Trustees until the Trustees further develop these standards in future iterations of the MAM Manual (Section 10.2 of SOP; DWH NRDA Trustees, 2016b). The Trustees developed these data standards to increase consistency in the way data are described and recorded.

1. Data collection: Field data should be collected with standardized datasheets or project-specific datasheets electronically on digital tablets where feasible, or on hard copy datasheets.
    a. Field datasheets should include standard data fields (described below) identified by the Trustees.
    b. Agreed-upon standard units of measure should be used if available.
2. Document revision: If a data file is revised after it has been published to the DIVER Restoration Portal or other data repository, the original datasheet should be preserved and changes to electronic data files should be tracked.
3. Sample/data transfer: Transfer of samples or data should be properly documented (e.g., chain of custody form, README file).
4. Document/data retention, storage, and accessibility: All documents (e.g., photographs, original hardcopy datasheets, notebooks) and electronic data files should be stored and managed in a secure location in such a way that the Implementing Trustee(s) is guaranteed to have access to all versions of the data for at least as long as agency retention requires. All original and revised data files should be retained.
    a. If an outside party is conducting the monitoring, the data submission to the Implementing Trustee(s) should occur at least yearly during the years when monitoring is being conducted.
5. Data format: The data format should be consistent with data standards developed by the Cross-TIG MAM work group. This includes the type of data file, standard data fields, and the units of the data.
6. Metadata: The data should have properly documented metadata, which may include geospatial metadata, a data dictionary, and/or a README file as appropriate.
    a. Federal geospatial metadata standards can be found at https://www.fgdc.gov/metadata/iso-standards.
    b. The data dictionary defines codes and fields used in the dataset.
    c. The README file should include information on how the data were collected, the QA/QC procedures, and other information about the data (e.g., meaning, relationships to other data, origin, usage, format). The README file can reference different documents.

   i. Example data fields: Data source; data collection purpose; data use qualifications; study; station; methods and QA/QC procedures; sample collection; sample analysis (if applicable); qualifiers; time and date of creation; creator or author of the data; and location of the data.
7. Data QA/QC and review: All data should undergo proper QA/QC protocols and be reviewed, following the process outlined in Section 3.1.2.
8. Data submission: Data should be submitted to the DIVER Restoration Portal or similar outside data platform within one year of data collection, unless otherwise specified in the MAM Plan.
9. Data sharing: All data should be made publicly available, in accordance with the Open Data Policy, through the DIVER Restoration Portal or another acceptable platform within a year of when the data collection occurred, unless otherwise specified in the MAM Plan. If MAM data are protected from public disclosure under other regulatory authorities (personally identifiable information, MSA, etc.), policies, or security measures, these reasons should also be explained, and any such limitations will be identified in the MAM Plan (Sections 10.6.3 and 11.4 of SOP; DWH NRDA Trustees, 2016b).

Standard data fields may include:

- Date
- Time
- Site
- Site name
- Station name/identification (ID)
- Latitude
- Longitude
- Sample ID
- Sample measurement
- Sample unit of measurement
- Field team leader
- Field team members.

Examples of commonly used digital formats:

- Excel spreadsheets (.xls)
- Access databases (.mdb)
- CSV files (.csv)
- Point, line, or polygon shapefiles (.shp)
- Rasters/imagery, such as TIFFs (.tif), ESRI grids, ASCII grids (.asc), ERDAS (.img), ENVI imagery, DEMs, and HDF
- Photographs, such as TIFFs (.tif), JPEGs (.jpg), or PNGs (.png)
- Geodatabases
- Web Mapping Services
- Google maps (kml, kmz).

4. MAM Priorities

The Trustee Council SOP specifies the need for TIGs to identify MAM priorities for the use of their designated MAM funds, including activities to identify and possibly address critical science and monitoring gaps relevant to its restoration priorities (Section 10.4.1.2 of SOP; DWH NRDA Trustees, 2016b). MAM priorities are defined as the knowledge gaps or information needs relevant to planning, implementing, and/or evaluating restoration that, if addressed, would help the Trustees successfully implement Gulf restoration. MAM priorities may be identified at any scale or at any time, including at a project concept or Restoration Technique level, a single Restoration Area or multiple Restoration Areas, and for a single Restoration Type or multiple Restoration Types. These knowledge gaps or information needs can change over time, and will be re-evaluated periodically, and are not meant to limit project selection. Once MAM priorities are identified, MAM activities (e.g., monitoring, modeling, data collection, research) can then be planned and implemented by the TIGs to address the MAM priorities. The distinction between MAM priorities and MAM activities is important to differentiate the information need from the mechanism to obtain it. Distinguishing between MAM priorities and activities allows for more efficient use of resources as multiple information needs (i.e., multiple MAM priorities) may be identified for different injured resources, for example, but ultimately may be addressed through the same MAM activity. This identification of priorities and activities also allows for screening MAM activities to those that best help address a MAM priority. MAM activities can be funded through multiple allocations depending on the nature of the information need that the activity is addressing, as further described in the SOP (Section 10.5 of SOP; DWH NRDA Trustees, 2016b). While MAM activities can be funded to address MAM priorities through the TIGs, it is also possible that activities addressing MAM priorities may be addressed by other programs or funding mechanisms (e.g., projects funded by other science or restoration programs).

Each of the seven existing TIGs is responsible for identifying MAM priorities for their Restoration Areas, although the spatial scale at which they are identified may differ among the TIGs. TIG MAM priorities can include important science and monitoring gaps relevant to the TIG's restoration priorities for planning, implementation, and evaluation. As such, the TIG MAM priorities will be used to guide decision-making for the usage of TIG MAM funds. The TIG MAM allocations are intended to support restoration planning and the evaluation of restoration progress across all Restoration Types within the respective TIG, allowing the Trustees to adjust restoration implementation over time, based on monitoring and evolving scientific understanding.

MAM priorities can also be identified for specific Restoration Types, which can be addressed using funding from the respective Restoration Type allocations. For example, data gaps and information needs identified in the Regionwide TIG Strategic Frameworks for oysters, birds, marine mammals, and sea turtles could be utilized by the individual TIGs to help plan and implement MAM activities that address those Restoration Type priorities that are relevant to their Restoration Area. TIGs may also identify and communicate additional Restoration Type MAM priorities specific to their Restoration Area. As such, coordination among the TIGs is essential as MAM priorities for all resources and Restoration Areas are identified.

The Cross-TIG MAM work group may review, upon request of a TIG, MAM priorities developed by each of the TIGs, including specific Restoration Type data gaps and information needs defined through the Regionwide TIG Strategic Frameworks, to identify MAM activities that can support multiple MAM priorities identified by different TIGs and/or for the restoration of different injured resources.

References

Barnes, T.K. and F.J. Mazzotti. 2005. Using conceptual models to select ecological indicators for monitoring restoration and management of estuarine ecosystems. In *Estuarine Indicators*, S.A. Bortone (ed.). CRC Press. pp. 493–502.

Bried, J.T. 2013. Adaptive cluster sampling in the context of restoration. *Restoration Ecology* 21(5):585–591.

Cohen, J. 1992. Statistical power analysis. *Current Directions in Psychological Science* 1:98–101.

Doremus, H., W.L. Andreen, A. Camacho, D.A. Faber, R.L. Glicksam, D.D. Goble, B.C. Karkkainen, D. Rohlf, A.D. Tarlock, S.B. Zellmer, S. Campbell-Jones, and Y. Huang. 2011. Making Good Use of Adaptive Management. Center for Progressive Reform White Paper No. 1104.

DWH NRDA Trustees. 2016a. *Deepwater Horizon* Oil Spill: Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS). Available: http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan.

DWH NRDA Trustees. 2016b. Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the *Deepwater Horizon* (DWH) Oil Spill. Originally approved May 4, 2016; revised November 15, 2016.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. Bureau of Land Management, National Business Center, Denver, CO. Available: https://www.blm.gov/nstc/library/pdf/MeasAndMon.pdf.

Fancy, S.G. 2000. Guidance for the Design of Sampling Schemes for Inventory and Monitoring of Biological Resources in National Parks. National Park Service Inventory and Monitoring Program. March 24. Available: https://cals.arizona.edu/classes/ram456a/NPSsampguide.pdf.

Fischenich, C. 2008. The Application of Conceptual Models to Ecosystem Restoration. ERDC/EBA-TN-08-1. Engineer Research and Development Center, Coastal and Hydraulics Lab, Vicksburg, MS.

Grant, W.E., E.K. Pedersen, and S.L. Marín. 1997. *Ecology and Natural Resource Management: Systems Analysis and Simulation*. John Wiley & Sons.

Gregory, R., and G. Long. 2009. Using structured decision making to help implement a precautionary approach to endangered species management. *Risk Analysis* 29(4):518–532.

Gucciardo, S., B. Route, and J. Elias. 2004. Conceptual Models for Long-Term Ecological Monitoring in the Great Lakes Network. National Park Service, Great Lakes Inventory and

Monitoring Network, Ashland, WI. National Park Service, Great Lakes Network Technical Report: GLK/2004/04.

ISO. 2014. Geographic Information-Metadata-Part 1: Fundamentals. ISO 19115-1:2014. International Organization for Standardization.

Jorgensen, S.E. 1988. Fundamentals of ecological modelling. In *Developments in Environmental Modeling 9*. Elsevier Publishers, Amsterdam, Oxford, New York.

Kincaid, T., T. Olsen, D. Stevens, C. Platt, D. White, and R. Remington. 2016. Package 'spsurvey.' R Package Version 3.3.

Lyons, J.E., M.C. Runge, H.P. Laskowski, and W.L. Kendall. 2008. Monitoring in the context of structured decision-making and adaptive management. *Journal of Wildlife Management* 72(8):1683–1692.

Maddox, G.D., K.E. Poiani, and R.E. Unnasch. 1999. Evaluating management success: Using ecological models to ask the right monitoring questions. In *The Ecological Stewardship Project: A Common Reference for Ecosystem Management*, N.C. Johnson, A.J. Malk, W.T. Sexton, and R. Szaro (eds.). Elsevier Science, Oxford, UK. pp. 563–584.

Margoluis, R., C. Stem, N. Salafsky, and M. Brown. 2009. Using conceptual models as a planning and evaluation tool in conservation. *Evaluation and Program Planning* 32:138–147.

McCall, C.H. 1982. *Sampling and Statistics Handbook for Research*. Iowa State University Press, Ames, IA.

McDonald, T. 2012. Spatial sampling designs for long-term ecological monitoring. In *Design and Analysis of Longterm Ecological Monitoring Studies*, R.A. Gitzen, J.J. Millspaugh, A.B. Cooper, and D.S. Licht (eds.). Cambridge University Press, Cambridge, UK. pp. 102–125.

Murray, S.N., R.F. Ambrose, and M.N. Nichols. 2002. Methods for Performing Monitoring, Impact, and Ecological Studies on Rocky Shores. (No. 70). U.S. Department of the Interior, Minerals Management Service, Pacific OCS Region.

NAS. 2016. *Effective Monitoring to Evaluate Ecological Restoration in the Gulf of Mexico*. The National Academies of Sciences. The National Academies Press, Washington, DC. Available: http://dels.nas.edu/Report/Effective-Monitoring-Evaluate-Ecological-Restoration/23476.

NOAA DWH Data Management Team. Undated. DIVER Portal-DWH Restoration User Manual.

NRC. 2004. *Adaptive Management for Water Resources Project Planning*. National Research Council. The National Academies Press, Washington, DC.

Ogden, J.C., S.M. Davis, K.J. Jacobs, T. Barnes, and H.E. Fling. 2005. Wetlands 25(4):795–809. Available: https://doi.org/10.1672/0277-5212(2005)025[0795:TUOCEM]2.0.CO;2.

Pastorok, R.A., A. MacDonald, J.R. Sampson, P. Wilber, D.J. Yozzo, and J.P. Titre. 1997. An ecological decision framework for environmental restoration projects. *Ecological Engineering* 9:89–107.

Runge, M.C. 2011. An introduction to adaptive management for threatened and endangered species. *Journal of Fish and Wildlife Management* 2(2):220–233.

Scott, C.T. 1998. Sampling methods for estimating change in forest resources. *Ecological Applications* 8(2):228–233.

Scott, M.L., A.M. Brasher, E.W. Reynolds, A. Caires, M.E. Miller, L.P. Thomas, and S. Garman. 2005. The Structure and Functioning of Riparian and Aquatic Ecosystems of the Colorado Plateau – Conceptual Models to Inform Monitoring. U.S. Geological Survey, Fort Collins, CO.

Segura, M., R. Woodman, J. Meiman, W. Granger, and J. Bracewell. 2007. Gulf Coast Network Vital Signs Monitoring Plan. Natural Resource Report NPS/GULN/NRR –2007/015. National Park Service, Fort Collins, CO.

Stevens, D.L. and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* 99(465):262–278.

Steyer, G.D. and D.W. Llewellyn. 2000. Coastal Wetlands Planning, Protection and Restoration Act: A programmatic application of adaptive management. *Ecological Engineering* 15(3–4):385–395.

Thom, R.M., G. Williams, A. Borde, J. Southard, S. Sargeant, D. Woodruff, J.C. Laufle, and S. Glasoe. 2005. Adaptively addressing uncertainty in estuarine and near coastal restoration projects. *Journal of Coastal Research* Special Issue No. 40. Coastal restoration: Where have we been, where are we now, and where should we be going? (Winter):94–108. Available: http://www.jstor.org/stable/25736618.

Thompson, S.K. 1990. Adaptive cluster sampling. *Journal of the American Statistical Association* 85(412):1050–1059.

Thompson, S.K. 1992. *Sampling*. John Wiley & Sons, New York.

Williams, B.K. 2011. Adaptive management of natural resources – framework and issues. *Journal of Environmental Management* 92:1346–1353.

Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2009. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

Wood, A., P. Stedman-Edwards, and J. Mang. 2000. *The Root Causes of Biodiversity Loss*. World Wildlife Fund. Earthscan Publications Ltd, London, UK.

A. Composition of the Cross-TIG MAM Work Group

Alabama Department of Conservation and Natural Resources

Florida Department of Environmental Protection

Florida Fish and Wildlife Conservation Commission

Geological Survey of Alabama

Louisiana Coastal Protection and Restoration Authority

Mississippi Department of Environmental Quality

National Oceanic and Atmospheric Administration

Texas Commission on Environmental Quality

Texas General Land Office

Texas Parks and Wildlife Department

U.S. Department of Agriculture

U.S. Department of the Interior

U.S. Environmental Protection Agency

B. MAM Manual Glossary of Terms

Adaptive management – Adaptive management is a form of structured decision-making applied to the management of natural resources in the face of uncertainty (Pastorok et al., 1997; Williams, 2011). It is an iterative process that integrates monitoring and evaluation of management actions with flexible decision-making, where adjustments are made to management approaches based on observed outcomes (NRC, 2004). Within the context of ecological restoration, adaptive management addresses uncertainties by linking science to restoration decision-making (Steyer and Llewellyn, 2000; Thom et al., 2005).

Compliance monitoring – Compliance monitoring is the collection of monitoring information needed to demonstrate compliance with regulatory requirements, including ESA and MMPA, among other applicable statutes. Compliance monitoring may include documentation that a project was built according to design and meets the terms and conditions of ESA Section 7 consultations.

Conceptual model – A conceptual model provides a visual and/or narrative framework that connects key environmental and social factors to ecosystem structure and processes (Thom, 2000; NAS, 2016).

Control site – A control site is a site (or other entity) that is similar to the site/entity to be restored before any restoration activities take place, but is left unrestored in order to evaluate the effectiveness of restoration treatments (NAS, 2016).

Core performance monitoring parameters – Core performance monitoring parameters are those used consistently across projects in order to facilitate the aggregation of project monitoring results and the evaluation of restoration progress for each Restoration Type (Appendix 5.E.4 of PDARP/PEIS; DWH NRDA Trustees, 2016a).

Corrective actions – Corrective actions are adjustments to the restoration project in order to comply with the terms of a Restoration Plan, monitoring plan, and/or settlement agreement (adapted from 15 CFR § 990.55(b)(2)). Corrective actions are typically triggered if performance criteria are not met; however, unanticipated consequences, previously unknown conditions, or unanticipated environmental drivers uncovered during the evaluation of data may also determine the need for corrective actions.

Cross-Trustee Implementation Group (Cross-TIG) Monitoring and Adaptive Management (MAM) work group – The Cross-TIG MAM work group was established by the Trustee Council to serve as a forum for the TIGs to collectively address MAM topics relevant to multiple TIGs. The Cross-TIG MAM work group has no independent authority to act except when directed by the Trustee Council. See Trustee Council SOPs for more information (DWH NRDA Trustees, 2016b).

Data dictionary – A data dictionary defines the codes and fields used in the dataset.

Data Integration Visualization Exploration and Reporting (DIVER) – DIVER is a data warehouse and query application developed by the National Oceanic and Atmospheric Administration (NOAA). DIVER integrates and standardizes datasets so users can query across data holdings and download information and results. See the DWH DIVER website for more information (https://dwhdiver.orr.noaa.gov/). DIVER has both an authorized user access and publicly available access.

DIVER Explorer – The DIVER Explorer is a querying tool that provides the ability to quickly browse, search, visualize, and download that data using different data categories:

- ***Projects and planning details:*** Logistical, financial, and organization information specific to projects, including site-specific restoration efforts.
- ***Environmental data:*** Detailed field and laboratory-based environmental characterization data obtained from the files collected in DIVER. These may include field observations; laboratory results for samples; and photographs that were logged and keyword-tagged using NOAA's Photologger, telemetry, and continuous-read instruments [e.g., conductivity temperature depth (CTD)]. See the DWH DIVER website for more information.

DIVER Explorer has both an authorized user access (https://portal.diver.orr.noaa.gov/group/deepwater-horizon) as well as a publicly available access (https://www.diver.orr.noaa.gov/#explorer-section).

DIVER Restoration Portal – The DIVER Restoration Portal was created by the Trustee Council to provide a centralized platform to support tracking and reporting of the Trustee Council restoration planning and project activities, monitoring, and financial expenditures. The Restoration Portal includes information for the project description, the location, the budget, restoration activities, monitoring, as-built accomplishments, and environmental compliance. Authorized users may access the Restoration Portal at https://portal.diver.orr.noaa.gov/group/trustee-council. The information and data gathered from the DIVER Restoration Portal are available for public consumption through the DIVER Explorer interface or through the Trustee Council Gulf Spill Restoration website (http://www.restoration.noaa.gov/dwh/storymap/).

Data quality objectives – Data quality objectives identify and define the type, quality, and quantity of data needed to satisfy a specified use (U.S. EPA, 2002).

Data standards – Data standards are documented agreements on representation, format, definition, structuring, tagging, transmission, manipulation, use, and management of data (https://www.epa.gov/data-standards/learn-about-data-standards).

Data validation – Data validation is an analyte- and sample-specific process that extends the evaluation of data beyond method, procedural, or contractual compliance (i.e., data verification) to determine the analytical quality of a specific dataset (U.S. EPA, 2002). The Implementing Trustee(s) should review the verified data and check for non-data entry errors (e.g., units, expected value range, date/time, latitude/longitude).

Data verification – Data verification is the process of evaluating the completeness, correctness, and conformance/compliance of a specific dataset against the method, procedural, or contractual specifications (U.S. EPA, 2002). This could include transcription verification; performing an initial check for non-data entry errors (e.g., units, expected value range); and verifying the metadata are complete.

Drivers – Drivers are outside forces, natural or anthropogenic, that have the potential to influence the outcomes of a restoration project. Drivers tend to be large-scale, long-term forces that are not easily controlled at the scale of a single restoration project (Harwell et al., 2016).

Evaluation – Evaluation is the synthesis of monitoring information to understand the progress toward restoration outcomes. This could be conducted at the project, Restoration Type, and programmatic levels.

- ***Project evaluation:*** A project evaluation is the synthesis of project-specific monitoring information to understand restoration effectiveness and the need for corrective action.
- ***Restoration Type evaluation:*** A Restoration Type evaluation is the synthesis of monitoring information at the resource level to understand restoration benefits within each of the Restoration Types. This evaluation will provide the feedback needed for adaptive management at the Restoration Type level and inform the planning and implementation of future restoration actions for a specific Restoration Type.
- ***Programmatic evaluation:*** Programmatic evaluation is the synthesis of monitoring information and overall restoration results to document progress toward meeting restoration goals and objectives. This evaluation will provide the feedback needed for adaptive management at the programmatic level, and inform the planning and implementation of future restoration actions under the Restoration Plan.

Federal Geographic Data Committee/International Organization for Standardization (FGDC/ISO) – These are Federal geospatial metadata standards (http://www.fgdc.gov/standards/projects/FGDC-standards-projects/metadata/base-metadata/v2_0698.pdf).

Implementing Trustee – The Trustee Agency designated by the TIG that is responsible for leading the implementation of a specific restoration project and MAM activities.

Injury – Injury is an observable or measurable adverse change in a natural resource or the impairment of a natural resource service (15 CFR § 990.30). Injury may occur directly or indirectly to a natural resource and/or service (15 CFR § 990.30).

Metadata – Metadata are data that provide information about other data.

Monitoring and Adaptive Management (MAM) activities – MAM activities are projects or other MAM efforts (e.g., monitoring, modeling, data collection, research) developed to address identified MAM priorities.

Monitoring and Adaptive Management (MAM) framework – The MAM framework is the iterative process that the Trustees outlined in Chapter 5 of the PDARP/PEIS (DWH NRDA Trustees, 2016a) to measure the impacts of restoration and support restoration decision-making. The steps of this iterative process include injury assessment, restoration planning (including the development of MAM Plans), implementation of the initial Restoration Plan, monitoring of restoration actions, evaluation of restoration effectiveness, feedback of information to restoration planning and implementation, refinements to restoration implementation, and reporting on restoration progress toward meeting restoration goals and objectives.

Monitoring and Adaptive Management (MAM) Plan – MAM Plans are project-specific plans developed by the Implementing Trustee(s) that outline MAM for a specific restoration project. MAM Plans are designed to evaluate the effectiveness of the proposed restoration projects in meeting the restoration objectives and to assist, where feasible, in determining the need for adaptive management, which includes corrective actions.

Monitoring and Adaptive Management (MAM) priorities – MAM priorities are the knowledge gaps or information needs that, if addressed, would help the Trustees successfully implement Gulf restoration. MAM priorities may be identified at any scale, or at any time, including at a project concept or Restoration Technique level, a single Restoration Area or multiple Restoration Areas, and for a single Restoration Type or multiple Restoration Types.

Monitoring and Adaptive Management Procedures and Guidelines Manual (MAM Manual) – The MAM Manual is a document developed by the Cross-TIG MAM work group that presents details on MAM procedures and guidelines.

Monitoring data – Monitoring data may include, but are not limited to, any datasets or model results collected, compiled, or utilized under a MAM Plan as part of the DWH NRDA restoration effort. Monitoring data may be generated during any phase or component of restoration (including, but not limited to, planning, compliance, engineering and design, construction, as-built, baseline, post-implementation, and others), or as part of any project-specific monitoring or non-project specific data collection (e.g., to address TIG, Restoration Type, or cross-resource MAM priorities).

Monitoring information – Monitoring information includes any descriptive activities, plans, documents, and reports generated outside of the Restoration Portal monitoring that support evaluations of progress toward restoration goals and potential needs for corrective actions.

Monitoring parameters – Monitoring parameters are physical, chemical, or biological factors (e.g., elevation, % cover, density) that will be measured.

Natural resource damage assessment (NRDA) – NRDA is the process of collecting and analyzing information to evaluate the nature and extent of injuries resulting from an incident, and determining the restoration actions needed to bring injured natural resources and services back to baseline and make the environment and public whole for interim losses (15 CFR § 990.30).

Oil Pollution Act (OPA) – OPA means the Oil Pollution Act of 1990, 33 U.S.C. 2701 et seq.

Objective-specific performance monitoring parameters – Objective-specific performance monitoring parameters are those parameters that are only applicable to projects with a particular restoration objective.

Performance criteria – Performance criteria are used to determine the success of restoration or the need for corrective actions (15 CFR § 990.55(b)(1)(vii)). Performance criteria may include structural, functional, temporal, and/or other demonstrable factors (15 CFR § 990.55(b)(2)). Performance criteria may include post-construction/post-execution performance criteria as well as construction/execution performance criteria, if those construction/execution criteria are related to the project’s performance monitoring.

Performance monitoring – Performance monitoring is the collection of monitoring information to support the evaluation of effectiveness of the project in meeting the established restoration objectives and assist in determining the need for corrective actions. Performance monitoring is intended to document whether the projects have met their established performance criteria and determine the need for corrective actions (15 CFR § 990.55(b)(1)(vii)).

Pre-restoration baseline monitoring – Pre-restoration baseline monitoring is information collected before or at the start of a given project that provides a basis for planning and/or evaluating subsequent progress and related impacts (adapted from NAS, 2016).

Programmatic goal (also referred to as programmatic trustee goals and ecosystem goals). Programmatic goals are the overarching goals the Trustees identified for restoration planning specific to addressing injury. Programmatic goals include Restore and Conserve Habitat; Restore Water Quality; Replenish and Protect Living Coastal and Marine Resources; Provide and Enhance Recreational Opportunities; and Provide for Monitoring, Adaptive Management, and Administrative Oversight to Support Restoration Implementation (Section 5.3.1 of PDARP/PEIS; DWH NRDA Trustees, 2016a).

Quality assurance (QA) – QA is an integrated system of management activities involving planning, implementation, assessment, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed and expected by the end user (U.S. EPA, 2002).

Quality control (QC) – QC is the overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the specifications established by the customer; and operational techniques and activities that are used to fulfill the need for quality (U.S. EPA, 2002).

README file – A README file can include information on the monitoring data (e.g., how data were collected; quality assurance/quality control procedures; other information about data such as meaning, relationships to other data, origin, usage, and format) and can reference different documents.

Reference site – A reference site is a site (or other entity) that is similar to the desired future state of the site/entity to be restored, after restoration activities take place (NAS, 2016).

Restoration – Restoration is any action or activity (or alternative), or combination of actions (or alternatives), to restore, rehabilitate, replace, or acquire the equivalent of injured natural resources and services (15 CFR § 990.30).

Restoration Approaches – Restoration Approaches are general restoration actions the Trustees identified for each of the Restoration Types. Restoration Approaches describe options for implementation, and some include techniques and provide examples for specific methods (Appendix 5.D of PDARP/PEIS; DWH NRDA Trustees, 2016a).

Restoration Areas – Restoration Areas are the geographic areas the Trustees identified to allocate specific funding. The Trustees identified seven Restoration Areas, including each of the five Gulf states, Regionwide, and Open Ocean (Sections 5.10.2 and 7.2 of PDARP/PEIS; DWH NRDA Trustees, 2016a). An eighth Restoration Area focused on Adaptive Management and Unknown Conditions will be established by the Trustees 10–15 years following the settlement (Sections 5.10.2 and 7.2 of PDARP/PEIS; DWH NRDA Trustees, 2016a).

Restoration objectives – Restoration objectives are specific objectives of the restoration project. Restoration objectives should be specific to the injuries addressed by the project and should clearly specify the desired outcome of the restoration project (15 CFR § 990.55(b)(2)).

Restoration Plan – A Restoration Plan presents the Trustees' preferred restoration alternatives that address one or more specific injuries associated with the incident. The Restoration Plan is developed in accordance with 15 CFR § 990.55(b).

Restoration Technique – Restoration Techniques are specific restoration actions the Trustees identified for each of the Restoration Approaches. Restoration Techniques may be used individually or in combination. Example Restoration Techniques are outlined in Appendix 5.D of the PDARP/PEIS (DWH NRDA Trustees, 2016a).

Restoration Types – Restoration Types are the broad restoration categories the Trustees identified pertaining to the programmatic goals. The Trustees identified 13 distinct Restoration Types, including Wetlands, Coastal, and Nearshore Habitats; Habitat Projects on Federally Managed Lands; Nutrient Reduction (nonpoint source); Water Quality; Fish and Water Column

Invertebrates; Sturgeon; Submerged Aquatic Vegetation; Oysters; Sea Turtles; Marine Mammals; Birds; Mesophotic and Deep Benthic Communities; and Provide and Enhance Recreational Opportunities. The Restoration Types are outlined in Chapter 5 of the PDARP/PEIS (DWH NRDA Trustees, 2016a).

Restoration Type goals – Restoration Type goals are the specific goals the Trustees developed for each of the Restoration Types. Restoration Type goals are presented in Chapter 5 of the PDARP/PEIS (DWH NRDA Trustees, 2016a).

Stressors – Stressors are the physical, chemical, or biological factors that directly cause ecological effects (Harwell et al., 2016).

Transcription verification – Transcription verification is a process where the entered data are checked to ensure they are transcribed accurately.

Trustee Implementation Groups (TIGs) – TIGs are the groups the Trustees established for the purposes of planning, administering, and implementing restoration. There are currently seven active TIGs, one for each Restoration Area, as follows: Alabama, Florida, Louisiana, Mississippi, Texas, Regionwide, and Open Ocean. An eighth TIG, the Adaptive Management and Unknown Conditions TIG, may be established by the Trustees 10–15 years following the settlement.

Trustees – Trustees (or natural resource trustees) are those officials of the Federal and State governments, of Indian tribes, and of foreign governments, designated under 33 USC 2706(b) of OPA (15 CFR § 990.30), to assess damages to natural resources, and develop and implement plans for the restoration, rehabilitation, replacement, or acquisition of the equivalent, of the natural resources under their trusteeship. The DWH NRDA Trustee Council is comprised of Trustee agencies from the States of Texas, Louisiana, Mississippi, Alabama, Florida, and four Federal agencies: the U.S. Department of Commerce (represented by NOAA), the U.S. Department of the Interior, the U.S. Department of Agriculture, and the U.S. Environmental Protection Agency.

Uncertainties – Uncertainties are information gaps that may affect decisions for a project or groups of projects that are the main focus within the context of adaptive management.

Unknown conditions – Unknown conditions are factors that may be discovered in the future that could influence the overall restoration progress and/or the recovery of resources.

Validation monitoring – Validation monitoring is the additional project-scale monitoring beyond performance monitoring to better understand ecosystem functions and services provided by projects (Neckles et al., 2002; Roni et al., 2005; La Peyre et al., 2014). Validation monitoring is intended to help project managers optimize implementation of the approach and address uncertainties in understanding the project function, as needed. Validation monitoring would help the Trustees better evaluate the benefits provided by restoration projects to the injured resources and inform the planning of future, similar projects.

References

DWH NRDA Trustees. 2016a. *Deepwater Horizon* Oil Spill: Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS). Available: http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan.

DWH NRDA Trustees. 2016b. Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the *Deepwater Horizon* (DWH) Oil Spill. Originally approved May 4, 2016; revised November 15, 2016.

Harwell, M.A., J.H. Gentile, L.D. McKinney, J.W. Tunnell Jr., W.C. Dennison, and R.H. Kelsey. 2016. A New Framework for the Gulf of Mexico EcoHealth Metrics. Available: http://www.harteresearchinstitute.org/sites/default/files/resources/Framework%20for%20the%20Gulf%20EcoHealth%20Metric.pdf.

La Peyre, M.K., A.T. Humphries, S.M. Casa, and J.F. La Peyre. 2014. Temporal variation in development of ecosystem services from oyster reef restoration. *Ecological Engineering* 63:34–44.

NAS. 2016. *Effective Monitoring to Evaluate Ecological Restoration in the Gulf of Mexico*. The National Academies of Sciences. The National Academies Press, Washington, DC. Available: http://dels.nas.edu/Report/Effective-Monitoring-Evaluate-Ecological-Restoration/23476.

Neckles, H.A., M. Dionne, D.M. Burdick, C.T. Roman, R. Buchsbaum, and E. Hutchins. 2002. A monitoring protocol to assess tidal restoration of salt marshes on local and regional scales. *Restoration Ecology* 10:556–563.

NRC. 2004. *Adaptive Management for Water Resources Project Planning*. National Research Council. The National Academies Press, Washington, DC.

Pastorok, R.A., A. MacDonald, J.R. Sampson, P. Wilber, D.J. Yozzo, and J.P. Titre. 1997. An ecological decision framework for environmental restoration projects. *Ecological Engineering* 9:89–107.

Roni, P., M.C. Liermann, C. Jordan, and E.A. Steel. 2005. Steps for designing a monitoring and evaluation program for aquatic restoration. In *Monitoring Stream and Watershed Restoration*, P. Roni (ed.). American Fisheries Society, Bethesda, MD. pp. 13–34.

Steyer, G.D. and D.W. Llewellyn. 2000. Coastal Wetlands Planning, Protection and Restoration Act: A programmatic application of adaptive management. *Ecological Engineering* 15(3–4):385–395.

Thom, R.M. 2000. Adaptive management of coastal ecosystem restoration projects. *Ecological Engineering* 15:365–372.

Thom, R.M., G. Williams, A. Borde, J. Southard, S. Sargeant, D. Woodruff, J.C. Laufle, and S. Glasoe. 2005. Adaptively addressing uncertainty in estuarine and near coastal restoration projects. *Journal of Coastal Research* Special Issue No. 40. Coastal restoration: Where have we been, where are we now, and where should we be going? (Winter):94–108.

U.S. EPA. 2002. *Guidance for Quality Assurance Project Plans*. EPA QA/G-5. EPA/240/R-02/009. December. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC. Available: https://www.epa.gov/sites/production/files/2015-06/documents/g5-final.pdf.

Williams, B.K. 2011. Adaptive management of natural resources – framework and issues. *Journal of Environmental Management* 92:1346–1353.

C. MAM Plan Template

The Cross-TIG MAM work group has established a template and set of guidelines for the development of project-level MAM Plans (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016). This template, in conjunction with the guidance in Section 2.4 and subsections within, is intended to serve as a resource for the TIGs in the development of their project-specific MAM Plans. Collectively, the components of the MAM Plan document the level of MAM needed at the project scale.

C.1 Introduction

C.1.1 Project Overview

C.1.2 Restoration Type Goals and Project Restoration Objectives (Section 2.4.1)

C.1.3 Conceptual Setting (Section 2.4.2)

C.1.3.1 Potential Sources of Uncertainty (Section 2.4.3)

C.2 Project Monitoring (Section 2.4.4)

C.3 Adaptive Management (Section 2.4.5)

C.4 Evaluation (Section 2.4.6)

C.5 Project-Level Decisions: Performance Criteria and Potential Correction Actions (Section 2.4.7)

C.6 Monitoring Schedule (Section 2.4.4.3)

C.7 Data Management (Section 2.4.8)

C.8 Reporting (Section 2.4.9 and Attachment D)

C.9 Roles and Responsibilities

C.10 References

C.11 MAM Plan Revision History

Reference

DWH NRDA Trustees. 2016. Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the *Deepwater Horizon* (DWH) Oil Spill. Originally approved May 4, 2016; revised November 15, 2016.

D. MAM Report Template

The following report template was developed during Early Restoration. The Cross-TIG MAM work group will continue to refine the contents and may update in future iterations of this MAM Manual.

Table of Contents

I. Introduction[1]

a. Project Overview [*including project location and description of restoration activities*]
b. Restoration Objectives and Performance Criteria

II. Methods[2]

III. Results [*e.g., tables or graphs of progress toward performance criteria and/or restoration objectives; site visit summaries; other datasets that support the analysis of the project's progress toward meeting performance standards*]

IV. Discussion [*optional for interim; standard for final*]

V. Conclusions [*optional for interim; standard for final; e.g., summary findings, progress toward meeting performance criteria and restoration objectives, and recommendations for corrective actions*]

VI. Project Highlights [*e.g., lessons learned on monitoring protocols, project engineering/design, etc., to inform future project planning and implementation*]

VII. Data [*including data that have gone through the QA/QC process; or description of data types/formats, data status (e.g., raw, analyzed, QA/QCed), data location, contact information for data custodian, and other relevant information regarding data quality, such as data gaps or issues encountered during data collection. Please include or note all data that were collected, even if not used in the report]*

VIII. References

1. Introduction can be pasted from MAM Plans and reused from report to report.

2. Methods can be pasted from MAM Plans and reused from report to report.

E: Monitoring Guidance

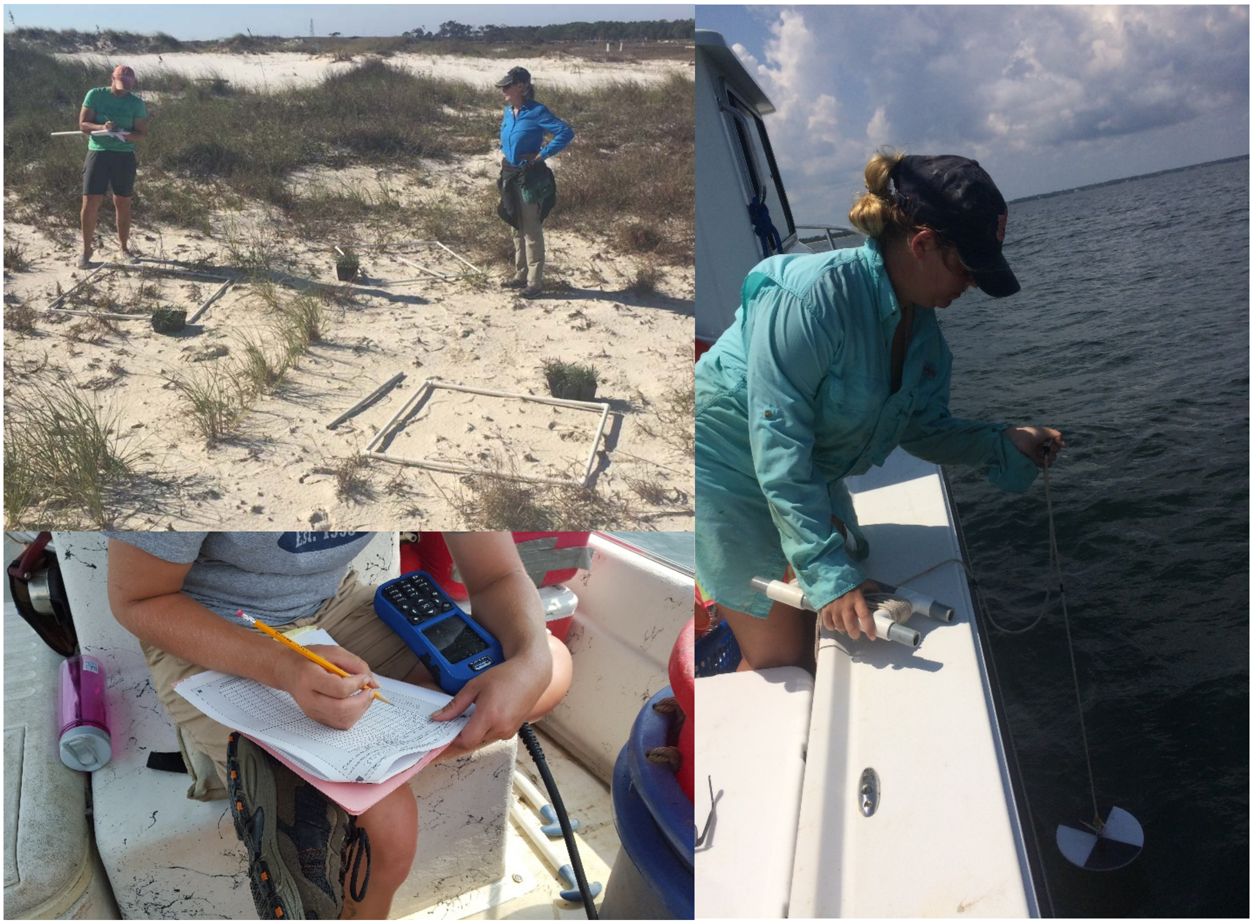

Table of Contents

E.1. Background

The Cross-TIG MAM work group has developed monitoring guidance, including core and objective-specific performance monitoring parameters and associated measurement units and data collection methods, for some Restoration Approaches, to promote consistency in data collection among similar types of projects and allow for future analysis across TIGs and Restoration Types (Section 10.6.2 of SOP; DWH NRDA Trustees, 2016). This guidance may also assist the TIGs by providing recommended methodologies for monitoring restoration projects, saving time and money spent developing suitable monitoring protocols for individual restoration projects. If adjustments from this monitoring guidance are needed for a particular project, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016).

Monitoring guidance has been developed for Restoration Approaches related to coastal wetlands; beaches, dunes, and barrier island habitats; water quality improvements; protection and conservation of marine, coastal, estuarine, and riparian habitats; oysters; submerged aquatic vegetation; and recreational use projects, using the process described in Section E.1. Monitoring guidance for additional Restoration Approaches will be included in future versions of this document. The monitoring guidance is organized in this manual as follows. First, the core and objective-specific performance monitoring parameters are presented in a single, alphabetized list that also includes recommended measurement units; monitoring methods; and guidance on the location, frequency, and duration of the sampling, as appropriate to each parameter. The remainder of the document presents guidance specific to each of the Restoration Approaches. For each approach, core and objective-specific performance parameters, and additional parameters for adaptive management or validation monitoring are provided in tables. Information related to the process (Section E.2) that informed the identification of the parameters, such as example drivers and uncertainties, is also included.

Project teams within each TIG will identify parameters applicable to the objectives for each individual restoration project when developing the project MAM Plan. In addition to the project monitoring guidance identified in this Manual, specific monitoring may be required to comply with permits granted by regulatory agencies. The TIGs are not restricted from adding additional parameters not identified herein, such as those needed for regulatory compliance, to evaluate pre-restoration baseline conditions, or to evaluate project “as-built” conditions. Other project monitoring that may be needed for specific projects should be determined by the TIGs.

Reference

DWH NRDA Trustees. 2016. Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the *Deepwater Horizon* (DWH) Oil Spill. Originally approved May 4, 2016; revised November 15, 2016.

E.2. Process for Developing Monitoring Guidance

The following process was used to develop monitoring guidance for each Restoration Approach:

1. Example project-specific restoration objectives were developed for each Restoration Technique, using the strategy described in Section 2.4.1.1 of the MAM Manual Version 1.0.
2. Drivers and potential uncertainties that may influence the project's ability to achieve the restoration objectives were documented. Existing conceptual models relevant to the Restoration Approach were compiled and reviewed, if available, such as those described in Section 2.4.2.1 of the MAM Manual Version 1.0.
3. Core performance monitoring parameters were identified, which could be used to evaluate progress toward the example restoration objectives. Monitoring frameworks developed by the Trustees for several commonly implemented types of projects during Early Restoration were reviewed to help identify relevant performance monitoring parameters. Existing monitoring plans developed for similar types of projects were also reviewed for relevant performance monitoring parameters.
4. Additional monitoring parameters were identified for each objective that may help resolve uncertainties, explain outside drivers, optimize project implementation, support decisions about corrective actions or other adaptive management of the project, and/or inform the design of future DWH NRDA projects.
5. The identified parameters were categorized into the following groups:
    a. Performance monitoring parameters: Two types of performance monitoring parameters were identified:
        i. Restoration Approach core performance monitoring parameters are used to evaluate project performance for restoration objectives common to projects under the Restoration Approach and should therefore be collected for projects within a Restoration Approach, to the extent practicable. The intent of performance monitoring is to document whether the projects have met their established performance criteria and determine the need for corrective actions (15 CFR § 990.55(b)(1)(vii)).
        ii. Objective-specific performance monitoring parameters are used for additional restoration objectives for a specific project under a Restoration Approach and should therefore be collected for projects that include those additional objectives to the extent practicable.
    b. Additional parameters for adaptive management or validation monitoring that may be used to resolve uncertainties, explain outside drivers, optimize project implementation, support decisions about corrective actions and other adaptive management of the project, and inform the planning of future DWH NRDA restoration projects, as described in Appendix 5.E.3.1 of the PDARP/PEIS (DWH NRDA Trustees, 2016). Selection of specific additional monitoring parameters will depend on the needs of the individual project, and additional monitoring parameters may not be needed for all projects.
6. For each core and objective-specific performance monitoring parameter, the parameter was defined and some technically sound data collection methods, including methodology references, monitoring location, frequency and duration, potential additional analyses, and additional relevant references were summarized, as appropriate.

Reference

DWH NRDA Trustees. 2016. *Deepwater Horizon* Oil Spill: Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS). http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan.

E.3. Restoration Approach Core and Objective-Specific Performance Monitoring Parameters

This guidance is intended to promote consistency in data collection among similar types of projects and allow for future analysis across TIGs and Restoration Types, (Section 10.6.2 of SOP; DWH NRDA Trustees, 2016). This guidance may also assist the TIGs by providing recommended methodologies for monitoring restoration projects, saving time and money spent developing suitable monitoring protocols for individual restoration projects. If adjustments from this monitoring guidance are needed for a particular project, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016). Project teams within each TIG will identify parameters applicable to the objectives for each individual restoration project when developing the project MAM Plan. In addition to the project monitoring guidance identified in this Manual, specific monitoring may be required to comply with permits granted by regulatory agencies. The TIGs are not restricted from adding additional parameters, and other project monitoring that may be needed for specific projects should be determined by the TIGs.

This list of core- and objective-specific monitoring parameters expands upon Section 2.4.4 and Attachments E.2–E.8 of the MAM Manual Version 1.0 and supplemental monitoring guidance developed for additional restoration approaches. It provides additional guidance on the development of the monitoring section of the MAM Plan. All core and objective-specific performance monitoring parameters across the subset of Restoration Approaches covered in the MAM Manual Version 1.0 as well as the monitoring guidance subsequently released for additional monitoring approaches are combined into an alphabetized list below and are numbered for ease of reference. The Restoration Approaches addressed to date include:

- Create, restore, and enhance coastal wetlands
- Create, restore, and enhance barrier and coastal islands and headlands
- Restore and enhance dunes and beaches
- Restore and enhance submerged aquatic vegetation
- Protect and conserve marine, coastal, estuarine, and riparian habitats
- Reduce nutrient loads to coastal watersheds
- Reduce pollution and hydrologic degradation to coastal watersheds
- Restore and enhance submerged aquatic vegetation
- Restore oyster reef habitat
- Enhance public access to natural resources for recreational use
- Enhance recreational experiences
- Promote environmental stewardship, education, and outreach

Additional monitoring parameters for consideration, such as those needed for additional Restoration Approaches identified in the PDARP (DWH NRDA Trustees, 2016a) and adaptive management or validation monitoring parameters listed in the monitoring guidance for each Restoration Approach, are not included in this list at this time. Each parameter in the alphabetized list includes guidance on measurement unit(s) and monitoring methods, with a crosswalk to the Restoration Approach(es) for which the parameter is identified as a core or objective-specific performance monitoring parameter, but not if the parameter is listed only as a parameter for consideration. Some parameters are measured directly while others are calculations (e.g., Oyster Reef Volume). Guidance on monitoring locations, frequencies, and durations of sampling are also included. For some parameters, additional guidance for potential analyses using that monitoring parameter (see Section 2.4.6 of the MAM Manual Version 1.0) is also provided. Although metric units are listed in the parameter descriptions, standard units are also acceptable.

This section is subject to change at the discretion of the Trustees, potentially as a result of newly identified and/or developed monitoring parameters, methods, and technologies. The monitoring parameters identified in a project MAM Plan should be consistent with the monitoring guidance outlined in this attachment, wherever appropriate. However, t content of the MAM Plan, including identification of Restoration Approaches, monitoring objectives, monitoring parameters, and budget is at the discretion of the TIG that is conducting restoration planning (Section 10.3.2 of SOP; DWH NRDA Trustees, 2016b). Monitoring frequency and duration may vary by project due to objectives, performance criteria, project-level decisions, and/or the need for corrective actions.

Section E.3 Table of Contents

E.3.1. Area

Parameter Type: Measured, Calculated, or Modeled

Units: square meters (m^2) or square kilometers (km^2)

Definition

Area may be defined three different ways depending on the project objectives. Projects should indicate which definition(s) is being used. Additional area definitions may also be developed for specific projects, as needed.

Area of Project Footprint: the maximum areal extent of restoration activities.

Area of Project Influence: the area affected by restoration activities as determined by the Implementing Trustee. This area may extend beyond the project footprint.

Area of Habitat: the summed area, by habitat type, of habitat patches within the project footprint.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Restore and Enhance Dunes and Beaches
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Enhance Public Access to Natural Resources for Recreational Use
- Restore and Enhance Submerged Aquatic Vegetation (SAV)
- Restore Oyster Reef Habitat

Potential Methodologies

Potential Field-Based or Remote Sensing Methodologies

Method 1: Project and habitat boundaries can be mapped based on aerial imagery collected by airplane, helicopter, unmanned aerial systems (UAS); high-resolution satellite imagery; or other appropriate remote sensing platforms. Imagery used to map wetland boundaries should include true color and infrared bands, and have a spatial resolution of 1 meter (m) or less. For comparison of different remote sensing platforms commonly used for wetland mapping, see Klemas (2011) and Klemas (2013). For additional information on the use of UAS for wetland mapping, see Klemas (2015), Madden et al. (2015), Zweig et al. (2015), and Samiappan et al. (2017). Source imagery should be orthorectified [i.e., free from distortions related to sensor optics, sensor tilt, and differences in elevation; see Rufe (2014)]. Collected imagery should be imported to spatial analysis software to digitize the perimeter of the project footprint and the boundaries of habitat areas within the project footprint. Additional guidance on using aerial imagery can also be found in Anders and Byrnes (1991), Crowell et al. (1991), Morton (1991), and FLDEP (2014). For coastal wetland projects, see Steyer and Llewellyn (2000) and Dahl and Bergeson (2009) for wetland habitat mapping procedures. For guidance on mapping SAV, see Kirkman 1996 and Vittor & Associates, 2016.

Method 2: Ground surveys can be used to map an area for smaller projects. Use a real-time kinematic Global Positioning System (RTK GPS) to take continuous measurements while walking, boating around, flying, or digitizing the perimeter of the project and along the boundaries of specific habitats within the project footprint. For wetlands, standard field wetland delineation techniques should be considered for areas where wetlands transition into non-wetland habitats (Federal Interagency Committee for Wetland Delineation, 1989). For SAV projects that aim to promote regrowth of native SAV, ground surveys should focus on areas targeted for regrowth.

Method 3: For SAV aerial mapping where airborne remote sensing cannot detect the deep edge of bed, towed underwater video can provide reliable estimates of seagrass area (Christiaen et al. 2016). New techniques for mapping SAV continue to be developed and piloted in localized applications.

Method 4: For intertidal oyster reefs, the footprint may be measured using a surveyor's measuring wheel, laser rangefinder, or transect tape (Baggett et al. 2014).

Method 5: For subtidal oyster reefs, the footprint may be measured using side-scan or multi-beam sonar (Baggett et al. 2014) or professional/survey grade echo sounder.

Method 6: For subtidal oyster reefs, the footprint may be measured using a sounding pole in conjunction with GPS (Baggett et al. 2014)

For many methods, the resulting data should be analyzed using spatial analysis software to calculate the area of habitat created, restored, enhanced, or protected. For habitat protection, conservation, or other habitat projects, the habitat type(s) should also be documented. For coastal wetland projects, Cowardin et al. (1979) provides an example for wetland classification standards.

Monitoring Locations for Field-Based or Remote Sensing Methodologies

Area of habitat built or enhanced should be determined for the entire project footprint. Some data, such as aerial photography, may be collected over larger areas. A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration for Field-Based or Remote Sensing Methodologies

For projects that do not include construction, project monitoring is suggested before and after project implementation. In general, for projects including construction activities, monitoring is proposed pre-construction, immediately after construction (as-built), and post-construction. A baseline pre-construction condition could be established based on data obtained during the Engineering and Design (E&D) period.

Beaches, dunes, and barrier islands: Monitoring is proposed immediately after construction (as-built) and every 3 years up to 10 years post-construction.

Coastal wetlands: Monitoring is proposed immediately after construction (as-built), with at least 1–2 additional monitoring events over the monitoring period. For further guidance and recommendations on wetland monitoring frequency and duration, see Tiner (1999), Neckles et al. (2002), and NAS (2017).

Submerged Aquatic Vegetation (SAV): Monitoring is proposed immediately after construction (as-built), 1 year post construction, and with additional monitoring every 5 years over the monitoring period (Neckles et al. 2012; Vittor & Associates, 2016). Seasonal sampling may be needed for species that exhibit high inter- and intra-annual variance due to seasonally changing environmental conditions.

Oyster reefs: Baggett et al. (2014) suggest monitoring occur pre-construction, within three months after construction, 1-2 years post-construction, and 4-6 years post-construction (a more ecologically relevant time scale, considering the oyster disease Dermo and salinity are correlated at a periodicity of 4 years (Soniat et al. 2009)) and after any event that may alter the habitat within the project footprint. For further guidance on oyster reef monitoring frequency and duration see Baggett et al. (2014) and NAS (2017).

Funding for one additional contingency monitoring event could be included in the monitoring budget, which could be implemented as needed to account for storm impacts.

Modeling Methodologies

Area of coastal wetlands with hydrology restored by the project will be estimated or modeled based on other parameters, including depth, duration, and frequency of flooding.

Method 1: The area influenced by a hydrologic restoration project can be estimated based on hydrodynamic modeling prior to project implementation. The area of influence should be estimated prior to project implementation to establish the restoration target. See MacBroom and Schiff (2012) for a review of commonly used 1- and 2-dimensional hydraulic modeling approaches for tidal restoration projects. Models should document assumptions and limitations in estimating the area of influence.

Method 2: Post-restoration, the area influenced can be calculated as the area over which the target depth, duration, and frequency of flooding has been achieved, based on water-level measurements, elevation data, ground survey and/or remote sensing data, and compared to projections from the hydrodynamic model.

Monitoring Locations for Modeling Methodologies

The location of monitoring should be estimated/modeled across the area surrounding the restoration project. The modeled area should extend slightly beyond the area where any influence is expected as a result of the project.

Guidance on Frequency and Duration for Modeling Methodologies

The area influenced by the project could be estimated prior to project implementation to establish a baseline. The area of influence could be calculated/modeled immediately after project implementation (as-built) and annually for up to five years following implementation, based on water level data and/or elevation data collected for the project. Additional measurements could be taken after events that could alter habitat within the project footprint (e.g., severe storms, sedimentation events).

Other Potential Analyses

Area measurements may also be used in conjunction with other parameters listed herein (e.g., elevation, vegetation percent cover and composition) to perform the following calculations and analyses: habitat type changes, shoreline change, land loss or gain, beach and dune profile change, volume change, bathymetric profile change, and sediment movement. Area measurements can also be used to help assess habitat or landscape connectivity and/or reductions in habitat fragmentation. Water depth and light availability may also be particularly relevant for understanding regrowth potential of SAV.

E.3.2. Bird Abundance, Density, and Community Composition

Parameter Type: Measured, Calculated, or Modeled

Abundance Units: none

Density Units: number per unit area (see **E.3.1 Area** for units)

Community Composition Units: none

Definition

Abundance is the total number of birds within a defined area of interest. Density is abundance divided by area. Community composition is the diversity and relative abundance of bird species within the area of interest.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Restore and Enhance Dunes and Beaches
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Restore Oyster Reef Habitat

Potential Methodologies

Conway (2011) provides a Standardized North American Marsh Bird Monitoring Protocol. This protocol, which employs a combination of point counts and call back surveys, was used to survey marsh birds in all affected states during the DWH oil spill.

Monitoring Location

Conway (2011) provides a discussion of survey site selection. The protocol recommends the establishment of permanent survey sites along a survey route.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-restoration (once, if applicable) and annually for five years, or longer, after restoration. Conway's (2011) methods include three surveys or more during the peak marsh bird breeding season. Surveys are usually conducted during the morning or evening.

E.3.3. Channel Dimensions

Parameter Type: Measured

Units: meters (m)

Definition

The cross-sectional profile (e.g., width and depth) of channels intended to convey water for the restoration project.

Restoration Approach

- Create, Restore, and Enhance Coastal Wetlands

Potential Methodologies

Method 1: For shallower channels, cross-sectional profiles can be measured using advanced survey instrumentation, such as RTK GPS or Total Station; traditional survey instrumentation, such as a level and rod; or using a measuring tape or equivalent linear measurement device. Special care should be taken to not damage the escarpments.

Method 2: In deeper water that cannot be measured with topographic survey techniques, a bathymetric survey can be conducted using a depth finder fitted with a differential GPS or another acoustic method as appropriate.

The position of the profiles should be carefully marked so that the same cross-sections can be repeatedly monitored following restoration. See Roegner et al. (2008) and U.S. Geological Survey (USGS, 2011) for more information on potential methodologies.

Method 3: For hardened channels or culverts, dimensions can be measured using a measuring tape or equivalent linear measurement device.

Monitoring Location

Cross-sectional profiles should be measured in the channels specifically targeted by the hydrologic restoration within the project area. A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-construction, immediately after construction (as-built), and post-construction. A baseline pre-construction condition could be established based on information obtained during the E&D. Sampling could be conducted pre-construction (once), immediately following construction (as-built), and annually thereafter. Monitoring is proposed for five years post-construction or longer to ensure channel dimensions are being maintained sufficiently to meet performance criteria. For fixed or hard structures such as culverts, additional monitoring following as-built measurements may not be necessary because the dimensions are assumed to be stable. However, additional sampling may be needed after large storm events.

Other Potential Analyses

Channel dimensions may also be used to calculate the cross-sectional area in square meters (m^2) or volume in cubic meters (m^3).

E.3.4. Debris

Parameter Type: Measured

Units: none (count of items) or weight in kilograms (kg)

Definition

The amount, source, location, movement and/or impact of marine debris.

Restoration Approach

- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Enhance Recreational Experiences

Potential Methodologies

For coastal projects, information about marine debris can be collected using shoreline surveys, benthic trawls, or floating litter survey operations (Cheshire et al., 2009). There are a number of different survey methods, including comprehensive and rapid beach assessments, and debris assessment and standing stock surveys [see Cheshire et al. (2009), Opfer et al. (2012), and Lippiatt et al. (2013)]. Surface water and at-sea surveys can also be conducted (Ryan et al., 2009).

Monitoring Location

Location of collecting debris is, in part, dependent on accessibility of the site and available equipment. Sampling should focus on areas where debris is suspected to accumulate, but may be stratified by factors such as land use, proximity to river mouths, substrate, tourism, fishing pressure, oceanic current patterns, bathymetry, and hydrodynamics (Lippiatt et al., 2013). For shoreline surveys, Opfer et al. (2012) developed walking patterns to ensure the entire shoreline site or transect is covered.

Guidance on Frequency and Duration

The amount of sampling necessary to assess debris concentrations depends on the spatial variability of the debris, the desired level of detection, and whether the project's objective is to estimate flux rate (accumulation rate of litter) or just standing crop (quantity of litter per unit area or length of transect) (Cheshire et al., 2009). Collection events every 28 days provide good estimates of monthly averages (Lippiatt et al., 2013), while collection events every three months allow for the interpretation of seasonal changes. Collection could also take place before/after cleanup events as applicable.

Other Potential Analyses

A pre-restoration assessment could be conducted to characterize conditions before cleanup.

E.3.5. Discharge

Parameter Type: Calculated

Units: cubic meters per second (m^3/s)

Definition

The volume of water through a channel (e.g., stream, river, or tidal creek) within a given time period, typically in units of cubic meters per second (m^3/sec) or cubic feet per second (cfs). In general, discharge is calculated by multiplying the velocity of the water (e.g., m/s) by the cross-sectional area (m^2).

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds

Potential Methodologies

Method 1: Calculate discharge by multiplying the water velocity by the cross-sectional area (m^2) of the channel (see Section E.9.29 Velocity, Water; and Section E.9.3 Channel Dimensions).

Method 2: An Acoustic Doppler Current Profiler (ADCP) can be used to measure both water velocity and water depth within a stream. Typically, the ADCP is mounted to a small water craft and guided along the stream channel to take the measurements.

Method 3: For streams where a stream gage is installed, the discharge can be calculated based on a stage-discharge relation. The development of a stage-discharge relation requires numerous discharge measurements at the given reach across all ranges of streamflow (Rantz et al., 1982; Turnipseed and Sauer, 2010). However, the stage-discharge relationship cannot be applied to tidally affected areas.

Method 4: Installation of Acoustic Doppler Velocity Meters (ADVMs) at index-velocity stream gages. Discharge is calculated using the index velocity method (Levesque and Oberg, 2012). This approach is best to calculate discharge in reaches with unsteady streamflow that prevents the development of a stage-discharge relationship.

See Steyer and Llewellyn (2000) and Olson and Norris (2007) for more information on potential methodologies.

Monitoring Location

Discharge should be measured or calculated for channels within the project area that are an important component of the project design. If discharge is calculated by multiplying the water velocity by the cross-sectional area, these two measurements should be taken in the same area. A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-construction, immediately after construction, and post-construction. A baseline pre-construction condition could be established based on information obtained during the E&D. Sampling could be conducted pre-construction (once), immediately following construction (once), and annually thereafter. Additional sampling may be needed after large storm events.

For projects with tidal influence, if continuous recorders are used, data could be collected for two weeks or longer during a sampling event to be able to capture one lunar cycle of spring and neap tides, but longer time periods (e.g., 3–4 months or year-round) are preferred. For discrete measurements, the discharge could be assessed over several tidal cycles.

For projects with riverine influence, sampling events could be designed to capture both high- and low-flow events. If continuous recorders are used, data could be collected for two weeks or longer during high- and low-water conditions, but year-round data collection for one or more years is preferred to fully capture the seasonal variability in flow conditions. For discrete measurements, the discharge could be assessed over a few weeks during both high- and low-flow conditions.

Other Potential Analyses

Discharge data may also be needed to model the area influenced by hydrologic restoration.

E.3.6. Dissolved Oxygen (DO)

Parameter Type: Measured

Units: milligrams per liter (mg/L) or parts per million (ppm)

Definition

DO represents the concentration of oxygen mixed and dissolved into the water column.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

A DO meter, water quality sonde, or data logging system can be used to record measurement data taken with a DO sensor. Data collection and calibration procedures of data sondes will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives. See USGS (2013).

E.3.7. Educational Materials

Parameter Type: Measured

Units: none (count) or as appropriate based on the nature of the materials

Definition

Number of, type, nature and/or extent of educational materials developed and/or distributed to promote environmental stewardship, education, and outreach. Materials may include flyers, pamphlets, videos, interactive learning screens, programs, or teacher-led activities.

Restoration Approach

- Promote Environmental Stewardship, Education, and Outreach

Potential Methodologies

Collection methods will vary depending on the type of educational materials developed. For example, if educational flyers are developed, the collection technique may be documenting the number of flyers printed, the number of types of flyers developed, etc. The information collected should include the type and number of educational materials, as well as a summary of the information presented in the educational materials.

Monitoring Location

Materials should be monitored at their distribution location(s). This could include location of sign posts, flyer distribution points, or locations where education activities occur, such as a school.

Guidance on Frequency and Duration

Materials could be monitored for the period in which they are produced. The materials will be distributed according to project specifications and the rate at which materials are distributed should be tracked throughout the distribution period and updated when needed.

Other Potential Analyses

Knowledge of the number of materials produced along with the frequency in which they are accessed by the public can help determine user preferences toward educational materials.

E.3.8. Elevation

Parameter Type: Measured, Calculated, or Modeled

Units: meters (m)

Definition

Elevation of the created or restored area/habitat relative to geodetic datums, tidal datums, or surrounding area.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Restore and Enhance Dunes and Beaches
- Restore and Enhance Submerged Aquatic Vegetation (SAV)
- Restore Oyster Reef Habitat

Potential Methodologies

Topographic Methodologies

To evaluate the effectiveness of the restoration on the elevation and area of beach, dune, oyster reef, SAV, and adjacent subtidal areas, measurements will be compared with previous measurements of shoreline position, elevation, beach and dune profile changes, and volumetric changes within the system when combined with bathymetric surveys as appropriate to the restoration approach. For guidance on elevation monitoring for beach, dune, and barrier island habitats, see FLDEP (2014). For guidance on elevation (reef height) monitoring for oysters, consult Baggett et al. (2014). For marsh habitats, topography and associated hydrologic regime are key determinants of the distribution and composition of marsh vegetation and faunal communities. To evaluate the effectiveness of the restoration design, targeted elevations should consider the desired wetland habitat.

Method 1: Topographic profiles can be done to measure land elevation by using RTK GPS surveys. Elevation is measured at evenly spaced distances along transects or on a grid, and interpolated using spatial analysis software to create a Digital Elevation Model (DEM). See CPRA (2016) for an example protocol for conducting RTK GPS ground surveys within restoration projects.

Method 2: Airborne topographic Light Detection and Ranging or Laser Imaging Detection and Ranging (LIDAR). This is an optical remote sensing technology that can measure the distance to targets by illuminating the target with laser light and analyzing the backscattered light. Ground control points should be established to calculate accuracy and ground surveys may be needed to develop ecosystem-specific correction factors in densely vegetated marshes. For additional information on the use of LIDAR to monitor marsh elevations, see Brock et al. (2002), Schmid et al. (2011), Hladik and Alber (2012), Heidemann (2014), Buffington et al. (2016), and Medeiros et al. (2015).

Method 3: Photogrammetric surveys along transects. Collect elevation data using stereo aerial photogrammetry, coupled with control point elevation measurements collected with RTK GPS (Smith and Vericat, 2015; Smith et al., 2016).

Method 4: For more frequent measurements of elevation to determine sediment compaction rates, settlement plates may be installed during project construction (Dunnicliff, 1993). Elevation of the plates and top of the structure can be measured using advanced surveying instrumentation (e.g., RTK GPS) and as-built elevation compared to elevation in years post-construction.

Method 5: Traditional survey equipment (level and rod or transit pole and self-leveling laser) (Baggett et al. 2014).

Method 6: Ruler, meter stick, or graduated rod (Baggett et al. 2014).

Regardless of method employed, the elevation should be measured relative to geodetic and/or tidal datums (Rydlund and Densmore, 2012). Vertical error should be summarized for all elevation measurements, regardless of the data collection method used. Remotely sensed elevation data should have vertical error reporting that adhere to American Society for Photogrammetry and Remote Sensing (ASPRS) standards, the general standards for gauging vertical error in DEMs.

Monitoring Location for Topographic Methodologies

Topographic profiles should be collected along the entire project footprint (typically collected for a larger area). A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration for Topographic Methodologies

For beaches, dunes, barrier island, oyster reef, and SAV projects, data collection could occur pre-construction, immediately after construction (as-built), and at an appropriate frequency and duration relevant to project-specific conditions. A baseline pre-implementation condition could be established based on information obtained during the E&D.

For marsh restoration projects, monitoring could occur immediately after construction (as-built), and post-construction at an appropriate frequency and duration relevant to project-specific conditions. Funding could also be included for an additional contingency data collection, to be implemented as needed, in response to storm impacts.

Bathymetric Methodologies

Bathymetric surveys can be performed to collect water depth information by using:

Method 1: RTK GPS in shallow waters.

Method 2: Single-beam sonar.

Method 3: Multi-beam sonar.

Method 4: Topobathymetric LIDAR surveys along transects.

Method 5: Echo-sounder (Baggett et al. 2014).

Method 6: Depth finder (Baggett et al. 2014).

Method 7: Sounding pole (Baggett et al. 2014).

For potential guidance on performing Methods 1 and/or 2, see Sallenger et al. (2003), Morton et al. (2005), Stockdon et al. (2009), Guy and Plant (2014), Heidemann (2014), and Smith et al. (2016). Elevation data acquired from remote sensing should have vertical error reporting and adhere to the ASPRS standards, the general standards for gauging vertical error in DEMs.

Monitoring Locations for Bathymetric Methodologies

Bathymetric profiles should be collected along the entire project footprint (typically to be collected for a larger area). A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration for Bathymetric Methodologies

In general, monitoring is proposed pre-construction, immediately after construction (as-built), and post-construction. A baseline pre-construction condition could be established based on profiles obtained during the E&D. Collections could be conducted pre-construction, immediately after construction (as-built), and post-construction at an appropriate frequency and duration relevant to site-specific conditions. Funding could also be included for an additional contingency data collection, to be implemented as needed in response to storm impacts or other factors that may influence elevation.

Other Potential Analyses

For beaches, dunes, and barrier islands, additional potential analyses using elevation data include shoreline change, habitat change, beach and dune profile change, volume change, bathymetric profile change, volume change, and sediment movement. For marshes, elevation data could be used to support calculation of the area of habitat built or enhanced within a particular elevation zone and to calculate the sediment compaction rate.

E.3.9. Enterococci

Parameter Type: Measured

Units: concentration expressed as the most probably number per hectoliter (MPN/100 L) or as Colony-Forming Units per deciliter (CFU/100 mL)

Definition

Pathogenic bacteria, or indicator species, are indicators of recent fecal matter contamination and that pathogens dangerous to human beings may be present.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds

Potential Methodologies

For methods on assessing Enterococci, see IDEXX Enterolert (Baird et al., 2017; and U.S. EPA, 2017). Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives.

Other Potential Analyses

Coliphages are additional pathogens that could be assessed as indicators of recent fecal matter contamination and exposure likelihood.

E.3.10. Epibenthos and Infaunal Abundance, Density, Composition, and Mass

Parameter Type: Measured, Calculated, or Modeled

Abundance Units: none (count) or catch per unit effort (CPUE)
Density Units: number of individuals per square meter (individuals/m^2)
Composition Units: none
Mass Units: grams (g)

Definition

Epibenthic and infaunal organism abundance, density, and composition on the inundated marsh platform, in tidal channels and ponds, oyster reefs, and/or adjacent unvegetated bottom habitat.

Restoration Approach

- Restore Oyster Reef Habitat

Potential Methodologies

Fisheries-independent monitoring approaches should be used to measure epibenthic organism abundance/density in and around restored marshes. Sessile epifaunal invertebrates may be sampled with the quadrat method used for oyster density sampling. Infaunal invertebrates may be sampled with cores (15 cm diameter, 15 cm depth), washing samples over a 2mm or smaller mesh.

Method 1: Use the quadrat sampling method for hard substrates to sample sessile invertebrates (see Oyster Density for methods).

Method 2: Use cores (15 cm diameter x 15 cm depth) to sample infaunal invertebrates, washing samples over a 2 mm or smaller mesh (Baggett et al. 2014).

Optionally, length and biomass may be measured for all or a subset of the sample. Data should be presented as density (individuals/m^2), wet weight (g/m^2), and/or length (cm) per species, as appropriate.

Monitoring Location

Collections should occur in the areas and habitats specifically targeted by the restoration (e.g., marsh edge, interior marsh, ponds, creeks, bay). A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-construction and post-construction. Monitoring could be conducted for three years post-construction or longer in order to be able to adequately capture the changes in community composition at the project site. Sampling could be conducted seasonally, during the spring and fall, both pre- and post-construction, or more frequently. Monthly sampling for two–three years pre-restoration and at two–three-year intervals post-restoration may be needed to evaluate changes associated with the restoration project.

E.3.11. ***Escherichia coli* (*E. coli*)**

Parameter Type: Measured or Calculated

Units: concentration expressed as the most probable number per hectoliter (MPN/100 L) or as Colony-Forming Units per deciliter (CFU/100 mL)

Definition

E. coli are indicators of recent fecal matter contamination, and that pathogens dangerous to human beings may be present.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds

Potential Methodologies

For methods on detection of *E. coli* in water samples, see IDEXX Colilert, IDEXX Colilert-18, EPA 1604, SM 9223 B (U.S. EPA, 2002, 2017; and Baird et al., 2017). Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives.

E.3.12. **Fecal Coliform Bacteria**

Parameter Type: Measured

Units: Colony-Forming Units per deciliter (CFU/100 mL)

Definition

A subset of total coliform bacteria, which are more fecal-specific in origin, are indicators that pathogenic bacteria, viruses, or protozoans dangerous to human beings may be present.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds

Potential Methodologies

Standard Methods for the Examination of Water and Wastewater (Baird et al., 2017; and U.S. EPA, 2017) provide analytical techniques for the determination of water quality. Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives.

E.3.13. Infrastructure or Habitat Constructed and/or Enhanced and Completed as Designed

Parameter Type: Measured

Units: none or units for measured deviations, as appropriate

Definition

Determination as to whether the infrastructure (e.g., artificial reef, educational facility, signs) was constructed or the habitat was enhanced (e.g., asphalt removed, trail enhanced) and completed as designed.

Restoration Approaches

- Enhance Public Access to Natural Resources for Recreational Use
- Enhance Recreational Experiences
- Promote Environmental Stewardship, Education, and Outreach

Potential Methodologies

The type of infrastructure will vary depending on the project objective(s) and the specific item or process that is being enhanced. The contractor is responsible for collecting this information and should record this as a part of their reporting and on-site inspections. Comparisons of as-built plans/reports and site inspections to construction drawings or other planning materials may be necessary.

Monitoring Location

This information is collected at the project site.

Guidance on Frequency and Duration

Infrastructure could be monitored for three years post-construction or longer. For artificial reefs, pre-construction monitoring might be related to siting and determining there is no hard substrate already present. Post-construction monitoring could occur annually for two years or longer. Depending on the project-specific objectives, other hard structures could be monitored more frequently and/or for a longer duration to evaluate weathering of the infrastructure.

E.3.14. Nekton Abundance, Density, Composition, Length, and Mass

Parameter Type: Measured, Calculated, or Modeled

Abundance Units: none (count) or catch per unit effort (CPUE)
Density Units: number of individuals per square meter (individuals/m^2)
Composition Units: none
Length Units: millimeters (mm) or centimeters (cm)
Mass Units: grams (g)

Definition

Nekton organism abundance, density, and composition on the inundated marsh platform, in tidal channels and ponds, oyster reefs, and/or adjacent unvegetated bottom habitat.

Restoration Approach

- Create, Restore, and Enhance Coastal Wetlands
- Restore Oyster Reef Habitat

Potential Methodologies

Fisheries-independent monitoring approaches should be used to measure nekton and epibenthic organism abundance/density in and around restored marshes. Sampling gears are designed to target specific sizes, species, and habitat(s). As such, different gears are recommended under specific circumstances. Nekton density on the marsh surface could be measured using drop samplers, lift nets, or throw traps. Nekton abundance along the marsh edge and within tidal creeks and adjacent open water areas may also be measured using trawls, but these methods do not provide density estimates, and abundance in open water habitat does not necessarily indicate nekton utilization of the marsh surface.

Density:

Method 1: Use drop samplers to sample small/medium crustaceans and fish on the marsh platform and in shallow open water habitat. Drop samplers allow for quantitative estimates of density and biomass. Potential methods are discussed in Zimmerman et al. (1984) and Minello (2000).

Method 2: Use lift nets to sample small/medium crustaceans and fish on the marsh platform and in shallow open water habitat. Potential methods are discussed in Rozas (1992).

Method 3: Use throw traps to sample small/medium crustaceans and fish on the marsh platform and in shallow open water habitat. Potential methods are discussed in Kushlan (1981) and Jordan et al. (1997). Throw traps are not as effective in areas of dense vegetation – drop samplers or lift nets are preferable gears for such conditions (Rozas and Minello, 1997).

Method 4: Use lift nets to sample small/medium crustaceans and fish on oyster reefs (Crabtree and Dean 1982; Tolley and Volety, 2005; Boudreaux et al 2006; Wenner et al 2006).

Abundance (catch per unit effort):

Method 1: Seines or hand trawls can be used if sampling small/medium crustaceans and fish along the marsh edge or in shallow open water habitat. However, these sampling devices are not suitable for sampling the marsh platform. Seines do not provide an accurate estimate of fish density, but can be used to measure abundance. The length of the seine/trawl and the distance traveled should remain constant from one sampling event to another in order to consistently sample the same area.

Method 2: Beam trawls should be used in open water habitat that is typically greater than 2 m in depth to sample juvenile and adult fish or large crustaceans. They may be less effective at sampling small crustaceans and fish than seines and drop samplers.

Method 3: Gill nets may be used to sample larger transient fish. The mesh size will vary depending on the size of the target species. Nets should be set 1 hour before sunrise and left in place for 2 hours. Data should be presented as the number of individuals of each species caught per hour (Baggett et al. 2014).

Note that data collected using different sampling gears are not always comparable. Generally, data collected using methods that measure density can be standardized and adjusted for recovery efficiency, but cannot easily be compared to data collected using methods that only measure abundance. See Rozas and Minello (1997) for a review of sampling gear in shallow estuarine habitats.

Optionally, in addition to determining species composition and abundance, measure length and biomass for all or a subset of the sample as grams (g) wet weight. Data should be presented as density (individuals/m^2), wet weight (g/m^2), and length-frequency distributions per species. For large collections (50 individuals or more of the same species), a subset of the entire sample for a given species may be measured and extrapolated to remaining individuals of the same species.

See Neckles and Dionne (2000) and Steyer and Llewellyn (2000) for more information on potential methodologies.

Monitoring Location

Nekton collections should occur in the areas and habitats specifically targeted by the hydrologic restoration (e.g., marsh edge, interior marsh, ponds, creeks, bay). A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-construction and post-construction. Monitoring could be conducted for three years post-construction or longer in order to be able to adequately capture the changes in community composition at the project site. Sampling could be conducted seasonally, during the spring and fall, both pre- and post-construction, or more frequently. Monthly sampling for two–three years pre-restoration and at two–three-year intervals post-restoration may be needed to evaluate changes associated with the restoration project.

Other Potential Analyses

Used to calculate measures of **Nekton Diversity (E.3.15)**.

E.3.15. Nekton Diversity

Parameter Type: Calculated

Units: none

Definition

Diversity is related to the species number and abundance within a particular location. There are a number of measurements and indices related to species diversity.

Restoration Approach

- Create, Restore, and Enhance Coastal Wetlands

Potential Methodologies

Based on **Section E.3.14 Nekton Abundance, Density, Composition, Length, and Mass**, many measures of diversity can be calculated.

Method 1: Species richness: The simplest measure of diversity, the total number of species present in a sample.

Method 2: Shannon-Wiener Index (Bradshaw and Brook, 2010).

Method 3: Simpson's Index (Bradshaw and Brook, 2010).

Monitoring Location

The monitoring location would vary based on project-specific objectives.

Guidance on Frequency and Duration

Whenever nekton sampling occurs.

E.3.16. Number of Improvement Practices Implemented

Parameter Type: Measured

Units: none (count)

Definition

Count of the number of water quality or wetland improvement practices that were implemented as part of the project.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats

Potential Methodologies

Count of improvements implemented.

E.3.17. Oyster Density

Parameter Type: Measured

Units: number of individual oysters per square meter (oysters/m^2)

Definition

The number of oysters, including recruits, per unit area. The density of live and dead oysters should be calculated separately. The age or size of recruits is project-specific and should be clearly defined.

Restoration Approaches

- Restore Oyster Reef Habitat

Potential Methodologies

Method 1: Place a quadrat on the reef and excavate all live and dead oysters within the quadrat. For rigid structures, place a quadrat on the surface of the reef structure and excavate to a depth necessary to collect all live oysters within the quadrat. For reefs constructed of bagged shell, take random samples by removing a bag of shell; the area sampled is the areal coverage of the bag. Convert densities to number per m^2. If placed along a shoreline, also report a number per linear meter of shore. Stratify samples as appropriate, such as by reef height, orientation to mainland, or distance from shore. For more information see Baggett et al. (2014).

Method 2: Use hydraulic patent tongs to sample the oyster reef. Like quadrats, they sample a known area and density can be calculated. For more information see Chai et al. (1992).

Monitoring Location

Samples may be taken over the entire area of the reef. See Baggett et al. (2014) for guidance on the appropriate number of samples.

Guidance on Frequency and Duration

Pre-restoration (once, if applicable), and at least annually for 5 years after restoration. Density should be measured after the growing season unless project objectives dictate otherwise.

Other Potential Analyses

Density of large oysters (brood stock) may be calculated using density and the oyster size frequency distribution. “Large” is defined for each project as appropriate.

E.3.18. Oyster Mortality

Parameter Type: Calculated or Modeled

Units: percentage (%)

Definition

The proportion of dead oysters on a reef expressed as a percentage.

Restoration Approaches

- Restore Oyster Reef Habitat

Potential Methodologies

Divide the number of dead oysters by the total number of live and dead oysters and express as a percentage.

Monitoring Locations

Samples may be taken over the entire area of the reef or control sites if appropriate habitats exist in the area. Control areas could consist of natural reefs, non-reef areas, or other restoration projects depending on the restoration goals. See Baggett et al. (2014) for guidance on the appropriate number of samples and “oyster density” above.

Guidance on Frequency and Duration

Recommended frequency: Pre-restoration (once, if applicable), and at least annually for 5 years after restoration. Sampling should be performed at the end of the oyster growing season in conjunction with sampling for oyster density. If possible, sampling should occur after newly settled oysters have grown to a size greater than 10 mm and can be confidently classified as recruits (Baggett et al., 2014).

E.3.19. Oyster Larval Settlement

Parameter Type: Calculated

Units: number of spat per square meter per day (spat/m^2·day), number of spat per square meter (spat/m^2), number of spat per liter of shell (spat/L of shell), number of spat per weight of shell (spat/kg of shell), or number of spat per individual shell (spat/shell), depending on the method used

Definition

Settlement is defined as the point at which a larva attaches to the substrate or metamorphoses into benthic form (Wildish and Kristmanson, 1997; Baggett et al., 2014). This differs from recruitment, which includes settlement and some period of post-settlement survival (Baggett et al., 2014).

Restoration Approaches

- Restore Oyster Reef Habitat

Potential Methodologies

Method 1. Settlement Plates or Shell Strings

Deploy settlement plates or shell strings. Collect and replace plates every 3 or 4 weeks. More frequent replacement will yield finer-scale temporal patterns of settlement. Report as # of spat/m^2 unit area per day.

Method 2. Quadrat

Estimates of settlement may be obtained from quadrat samples used for density estimates. The number of oyster spat/quadrat should be expressed in #/m^2 so that density can be compared between project types and sites. If the project is a living shoreline or is designed to protect a marsh shoreline, then also report the number of spat per linear meter of shoreline.

Method 3. Shell Bags

If sampling with mesh bags filled with oyster shell, bags should be placed adjacent to or directly on the site of interest. Record the number and volume of bags of cultch material. Report as #spat/L of pre-deployed shell, # spat/individual shell, or # spat/weight of pre-deployed shell.

Method 4. Oyster Dredge

For an oyster dredge, tow for a specified time and method (e.g., linear or circular tow direction, speed). Measure the dredge width and tow distance to calculate the area swept. Correct for dredge efficiency as appropriate. Report as, # spat/L of shell, or average # spat/individual shell.

Monitoring Location

Samples may be taken across the entire reef area as appropriate.

Guidance on Frequency and Duration

Deploy plates or shell strings annually beginning the first week of April. Collect and replace plates or strings at least every 3 or 4 weeks until the end of the known settlement season for the area. Quadrat, shell bag, and dredge sampling may be conducted annually, preferably after fall settlement

E.3.20. Oyster Reef Volume

Parameter Type: Calculated

Units: cubic meters (m^3)

Definition

The space occupied by an oyster reef

Restoration Approaches

- Restore Oyster Reef Habitat

Potential Methodologies

These methods assume that the reef is not harvested.

Method 1: Reef volume may be calculated by multiplying reef area by elevation (mean reef height).

Method 2: Data from a combination of sources may be used to calculate reef volume. Data from side-scan sonar can be digitized into raster data and analyzed in ArcGIS or other software. Reef elevation data can be gathered from a scientific echo sounder (or other appropriate sonar devices like multibeam or interferometric sides scan sonar). Pre- and post-restoration elevation data allows the elevation above surrounding non-reef areas to be determined. Area * mean height = reef volume.

Monitoring Location

Reef volume may be calculated for the entire area occupied by the reef.

Guidance on Frequency and Duration

Reef volume could be calculated immediately after project implementation and annually for up to five years following implementation. Additional measurements could be taken after events that could alter reef volume, such as storms, or extended periods of water quality detrimental to oyster survival (e.g., low salinity events).

Other Potential Analyses

Reef volume may be used to calculate a shell budget for the reef.

E.3.21. Oyster Size Frequency Distribution

Parameter Type: Measured

Units: millimeters (mm)

Definition

Oyster shell height measured from the umbo to the opposite edge of the shell.

Restoration Approaches

- Restore Oyster Reef Habitat

Potential Methodologies

Measure the shell height (umbo to opposite edge) of each live and dead oyster collected.

Monitoring Locations

Samples may be taken over the entire area of the reef. Measure at least 50 oysters per sample, or enough oysters to equal 250 per reef (Baggett et al. 2014).

Guidance on Frequency and Duration

Pre-restoration (once, if applicable), and at least annually for 5 years after restoration. Sampling should be performed at the end of the oyster growing season in conjunction with sampling for oyster density. If possible, sampling should occur after newly settled oysters have grown to a size greater than 10 mm and can be confidently classified as recruits (Baggett et al., 2014).

E.3.22. pH (acidity)

Parameter Type: Measured

Units: Standard Units (pH)

Definition

Measure of acidity or potential activity of hydrogen ions (H+).

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

pH can be measured using:

Method 1: An electronic pH meter.

Method 2: A litmus paper strip coated in a pH-indicating dye.

Method 3: pH dye testing kit for liquids.

Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives.

E.3.23. Recreational Activities Utilized by Public

Parameter Type: Measured, Calculated, or Modeled

Units: none (counts by activity), person-hours/days/nights per activity, or none (average rating), depending on the nature and extent of the evaluation

Definition

Amount of recreational use on the land and/or water, organized by category, where the activities take place, and for how long or how often.

Restoration Approach

- Enhance Public Access to Natural Resources for Recreational Use

Potential Methodologies

Monitoring could be conducted using key location or onsite surveys, as well as offsite regional telephone or mail surveys.

Use direct observations of recreational use activities (e.g., to determine if visitors are swimming, using the beach).

Conduct surveys. These surveys should be conducted at key locations across the recreational use area. Surveys may include the following types of questions:

How often do you visit the acquired land?

With whom are you visiting the acquired land (commercial tour operator vs. family/friends/self)?

What is your motivation for visiting the site?

What benefits do you expect from visiting the site?

What activities are you participating in (could provide a list based on what recreational activities the land may be used for, with an option for “other”)?

How long are you at the acquired land (hours, overnight, days)?

How would you rate the amount of influence that various setting features had on your experience?

See Moscardo and Ormsby (2004), U.S. Census Bureau et al. (2011), Louisiana Department of Culture, Recreation, and Tourism (2014), and Miller et al. (2014) for additional information.

Monitoring Location

Selection of respondents could use some systematic random sampling procedure within the units chosen for study. This procedure is intended to ensure that the respondents within a location have an equal probability of being asked to participate and, that the choice of target respondents is determined by the sampling system and not by the interviewers.

Guidance on Frequency and Duration

The survey could be conducted pre- and post-construction or more often depending on the objectives of the project. If appropriate for the project, monitoring should aim to cover different seasons and include weekdays, weekends, and holidays.

E.3.24. Right of Entry

Parameter Type: Calculated

Units: days

Definition

The right of entry to a project area is measured in terms of the number of days the area was open and closed to the public. This only applies to projects that can be closed or opened, and not to areas/projects that are always open.

Restoration Approaches

- Enhance Public Access to Natural Resources for Recreational Use
- Promote Environmental Stewardship, Education, and Outreach

Potential Methodologies

Document the number of days the project area is open and closed using beach closure information, information on restrictions in place due to severe weather, or other similar information.

Monitoring Location

The information is collected at the location for which access can be restricted.

Guidance on Frequency and Duration

Duration and frequency will ultimately depend on site specific conditions, project objectives, and the monitoring period identified in the project-specific MAM plan.

Other Potential Analyses

The information can help inform trends in visitor use. For example, if severe weather prevents the opening of a facility, visitor use numbers will decline during that period. This additional piece of information will help explain these patterns in visitor use.

E.3.25. Salinity

Parameter Type: Measured or Modeled

Units: parts per thousand (ppt), Practical Salinity Units (PSU), or unitless. These systems of units are interchangeable, by design.

Definition

The concentration of dissolved salts in water reported as parts per thousand (ppt), practical salinity units, or may be unitless (indicating the use of the Practical Salinity Scale).

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

Method 1: Surface water salinity may be measured continuously with an in-situ salinity/conductivity sonde and data logger.

Method 2: Take discrete samples using a hand-held salinity/conductivity probe or refractometer.

See Neckles and Dionne (2000), Steyer and Llewellyn (2000), Wagner et al. (2006), and U.S. EPA (2014) for additional information on salinity monitoring protocols.

Monitoring Location

Spatial distribution of salinity measurements will depend on the project type and hydrologic characteristics of the project area. Salinity measurements could be taken near the source of the hydrologic restoration, within the boundary of the area influenced by the project, near the edge of boundary, and outside the boundary if adjacent to other habitats. A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-construction, immediately after construction, and post-construction. A baseline pre-construction condition could be established based on information obtained during the E&D. Recommend sampling immediately following construction (as-built) and annually thereafter.

If the parameter is linked to a performance criterion, it could be monitored until the criterion has been met and then sustained for three years. Otherwise, establish a monitoring period long and frequent enough to satisfy project objectives. This may involve capturing annual/inter-annual variability based on factors that could influence salinity at the project site (e.g., precipitation, freshwater inflow).

E.3.26. Scarring

Parameter Type: Measured or Calculated

Count Units: none
Length Units: meters (m)
Depth Units: centimeters (cm)
Area Units: square meters (m^2)

Definition

Disturbed or damaged SAV and surrounding sediments as a result of boat propeller damages or other human impacts. Measurement includes counts, lengths, depths, and areas of scars.

Restoration Approach

- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

Method 1: Scar boundaries, number, length can be mapped based on aerial imagery collected by airplane, helicopter, unmanned aerial systems (UAS); high-resolution satellite imagery; or other appropriate remote sensing platforms. Recommended landscape-scale monitoring is 1: 9,600 scale to effectively estimate bare patches (< 2-3 m2, Dunton and Pulich 2007). Imagery used to establish SAV boundaries should include true color and infrared bands, and have a spatial resolution of 1 meter (m) or less. Source imagery should be orthorectified [i.e., free from distortions related to sensor optics, sensor tilt, and differences in elevation; see Rufe (2014)]. Collected imagery should be imported to spatial analysis software to digitize the perimeter of the project footprint and the boundaries of habitat areas within the project footprint. Additional guidance on using aerial imagery can also be found in Anders and Byrnes (1991), Crowell et al. (1991), Morton (1991), and FLDEP (2014).

Method 2: Ground surveys can be used to map the area of small scars. Use a real-time kinematic Global Positioning System (RTK GPS) to take continuous measurements while walking the perimeter of the project and along the boundaries of specific habitats within the project footprint. If taking depth measurements, record depth of scar at various waypoints while mapping the area of the scar.

Method 3: Grid mapping can be used to calculate the area of prop scars; it is best used when scarring is linear (EBAP and FLDEP 2015). A fiberglass measuring tape is extended down the midline of the scar from two anchor points located at each end of the scar. At specified intervals (~1 m) length measurements are taken at right angles from the centerline to the edges of the scar (Hudson and Goodwin 2001). Using this information, a graphical representation of the injury can be made by plotting measured points on a Cartesian plane from which the area of the scarring can be calculated.

Method 4: GPS/Trimble Method is best used on wide scars, or scars that may have merged to form larger patches (EBAP and FLDEP 2015). NOAA and the FLDEP utilize this method to collect data about areas with high boat traffic. The Trimble receiver collects points while being walked around the perimeter of the scar or being dragged in a float. The total number of points recorded is dependent on the complexity of the scar; more complex features will require more points to accurately represent the shape. The points are then connected to create a polygon feature in ESRI ArcView or Trimble Pathfinder Office. From that, the area of scarring can be calculated.

Monitoring Location

Area of habitat impacted should be determined for the entire project footprint. Some data, such as aerial photography, may be collected over larger areas. If using signage and/or buoys to mark boundaries of the project, scarring should be monitored within the boundaries.

Guidance on Frequency and Duration

In general, monitoring is proposed twice a year, once in the growing season (approximately April through October) and once again in the dormant season, allowing data collection to coincide with the yearly minimum and maximum seagrass densities (EBAP and FLDEP 2015). In general, monitoring is proposed pre-restoration, immediately after restoration, and post-restoration.

Other Potential Analyses

Scarring measurements may also be used in conjunction with other parameters listed herein (e.g., elevation, vegetation percent cover and composition, turbidity) to perform the following calculations and analyses: habitat type changes, bathymetric profile change, and sediment movement.

E.3.27. Shoreline Position

Parameter Type: Measured, Calculated, or Modeled

Units: positions should be georeferenced (latitude, longitude, elevation) or relative changes may be measured in meters (m)

Definition

The location of the boundary between the land and water at a particular tidal elevation. Calculations of shoreline position will allow for documentation of shoreline change over time, including in response to particular disturbance events.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Restore and Enhance Dunes and Beaches
- Restore Oyster Reef Habitat

Potential Methodologies

The shoreline position can be measured using high-resolution, near-vertical aerial imagery, RTK GPS survey data, or by measuring shoreline locations along established transects. Comparing shoreline position over time provides information on shoreline change. Any shoreline measurement may be tied to a relevant tidal datum [e.g., mean sea level (MSL), mean high water (MHW), mean low water (MLW)]. Shoreline change should be calculated between shorelines tied to the same tidal datum.

Method 1: Delineate the shoreline based on orthophotography collected by aerial survey (see Sections E.9.1 Area and E.9.8 Elevation for methods). Aerial surveying is a method of collecting geomatics or other imagery by using airplanes, helicopters, UAS, or other aerial methods. Imagery acquired should be orthorectified (i.e., free from distortions related to sensor optics, sensor tilt, and differences in elevation). For guidance on collecting aerial orthoimagery please see Rufe (2014). Orthoimagery for monitoring shoreline change should have a spatial resolution of at least 1 m. Additional guidance on using aerial imagery can also be found in Anders and Byrnes (1991), Crowell et al. (1991), Morton (1991), and FLDEP (2014).

Method 2: RTK GPS ground surveys can be used for smaller projects to measure land elevation. Walk the shoreline while taking continuous measurements using an RTK GPS. Import the spatial information into ArcGIS and map the shoreline position. For wetlands, the shoreline is defined as the lower/seaward extent of the emergent marsh vegetation. Import and analyze the data using spatial analysis software. Determine the shoreline loss/gain in meters per year. See Steyer and Llewellyn (2000) for more information on this method.

Method 3: Establish permanent base stakes along the length of the shoreline at least 10 m inward of the marsh edge and determine the GPS coordinates of each base stake. Measure the linear distance from the base stake to the marsh edge along an established compass direction. The marsh edge is defined as the lower/seaward extent of the emergent marsh vegetation. Import and analyze the data using spatial analysis software. Determine the shoreline loss/gain in meters per year. See Steyer and Llewellyn (2000) for more information on this method.

For additional information on shoreline mapping methods, see Morton et al. (2005), Fearnley et al. (2009), Martinez et al. (2009), FLDEP (2014), and Guy (2015).

Repeated measurements of the shoreline position over time enables calculations of shoreline change, including erosion or seaward expansion. Several references are available for calculating shoreline change over time (e.g., Moore, 2000; Ramsey et al., 2001; Boak and Turner, 2005; Morton et al., 2005; Thieler et al., 2009; Gens, 2010; Rangoonwala et al., 2016).

Monitoring Location

The shoreline change should be determined for the entire project footprint. For some collection techniques, such as aerial photography, the data will be collected for a larger area. A reference and/or control site could be established, where appropriate and applicable, to calibrate and validate remote sensing data. Spatial variation in the direction and magnitude of shoreline displacement can be measured by selecting reference and/or control points that are surveyed repeatedly over time.

Guidance on Frequency and Duration

In general, monitoring should be conducted pre-construction, immediately following construction, and post-construction. A baseline pre-construction condition should be established based on data obtained during the E&D. For beaches, dunes, and barrier islands, data collection could occur immediately following construction (as-built) and frequently enough to satisfy project objectives. For coastal wetlands projects, data collection could occur immediately following construction (as-built) and one–two more times over the monitoring period, or longer. In some cases, sampling throughout the year may be useful to identify seasonal patterns in erosion or accretion. Funding for contingency data collection could be included to evaluate storm impacts, as needed.

The duration will ultimately depend on site-specific conditions, project objectives, and the monitoring period identified in the project-specific MAM Plan.

Other Potential Analyses

Shoreline erosion rate, habitat type changes, shoreline change, habitat change, beach and dune profile change, volume change, bathymetric profile change, volume change, and sediment movement.

E.3.28. Specific Conductance

Parameter Type: Measured

Units: microsiemens per centimeter (µS/cm)

Definition

Measure of how well water can conduct an electrical current.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

Method 1: Specific conductance can be measured using a multi-parameter water quality sonde.

Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives. See Wagner et al. (2006).

E.3.29. Structural Integrity and Function of Constructed Features

Parameter Type: Qualitative or Measured

Units: none or as appropriate for the dimensions or functions evaluated

Definition

A series of observations and/or measurements to evaluate the integrity and function of constructed project features, such as breakwaters, weirs, culverts, tidal channels/creeks and/or access control measures such as signs, boardwalks, and fencing. The consolidation of a structure over time may also be monitored through repeated elevation measurements. The integrity of the structure, and its foundation and function are evaluated so that appropriate maintenance or alternative actions can be taken if the constructed feature is not performing as constructed or designed.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Restore and Enhance Dunes and Beaches
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

Method 1: Conduct visual observations and photograph the project site. Visual surveys may be used subjectively to record the overall conditions, integrity, and effectiveness of the structure, including observations of material movement, changes in profile, change in habitat, etc. For hydrologic connectivity projects in which culverts are used, this should include checking for any obstructions to flow through the culvert. For recreational use projects, this may include an inspection of the project features such as entry points, parking lots, signage, and self-registration booths. For barrier island, dune, or beach projects, this may include an inspection of the project features such as dune walkovers, bollards and cable functioning, and other habitat protection features. For SAV projects, this may include inspection of bird stakes used to enhance nutrient levels (Powell et al. 1991), signage, and/or buoys which delineate the edges of the restoration zone, or breakwaters which could include oyster reefs or bio-engineered products.

Method 2: Use imagery collected during aerial surveys (see Section E.9.1 Area) to measure changes to the structure.

Method 3: Conduct an elevation and/or bathymetric survey of the structure to describe its outer surface geometry and measure changes over time. Measure the elevation of 2–10 points on the structure in relation to an established datum.

- Composition: Position and size of unstable pieces, including major voids and exposures to core or underlayer
- Element composition: shape, size, and position of armor stone, including any fractures.

See Chapter 10 of CIRIA et al. (2007).

Monitoring Location

Along the entire length of the structure.

Guidance on Frequency and Duration

Post-construction observations could be made immediately following construction (as-built) and annually for five years post-construction. Additional observations may be needed following extreme weather events. Intervals between monitoring could be predetermined by the risk associated with particular failure mechanisms, structural elements, foundation conditions, exposure conditions, and design criteria.

Other Potential Analyses

Repeated measurements of the elevation of a structure can be used to calculate a consolidation rate.

E.3.30. Targeted Injured Species Abundance or Density

Parameter Type: Measured, Calculated, or Modeled

Abundance Units: none (count)

Density Units: individuals per square meter (number/m^2) or individuals per square kilometers (number/km^2)

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Restore and Enhance Dunes and Beaches
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

The appropriate sampling methodologies will be dependent on the species targeted by the project.

Monitoring Location

The restoration project. A reference and/or control site could be established, where appropriate and applicable. Specific sampling locations will depend on the species targeted.

Guidance on Frequency and Duration

In general, monitoring is proposed pre- and post-construction, and is proposed for three years post-construction to adequately capture the changes in community composition at the project site. Monitoring frequency and seasonal timing will depend on the species targeted.

E.3.31. Temperature

Parameter Type: Measured or Modeled

Units: degrees Celsius (°C)

Definition

A measure of the warmth or coldness of water with reference to some standard value.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

Can be obtained using a thermometer or temperature probe. Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives. See also Wagner et al. (2006).

E.3.32. Terms of conservation/management plan met

Parameter Type: Qualitative

Units: none

Definition

Determination as to whether the terms of the conservation and/or management agreement, as applicable, have been met.

Restoration Approaches

- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats

Potential Methodologies

If the project includes a management agreement, the contractor would be responsible for collecting this information and should record this as a part of their reporting and on-site inspections. Comparisons of management reports and site inspections or other planning materials may be necessary. If the project includes a conservation agreement (e.g., easement), the implementing Trustee would determine if the conservation agreement terms were being met through a site visit or discussions with the managing agency or party.

E.3.33. Total Nitrogen (TN)

Parameter Type: Measured

Units: milligrams per liter (mg/L) or parts per million (ppm)

Definition

The sum of organic and inorganic forms of nitrogen in a water sample.

Restoration Approaches

- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Create, Restore, and Enhance Coastal Wetlands
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

For guidance on potential methodologies to measure TN, see ASTM D5176 (ASTM, 2013a, 2013b) and USGS-NWQL I-2650-03. However, in some cases, directly-measured TN may not be statistically comparable to TKN + NO_2 + NO_3 (Patton and Kryskalla, 2003).3 See also the U.S. Geological Survey National Field Manual for the Collection of Water-Quality Data (https://water.usgs.gov/owq/FieldManual/). TN and total phosphorus (TP) measurements are the United States Environmental Protection Agency's preferred metrics for evaluating nutrient concentrations in waters of the United States (Stoner, 2011). Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives. See the U.S. Geological Survey National Field Manual for the Collection of Water-Quality Data (https://water.usgs.gov/owq/FieldManual/).

Other Potential Analyses

Loads and depth of the sample and collection method could be recorded. Further, TKN, NH_4-N (ammonium nitrogen), NO_2-N + NO_3-N (nitrite plus nitrate), NO_2-N (nitrite), and NO_3-N (nitrate) could be analyzed from the samples.

E.3.34. Total Phosphorous (TP)

Parameter Type: Measured

Units: milligrams per liter (mg/L) or parts per million (ppm)

Definition

The measure of the sum of all forms of phosphorus, including inorganic and organic forms.

Restoration Approaches

- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Create, Restore, and Enhance Coastal Wetlands
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

For guidance on potential methodologies to measure TP, see EPA 300.0, EPA 365.2, EPA 365.3, EPA 300.1, SM 4110C, SM 4110B, and USGS-NWQL I-4650-03. Data

1. 3 TKN + NO_2 + NO_3 has been traditionally used by some agencies as an estimate of TN, but that practice is changing due to the development of less labor-intensive procedures (Walker 2014) and more precise methods (Smart et al. 1981).

collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives.

Other Potential Analyses

Soluble reactive-P (orthophosphate phosphorus) and chlorophyll *a* may also be analyzed.

E.3.35. Total Suspended Solids (TSS)

Parameter Type: Measured

Units: milligrams per liter (mg/L) or parts per million (ppm)

Definition

The dry weight of sediment from the known volume of a sub-sample of the original water sample.

Restoration Approaches

- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Create, Restore, and Enhance Coastal Wetlands

Potential Methodologies

For methods on collection of TSS, see EPA 160.2. Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives.

E.3.36. Turbidity

Parameter Type: Measured

Units: nephelometric turbidity unit (NTU)

Definition

A measure of intensity of light scattered by a sample, or the cloudiness or haziness of a sample.

Restoration Approaches

- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds
- Create, Restore, and Enhance Coastal Wetlands
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

For methods on assessing water turbidity see EPA 180.1 and Wagner et al. (2006).

Data collection and calibration procedures of detection instruments will be determined by the respective instrument's QA/QC procedures. Site determination for the data collection, as well as the frequency and duration, will be determined by the project-specific objectives.

E.3.37. Velocity

Parameter Type: Measured, Modeled, or Calculated

Units: meters per second (m/s)

Definition

The speed of water moving in a particular direction. Flow velocity can be measured for constrained flow within channels or structures (e.g., culverts), but can also be measured for sheet flow. Velocity can also be measured for bi-directional tidal flows, where flow in the opposite direction has a negative velocity.

Restoration Approaches

- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Reduce Nutrient Loads to Coastal Watersheds
- Reduce Pollution and Hydrologic Degradation to Coastal Watersheds

Potential Methodologies

Method 1: Measure water velocity (typically in units of m/s) within a channel with a current meter. Typically, multiple velocity measurements should be taken both across the stream and at different depths.

Method 2: An ADCP can used to measure both water velocity and water depth within a stream. Typically, the ADCP is mounted to a small water craft and guided along the stream channel to take the measurements.

Monitoring Location

Water velocity should be measured for channels within the project area that are an important component of the project design, or at other locations within the project footprint where the maintenance or restoration of hydrologic flows is important. Water velocity can be measured at a reference and/or control site, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-construction, immediately after construction, and post-construction. A baseline pre-implementation condition could be established based on information obtained during the E&D. Propose conducting sampling pre-construction (once), immediately following construction (once), and annually thereafter. Additional sampling may be needed after large storm events.

For projects with tidal influence and if continuous recorders are used, the data could be collected for two weeks or longer during a sampling event to be able to capture one lunar cycle of spring and neap tides, but longer time periods (e.g., three–four months or year-round) are preferred. If discrete measurements are taken, the water velocity could be assessed over several tidal cycles.

For projects with riverine influence, sampling events could be designed to capture both high- and low-flow events. If continuous recorders are used, the data could be collected for two weeks or longer during high- and low-water conditions, but year-round data collection for one or more years is preferred to fully capture the seasonal variability in flow conditions. If discrete measurements are taken, the water velocity could be assessed over a few weeks during both high- and low-flow conditions.

If velocity measurements will be used to calculate discharge (volume of flow), velocity could be measured at about the same time the channel dimensions are measured.

Other Potential Analyses

Can be used with **Channel Dimensions (Section E.3.3)** to calculate the flow volume, or **Discharge (Section E.3.5)**.

E.3.38. Vegetation Density

Parameter Type: Calculated

Units: number of individual plants per square meter (number/m^2) or number of individual plants per square kilometer (number/km^2)

Definition

Abundance of vegetation in a given area (typically in units of number of individuals or objects per m^2). The term refers to the closeness of individual plants to one another.

Restoration Approaches

- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Restore and Enhance Dunes and Beaches

Potential Methodologies

Use a quadrat to estimate plant species density within a defined area (e.g., 1 x 1-m plots or 2 x 2-m plots). Data recorded by collecting number of plants per unit area in the planted area will include:

- Species identification
- Density of native species
- Density of invasive species if present.

Monitoring Location

Data could be collected throughout the entire project footprint and at a reference and/or control site, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed (pre-construction, immediately after construction, and post-construction). A baseline pre-construction condition should be established if possible. Data collections could occur pre-construction, immediately after construction (could be included in as-built), and every three years for the minimum monitoring period. One additional contingency data collection could be included in the monitoring plan to be implemented as needed to account for storm impacts.

E.3.39. Vegetation Percent Cover or Composition

Parameter Type: Calculated or Modeled

Units: percentage (%)

Definition

The proportion of ground area in a sampling unit covered by the canopy (leaves, stems, etc.).

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Restore and Enhance Dunes and Beaches
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

Method 1: Establish plots within the project area and record plot locations with a GPS and/or mark the plots with corner poles to allow for revisiting over time. Estimate percent cover as defined in the project MAM Plan. Percent cover of each species or species category of interest (e.g., native, invasive, herbaceous layer) may also be collected during this time if Vegetation Species Composition is a parameter of interest, as defined in the project MAM Plan. See U.S. EPA (2011) for additional guidance on performing visual estimates of vegetation percent cover. Typical plot sizes for SAV are 0.25 to 1 m^2, herbaceous vegetation are 1 to 4 m^2 plots and for trees, 50 to 100 m^2 plots or greater, but will be project-dependent. Data collected will vary based on the project but would typically include:

- Visual assessment of total vegetation percent cover of target and undesirable species
- Percent cover by layer (e.g., herbaceous, shrubs, canopy), percent cover of native species, or percent cover of invasive species, if present.
- Percent cover of individual species, if also collecting Vegetation Species Composition.

For additional information on measuring and analyzing plant cover and composition, see Knapp (1984), Elzinga et al. (1998), Coulloudon et al. (1999), Bonham (2013), and Folse et al. (2014).

For SAV, monitoring often requires SCUBA divers to assess composition and percent cover along transects. Permanent transects are often used, with photographs along the transect line recommended for future comparisons (Kirkman 1996, Neckles et al. 2012, Short et al. 2006). For shallow water monitoring, an aquascope or 'fish eye' can provide an accurate means of quantifying seagrass cover and composition without physically entering the water and disturbing sediments (Jackson and Nemeth 2007, Thayer et al. 2005).

Method 2: Conduct a visual field inspection with ground photographs and/or high-resolution aerial photography to document that the performance criteria related to percent cover have been met. Note dominant species and the presence or absence of invasive species and any targeted species, along with their relative abundance. This method may be appropriate in some cases when it can be determined with high confidence based on visual inspection that the performance criteria for the project are being met. Note that it may not be appropriate to combine data collected using this method with data collected using Method 1.

Method 3: For SAV percent cover, analyze video footage of quadrats along transects to detect change in cover (McDonald et al. 2006). This method is particularly useful in fragile environments when there is a need to minimize disturbance to the site, although it may not be applicable in turbid areas.

Method 4: For areas with no or limited visibility, establish 100 m transects and use a rake to sample every 10 m and recording presence/absence. Species may also be recorded if also collecting **Vegetation Species Composition** (Johnson and Newman 2011, Rodusky et al. 2005).

Monitoring Location

Vegetation percent cover should be measured throughout the entire project footprint. For hydrologic restoration projects, transects typically go from areas of higher hydrologic influence (such as close to creeks) to areas of lower hydrologic influence (such as interior marshes). A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

In general, monitoring is proposed pre-construction, immediately after construction, and annually post-construction until performance criteria are met and sustained for three years. Baseline pre-construction conditions could be established based on information obtained during the E&D. Monitoring could occur pre-construction, immediately after construction (as-built), and then once a year at the peak of the growing season (mid- to late summer).

More frequent monitoring is proposed during the first five years following restoration to allow for the identification of problems and the implementation of adaptive management actions as needed. As the restoration project stabilizes, less-frequent monitoring may be appropriate. Monitoring should be conducted following disturbances to assess impacts and implement adaptive management actions, if needed.

While five years of monitoring is usually sufficient to demonstrate achievement of vegetation performance criteria for herbaceous vegetation, longer monitoring durations are generally needed for forested wetlands to demonstrate successful establishment of the plant community.

Other Potential Analyses

Vegetation volume may also be calculated by estimating the percent cover (and of each species if also interested in **Vegetation Species Composition**) and multiplying by height to provide a measure of aboveground structure. Vegetation percent cover when used in conjunction with **Vegetation Species Composition** can also be used to assess biological diversity, species richness, and evenness. Community composition metrics include (see Matthews et al., 2009; Magurran and McGill, 2011; and references therein for more information on these metrics):

- Simpson's diversity index
- Shannon-Wiener index
- Mean coefficient of conservatism

- Floristic quality index (FQI) or Forested floristic quality Index (FFQI)
- Community diversity index.

E.3.40. Vegetation Species Composition

Parameter Type: Measured or Calculated

Units: none

Definition

The collection of plant species within the vegetation. Can be expressed as list of individual species or proportion of each species within a given area.

Restoration Approaches

- Create, Restore, and Enhance Coastal Wetlands
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Restore and Enhance Dunes and Beaches
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

See Section **E.3.39 Vegetation Percent Cover or Composition** for relevant methods and references.

E.3.41. Vegetation Survival

Parameter Type: Calculated

Units: percentage (%)

Definition

Count, estimated percentage, or calculation of surviving planted individuals, used to evaluate whether additional plantings are needed to promote and establish appropriate vegetation communities.

Restoration Approach

- Create, Restore, and Enhance Coastal Wetlands
- Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats
- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

Method 1: Count the total number of planted plants, and the number of live or dead plantings within established plots. Field sampling could include quadrats, transects, or point surveys. Data collected will be used to calculate vegetation survival.

See Section E.9.31 Vegetation Percent Cover and Composition for additional methods and references.

Method 2: Conduct a visual field inspection with ground photographs and/or high-resolution aerial photography to document that performance criteria related to percent cover have been met. Note dominant species and the presence or absence of invasive species and any targeted species, along with their relative abundance. This method may be appropriate in some cases when it can be determined with high confidence based on visual inspection that the performance criteria for the project are being met. Note that it may not be appropriate to combine data collected using this method with data collected using Method 1.

Monitoring Location

Plots could be distributed over the entire planted area.

Guidance on Frequency and Duration

For projects with a planting component, survival/mortality of marsh grasses may be assessed for at least one full year following the initial installation. Monitoring could occur twice during the first growing season after planting (recommend 30 days and 90 days post-planting) and again one year after planting, while seasonal sampling may be needed for species that exhibit high inter- and intra-annual variance due to seasonally changing environmental conditions. Additional monitoring may be needed if replanting is required. Survival/mortality of planted trees (e.g., mangroves) should be monitored for three years or longer (Lewis, 2005, 2009). Once the planted vegetation has become established, vegetation monitoring could focus on cover and composition (see Section E.9.31 Vegetation Percent Cover and Composition).

E.3.42. Visitor Satisfaction

Parameter Type: Qualitative

Units: none

Definition

Visitor behavior in, and satisfaction with, project areas.

Restoration Approaches

- Enhance Public Access to Natural Resources for Recreational Use
- Enhance Recreational Experiences
- Promote Environmental Stewardship, Education, and Outreach

Potential Methodologies

Social indicator monitoring systems can be used to measure visitor satisfaction with restoration project areas, and monitor response behavior toward restoration activities. Surveys may include information on visitor satisfaction depending on project objectives (Moscardo and Orsmby, 2004).

Monitoring Location

Selection of respondents should use a systematic random sampling procedure within the units chosen for study. This is intended to ensure that the respondents within a location have an equal probability of being asked to participate, and the choice of target respondents is determined by the sampling system and not by the interviewers. An offsite regional telephone survey, a key locations survey, or an onsite survey may be used (Moscardo and Orsmby, 2004).

Guidance on Frequency and Duration

The survey could be conducted pre- and post-implementation or more often depending on the design of the project. Monitoring should aim to cover different seasons and include weekdays, weekends, and holidays.

Other Potential Analyses

Visitor satisfaction and behavior may be influenced by an array of outside drivers. Consideration of these factors during the survey can help interpret survey responses:

- Visitor characteristics, especially motives and levels of experience with both the places visited and activities participated in, and cultural background
- Visitors' perceptions of the quality of the physical environment, especially judgments of scenic beauty and human impacts on the setting
- Interactions with other people, including tour and park staff
- Effectiveness of programs or activities available
- Perceived quality of the service provided
- Perceived quality of the facilities and built infrastructure.

Visitor satisfaction surveys could also be designed to collect information on visitor impact on acquired lands for protection or restoration. Sampling strategies for determination of impacts within visitor nodes (e.g., sites) and linkages (e.g., trails) are well-developed and have been extensively reviewed [e.g., Hammitt and Cole (1998), Monz (2000), and others] and applied (Monz and Leung, 2006). The National Park Service (NPS) Visitor Impact Phase 1 and 2 Reports can provide additional guidance on monitoring methods (Monz and Leung, 2003a, 2003b). This information could also be used to inform potential wildlife behavior responses resulting from visitor use.

E.3.43. Visitor Use/Access

Parameter Type: Measured

Units: none (count) or number of visitors per unit of time (day, month, year, etc.)

Definition

Public access to the natural resources or project area and/or the number of visitors using the recreational area.

Restoration Approaches

- Enhance Public Access to Natural Resources for Recreational Use
- Create, Restore, and Enhance Barrier and Coastal Islands and Headlands
- Restore and Enhance Dunes and Beaches

Potential Methodologies

Method 1: Direct observations, including staff observations on-site using hand counters or recording forms, camera recordings, remote sensing, aerial surveys.

Method 2: On-site counters, including devices or sensors used to generate counts, such as pressure pads, turnstiles, light beams, active or passive infra-red, or acoustic data loggers.

Method 3: Review registrations, including voluntary registrations or permit records, such as track registers, site visitor books, registration or entrance fees, or trip bookings.

Method 4: Inferred counts, including indirect counts, such as interviews or counts of elements linked to visitor use such as car park counts, litter, or trail deterioration.

For guidance and methodologies of how to measure visitor use/access, see Cessford and Muhar (2003), Moscardo and Ormsby (2004), FWS (2005), Leggett (2015, 2017), and Horsch et al. (2017).

Monitoring Location

Visitor use patterns may vary depending on the activity, the number of individuals engaged, and the areas these activities take place. As a result, counting locations should be identified at strategic locations that are representative of the whole recreational use area. Priority sites may include:

- Places of specific management concern
- Places where specific management actions are under consideration
- Places that are considered representative of broader management issues
- Access points such as entrances to public areas/parks
- Locations that represent the diversity of activities such as along beaches, swimming areas, etc. (particularly if completing a survey).

Sampling locations could include a mixture of permanent sites, rotating sites according to needs, and flexible sites identified on case-by-case locations for short-term needs (Cessford and Muhar, 2003).

Guidance on Frequency and Duration

Data collection is proposed pre-implementation, immediately after implementation (as-built), and at an appropriate frequency and duration relevant to project-specific conditions. The variety of monitoring options to meet differing needs and site situations will impact the timing and frequency of monitoring. Generally, counts should be representative of as full a range of site conditions as possible, taking into account varying times of the day, week, or year; seasonal variations; weather variation; and special use occasions such as holidays or community events. Counts may also be established as a continuous and long-term process at a site, depending on the method utilized.

Other Potential Analyses

Visitor use counts should consider the number of days the acquired land is accessible/closed in order to accurately interpret changes in visitor use patterns. Project managers should also track the number of days the area is open or closed and the reasons for closure (e.g., beach closures due to water quality concern). See **Section E.3.24 Right of Entry**.

E.3.44. Water Level

Parameter Type: Measured or Modeled

Units: meters (m)

Definition

Elevation of the water surface, measured or modeled, relative to a geodetic or tidal datum. Water level measurements or estimates can be used to characterize the flooding regimes across the range of habitats restored, including the depth, frequency, and duration of flooding on the marsh surface and within any channels. When channels are an important feature of the project design, water level in the channel(s) should be measured or calculated at mean low tide to evaluate access to marsh surface for marine organisms.

Restoration Approach

- Restore and Enhance Submerged Aquatic Vegetation (SAV)

Potential Methodologies

The elevations of water level recorders and/or staff gauges should be determined and referenced to an appropriate vertical datum to obtain a relationship to marsh surface elevation. Water-level data can also be used to calculate the frequency and duration of flooding at specific locations within the restored area.

Method 1: Deploy multiple water level recorders to collect continuous measurements across the restored habitats.

Method 2: Collect elevation/bathymetry data (see **Section E.3.8 Elevation**) and install a single water level recorder to monitor the water surface elevation at one point, and calculate water levels across the marsh surface based on the elevation data. Assumes hydrologic connectivity is uniform across project area.

Method 3: Collect elevation/bathymetry data (see **Section E.3.8 Elevation**) and utilize data from an existing permanently deployed water level recorder(s) within or near the project site to calculate water levels across the marsh surface based on the elevation data.

Method 4: Install staff gauges at specific locations and make measurements by visual inspection, in combination with installation of one or more continuous water level recorders.

Method 5: To evaluate water level in narrow channels, take in-situ measurements using water level loggers along the created channel during mean low tide, including the channel openings or on either side of culverts, or other features that could constrict flow.

See Neckles and Dionne (2000), Steyer and Llewellyn (2000), and Sauer and Turnipseed (2010) for more information on potential methodologies.

Monitoring Location

Spatial distribution of water level recorders will depend on the project type and the hydrologic characteristics of the project area. Potential locations for water level recorders include near the source of restored hydrologic flows, within the project boundary, near the edge of the influenced area, and outside the influenced area, if adjacent to other habitats. A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

Frequency and duration will be project-dependent based on objectives and the need for corrective actions, but in general monitoring is proposed pre-construction, immediately after construction (as-built), and annually post-construction.

If continuous recorders are used, data could be collected for two weeks or longer during a sampling event to capture one lunar cycle of spring and neap tides, but longer time periods (e.g., three–four months or year-round) are preferred. Frequency of measurement from continuous recorders (tide gauges and water level loggers) can vary from every five minutes to every hour, and could be selected based on the resolution needed to meet project objectives.

If discrete measurements are taken, the water level should be assessed over several tidal cycles.

For projects with riverine influence, sampling events could be designed to capture both high- and low-flow events. If continuous recorders are used, data could be collected for at least two weeks during high- and low-water conditions, but year-round data collection for one or more years is preferred to fully capture seasonal variability in the water level. If discrete measurements are taken, the water level should be assessed over a few weeks during both high- and low-flow conditions.

Other Potential Analyses

Bathymetric profile change, sediment movement, hydrologic connectivity, saturation of root zone, accessibility by fish or waterbirds, and meteorological events and conditions.

E.3.45. Waves

Parameter Type: Measured or Modeled

Units: wave heights should be measured in meters (m), directions should use compass headings, wave period should be measured in seconds (s).

Restoration Approach

- Restore and Enhance Submerged Aquatic Vegetation

Potential Methodologies

Wave generation in inland or sheltered coastal water bodies are influenced by wind speed and duration and available fetch such that heights and periods are generally less than those observed on open ocean coastlines (Miller et al. 2015). Instrumentation used in monitoring waves should thus be tailored to those capable of capturing these conditions.

Method 1: Field based measurements of wave heights, direction, and period can be collected using a number of instruments, depending on application, and include pressure gauges, accelerometer buoy, acoustic wave gauge, acoustic doppler current profilers, wave wires, and remote sensing techniques (Miller et al. 2015; Pandian et al. 2010)

Method 2: In conjunction with field data collection described in Method 1, wave models may also be used to evaluate wave conditions around the entire project site (e.g., Coast & Harbor Engineering 2015; Thomas and Dwarakish 2015). The use of models will also require calibration and validation procedures to ensure model results accurately reproduce the physical measurements (Miller et al. 2015).

Monitoring Location

The monitoring location will depend on the methods selected, as some deployments require certain depths or to be placed in an array, for example. Wave information should be collected on either side of constructed feature, if used, so that comparisons of wave heights can be made to determine whether performance criteria have been met. In modeling applications, monitoring locations may extend beyond the immediate project site in order to capture necessary boundary conditions.

Guidance on Frequency and Duration

The appropriate sampling interval and duration should be tied to the conditions the monitoring is intended to sample. Changes in weather patterns (especially winds) will affect wave conditions at a local site so monitoring frequency and duration may consider capturing the range of conditions most frequently experienced at the project site. Rapid response monitoring to capture extreme weather events (e.g., hurricanes) may also be considered for some projects.

For living shoreline projects that are intended to reduce wave heights, monitoring may be needed through several growing seasons of the living shoreline in order to achieve targeted wave reduction benefits.

Additional monitoring may also be needed if changes in the conformation of natural or constructed features that reduce wave energy occur. For example, a breakwater may partially collapse if undercut by scouring, resulting in changes in wave energy around the structure. This monitoring data could be used to inform decisions regarding potential corrective actions.

Other Potential Analyses

Wave energy, maximum wave height, wave attenuation, and other commonly used statistics can be calculated from measurements of wave heights, periods, and direction.

E.3.46. Wetland Edge

Parameter Type: Measured or Calculated

Units: positions should be georeferenced (latitude, longitude, elevation); relative differences between positions should be measured using meters (m) or kilometers (km); ratios are unitless

Definition

The boundary between the vegetated wetland surface and non-wetland areas, including water features such as tidal creeks, ponds, unvegetated bottom, or other open water areas.

Restoration Approach

- Create, Restore, and Enhance Coastal Wetlands

Potential Methodologies

A number of different methods can be used to approximate the amount of wetland edge. Note that not all of these methods measure the same thing and they, therefore, may not produce comparable data.

Method 1: The linear distance of wetland edge and the total area of marsh habitat can be calculated based on imagery collected by airplane, helicopter, or UAS; high-resolution satellite imagery; or other appropriate remote sensing platform. Imagery used to map wetland boundaries should include true color and infrared bands, and have a spatial resolution of 1 m or less. Imagery acquired should be orthorectified imagery (i.e., free from distortions related to sensor optics, sensor tilt, and differences in elevation). For guidance on collecting aerial orthoimagery, please see Rufe (2014). The boundaries of wetland habitats and water features can be delineated and the linear length of wetland edge habitat can be measured using appropriate spatial analysis software. The ratio of linear wetland edge to total area of interior wetland habitat can then be calculated. For additional information and references related to mapping wetland boundaries based on remote sensing data, see Section E.9.1 Area.

Method 2: Conduct a field survey to map the boundaries of vegetated wetland habitat and water features within the project area. The length of the wetland edge, the total area of wetland habitat, and the ratio of marsh edge to interior marsh habitat can then be calculated. For additional information and references related to conducting ground surveys of wetland boundaries, see Section E.9.1 Area.

Method 3: Ratio of wetland habitat to open water (sometimes referred to as land:water ratio) is also used as a proxy for edge in habitat suitability index models. For additional methods on mapping wetlands, see Section E.9.1 Area. Note that this method does not result in an edge-to-interior ratio, and cannot be directly compared to data collected using Methods 1 and 2.

Method 4: A number of different fragmentation indices have been developed to quantitatively describe the configuration of wetland and water. See Suir et al. (2013) and Couvillion et al. (2016) for examples.

Monitoring Location

The entire project footprint. A reference and/or control site could be established, where appropriate and applicable.

Guidance on Frequency and Duration

Monitoring is recommended immediately following construction (as-built) with one–two additional monitoring events, or more over the monitoring period. Funding for one additional contingency monitoring event could be included in the monitoring budget, which could be implemented as needed to account for storm impacts.

Other Potential Analyses

In some cases, this parameter can also be used as a proxy for landscape fragmentation.

References

Anders, F.J. and M.R. Byrnes. 1991. Accuracy of shoreline change rates as determined from maps and aerial photographs. *Shore and Beach* 59(1):17–26.

ASTM. 2013a. Annual Book of ASTM Standards, Section 11, Water and Environmental Technology, Volume 11.01, Water (I). American Society for Testing and Materials, Conshohocken, PA.

ASTM. 2013b. Annual Book of ASTM Standards, Section 11, Water and Environmental Technology, Volume 11.02, Water (I). American Society for Testing and Materials, Conshohocken, PA.

Baggett, L.P., S.P. Powers, R. Brumbaugh, L.D. Coen, B. DeAngelis, J. Greene, B. Hancock, and S. Morlock. 2014. Oyster Habitat Restoration Monitoring and Assessment Handbook. The Nature Conservancy, Arlington, VA, USA. 96pp.

Baird, E.W., A.D. Eaton, and E.W. Rice. 2017. *Standard Methods for the Examination of Water and Wastewater, 23rd Edition*. American Public Health Association, American Water Works Association, and Water Environmental Federation.

Barry A. Vittor & Associates, Inc. 2016. Submerged aquatic vegetation mapping in Mobile Bay and adjacent waters of coastal Alabama in 2015. Prepared for the Mobile Bay Estuary Program and Alabama DCNR State Lands Division Coastal Section.

Boak, E.H. and I.L. Turner. 2005. Shoreline definition and detection: A review. *Journal of Coastal Research* 21(4):688–703.

Bonham, C.D. 2013. *Measurements for Terrestrial Vegetation*. Second Edition. John Wiley & Sons.

Bradshaw, C.J.A. and B.W. Brook. 2010. The conservation biologist’s toolbox – principles for the design and analysis of conservation studies. Chapter 16 in *Conservation Biology for All*, N.S. Sodhi and P.R. Ehrlich (eds.). ISBN 978-0199554249. Oxford University Press, Oxford. pp. 313–339.

Brock, J.C., C.W. Wright, A.H. Sallenger, W.B. Krabill, and R.N. Swift. 2002. Basis and methods of nasa airborne topographic mapper lidar surveys for coastal studies. *Journal of Coastal Research* 18(1):1–13.

Buffington, K.J., B.D. Dugger, K.M. Thorne, and J.T. Takekawa. 2016. Statistical correction of lidar-derived digital elevation models with multispectral airborne imagery in tidal marshes. *Remote Sensing of Environment* 186:616–625.

Cessford, G. and A. Muhar. 2003. Monitoring options for visitor numbers in national parks and natural areas. *Journal for Nature Conservation* 11(4):240–250.

Chai, A.L., M. Homer, C.F. Tsai, and P. Goulletquer. 1992. Evaluation of oyster sampling efficiency of patent tongs and an oyster dredge. North American Journal of Fisheries Management 12: 825-832. DOI: 10.1577/1548-8675(1992)012<0825:EOOSEO>2.3.CO;2

Cheshire, A.C., E. Adler, J. Barbière, Y. Cohen, S. Evans, S. Jarayabhand, L. Jeftic, R.T. Jung, S. Kinsey, E.T. Kusui, I. Lavine, P. Manyara, L. Oosterbaan, M.A. Pereira, S. Sheavly, A. Tkalin, S. Varadarajan, B. Wenneker, and G. Westphalen. 2009. UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter. Regional Seas Reports and Studies No. 186, IOC

Technical Series No. 83. United Nations Environment Programme/Intergovernmental Oceanographic Commission. Available: http://staging.unep.org/gpa/Documents/Publications/MarineLitterSurveyandMonitoringGuidelines.pdf.

Christiaen B., P. Dowty, L. Ferrier, Jeff Gaeckle, H. Berry, J. Stowe, and E. Sutton. 2014. Puget Sound Submerged Vegetation Monitoring Program 2014 Report. Nearshore Habitat Program, Aquatic Resources Division, Washington State Department of Natural Resources.

CIRIA, CUR, and CETMEF. 2007. *The Rock Manual. The Use of Rock in Hydraulic Engineering (2nd ed.)*. London, UK.

Coast & Harbor Engineering. 2015. Living Shoreline Demonstration Project Jefferson Parish - Coastal Engineering and Alternatives Analysis. Submitted to Louisiana Coastal Protection and Restoration Authority (July 23, 2015).

Conway, C.J. 2011. Standardized North American marsh bird monitoring protocol. *Waterbirds* 34(3):319–346.

Coulloudon, B., K. Eshelman, J. Gianola, N. Habich, L. Hughes, C. Johnson, and J. Willoughby. 1999. Sampling vegetation attributes, technical reference 1734-4. Bureau of Land Management, Denver, CO.

Couvillion, B.R., M.R. Fischer, H.J. Beck, and W.J. Sleavin. 2016. Spatial configuration trends in coastal Louisiana from 1985 to 2010. *Wetlands* 36(2):347–359.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Department of the Interior, U.S. Fish and Wildlife Service. Available: https://www.fws.gov/wetlands/Documents/Classification-of-Wetlands-and-Deepwater-Habitats-of-the-United-States.pdf.

CPRA. 2016. A Contractor's Guide to the Standards of Practice: For CPRA Contractors Performing GPS Surveys and Determining GPS Derived Orthometric Heights within the Louisiana Coastal Zone. Coastal Protection and Restoration Authority. January. Available: ftp://ftp.coastal.la.gov/Large%20Data%20Requests/GPS_Benchmarks_2016_Update/LCZ%20GPS%20Guidelines%20March%202016.pdf.

Crowell, M., S.P. Leatherman, and M.K. Buckley. 1991. Historical shoreline change: Error analysis and mapping accuracy. *Journal of Coastal Research* 839–852.

Dahl, T. and M. Bergeson. 2009. Technical Procedures for Conducting Status and Trends of the Nation's Wetlands. U.S. Fish and Wildlife Service, Division of Habitat and Resource Conservation, Washington, DC.

Dunnicliff, J. 1993. *Geotechnical Instrumentation for Monitoring Field Performance.* John Wiley & Sons, Canada.

Dunton K.H., and W. Pulich Jr. 2007. Final Report: Landscape monitoring and biological indicators for seagrass conservation in Texas coastal waters. Coastal Bend Bays and Estuaries Program, Inc. Contract No. 0627.

DWH NRDA Trustees. 2016a. *Deepwater Horizon* Oil Spill: Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS). Available: http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan.

DWH NRDA Trustees. 2016b. Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the *Deepwater Horizon* (DWH) Oil Spill. Originally approved May 4, 2016; revised November 15, 2016.

EBAP and FLDEP. 2015. Seagrass Protection and Restoration Plan. Estero Bay Aquatic Preserve and Florida Department of Environmental Protection. June 30, 2015.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring & Monitoring Plant Populations. Bureau of Land Management, Denver, CO. Available: https://www.blm.gov/nstc/library/pdf/MeasAndMon.pdf.

Fearnley, S., L.F. Brien, L. Martinez, M. Miner, M. Kulp, and S. Penland. 2009. Louisiana Barrier Island Comprehensive Monitoring Program (BICM). Volume 5: Chenier Plain, South-Central Louisiana, and Chandeleur Islands, Habitat Mapping and Change Analysis 1996 to 2005. Part 3: Habitat Class Tables, Habitat Change Tables, and Final Statistics 1996 to 2005. Pontchartrain Institute Reports and Studies. Paper 4. Available: http://scholarworks.uno.edu/cgi/viewcontent.cgi?article=1012&context=pies_rpts.

Federal Interagency Committee for Wetland Delineation. 1989. *Federal Manual for Identifying and Delineating Jurisdictional Wetlands.* U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and U.S.D.A. Soil Conservation Service, Washington, DC. January 10. Available: https://www.fws.gov/northeast/ecologicalservices/pdf/wetlands/interagency%20wetland%20delineation%20manual%201989.pdf.

FLDEP. 2014. Monitoring Standards for Beach Erosion Control Projects. Florida Department of Environmental Protection. May. Available: https://floridadep.gov/sites/default/files/PhysicalMonitoringStandards.pdf.

Folse, T.M., L.A. Sharp, J.L. West, M.K. Hymel, J.P. Troutman, T. McGinnis, D. Weifenbach, W.M. Boshart, L.B. Rodrigue, D.C. Richardi, W.B. Wood, and C.M. Miller. 2014. A Standard Operating Procedures Manual for the Coast-Wide Reference Monitoring System-Wetlands: Methods for Site Establishment, Data Collection, and Quality Assurance/Quality Control. Louisiana Coastal Protection and Restoration Authority, Office of Coastal Protection and Restoration. Baton Rouge, LA. Available: https://www.lacoast.gov/reports/project/CRMS%20SOP%202014_MASTER_Final.pdf.

FWS. 2005. *Visitation Estimation Workbook, National Wildlife Refuge System*. U.S. Fish & Wildlife Service.

Gens, R. 2010. Remote sensing of coastlines: Detection, extraction and monitoring. *International Journal of Remote Sensing* 31(7):1819–1836.

Guy, K.K. 2015. Barrier Island Shorelines Extracted from Landsat Imagery. U.S. Geological Survey Open-File Report 2015–1179. Available: https://pubs.usgs.gov/of/2015/1179/ofr20151179.pdf.

Guy, K.K. and N.G. Plant. 2014. Topographic Lidar Survey of Dauphin Island, Alabama and Chandeleur, Stake, Grand Gosier and Breton Islands, Louisiana, July 12–14, 2013. U.S. Geological Survey. Available: https://pubs.usgs.gov/ds/0838/ds838title.html.

Hammitt, W.E. and D.N. Cole. 1998. *Wildland Recreation Ecology and Management* (2nd ed.). John Wiley & Sons, New York.

Heidemann, H.K. 2014. Lidar Base Specification (Ver. 1.2, November). U.S. Geological Survey Techniques and Methods, Book 11, Chapter B4. Available: https://pubs.usgs.gov/tm/11b4/pdf/tm11-B4.pdf.

Hladik, C. and M. Alber. 2012. Accuracy assessment and correction of a lidar-derived salt marsh digital elevation model. *Remote Sensing of Environment* 121:224–235.

Horsch, E., M. Welsh, and J. Price. 2017. Best Practices for Collecting Onsite Data to Assess Recreational Use Impacts from an Oil Spill. U.S. Department of Commerce, Silver Spring, MD.

Jackson J.B., and D.J. Nemeth. 2007. A new method to describe seagrass habitat sampled during fisheries-independent monitoring. Estuaries and Coasts 30: 171-178. DOI: 10.1007/BF02782977

Johnson H.A., and R.M. Newman. 2011. A comparison of two methods for sampling biomass of aquatic plants. Journal of Aquatic Plant Management 49:1-8.

Jordan, F., S. Coyne, and J.C. Trexler. 1997. Sampling fishes in vegetated habitats: Effects of habitat structure on sampling characteristics of the 1-m^2 throw trap. *Transactions of the American Fisheries Society* 126(6):1012–1020.

Kirkman H. 1996. Baseline and monitoring methods for seagrass meadows. Journal of Environmental Management 47: 191-201. DOI: 10.1006/jema.1996.0045

Klemas, V. 2011. Remote sensing of wetlands: Case studies comparing practical techniques. *Journal of Coastal Research* 27(3):418–427.

Klemas, V. 2013. Using remote sensing to select and monitor wetland restoration sites: An overview. *Journal of Coastal Research* 29(4):958–970.

Klemas, V.V. 2015. Coastal and environmental remote sensing from unmanned aerial vehicles: An overview. *Journal of Coastal Research* 31(5):1260–1267.

Knapp, R. 1984. Sample (relevé) areas (distribution, homogeneity, size, shape) and plot-less sampling. *Handbook of Vegetation Science*.

Kushlan, J.A. 1981. Sampling characteristics of enclosure fish traps. *Transactions of the American Fisheries Society* 110(4):557–562.

Leggett, C.G. 2015. Estimating Visitation in National Parks and Other Public Lands. Report submitted to the National Park Service. Bedrock Statistics, LLC, Gilford, NH. April 13.

Leggett, C.G. 2017. Sampling strategies for on-site recreation counts. *Journal of Survey Statistics and Methodology* 5(3):326–349.

Levesque, V.A. and K.A. Oberg. 2012. Computing Discharge Using the Index Velocity Method: U.S. Geological Survey Techniques and Methods 3–A23. Available: https://pubs.usgs.gov/tm/3a23/.

Lewis III, R.R. 2005. Ecological engineering for successful management and restoration of mangrove forests. *Ecological Engineering* 4(5):403–418.

Lewis III, R.R. 2009. Methods and criteria for successful mangrove forest restoration. Chapter 28 in *Coastal Wetlands: An Integrated Ecosystem Approach.* Elsevier, Amsterdam. pp. 787–800.

Lippiatt, S., S. Opfer, and C. Arthur. 2013. *Marine Debris Monitoring and Assessment: Recommendations for Monitoring Debris Trends in the Marine Environment.* U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, and NOAA Marine Debris Program.

Louisiana Department of Culture, Recreation, and Tourism. 2014. *2014–2019 Louisiana Statewide Comprehensive Outdoor Recreation Plan*. Baton Rouge, LA.

MacBroom, J.G. and R. Schiff. 2012. Predicting the hydrologic response of salt marshes to tidal restoration. In *Tidal Marsh Restoration,* C.T. Roman and D.M. Burdick (eds.). pp. 13–38. Island Press, Washington, DC.

Madden, M., T. Jordan, S. Bernardes, D.L. Cotten, N. O'Hare, and A. Pasqua. 2015. Unmanned aerial systems and structure from motion revolutionize wetlands mapping. In *Remote Sensing of Wetlands: Applications and Advances*, R.W. Tiner, M.W. Lang, and V.V. Klemas (eds.). CRC Press, Boca Raton, FL. pp. 195–222.

Magurran, A.E. and B.J. McGill (eds.). 2011. *Biological Diversity: Frontiers in Measurement and Assessment*. Oxford University Press, New York.

Martinez, L., S. O'Brien, M. Bethel, S. Penland, and M. Kulp. 2009. Louisiana Barrier Island Comprehensive Monitoring Program (BICM). Volume 2: Shoreline Changes and Barrier Island Land Loss 1800's–2005. Pontchartrain Institute Reports and Studies. Available: http://scholarworks.uno.edu/cgi/viewcontent.cgi?article=1000&context=pies_rpts.

Matthews, J.W., G. Spyreas, and A.G. Endress. 2009. Trajectories of vegetation-based indicators used to assess wetland restoration progress. *Ecological Applications* 19(8):2093–2107.

McDonald J.I., G.T. Coupland, and G.A. Kendrick. 2006. Underwater video as a monitoring tool to detect change in seagrass cover. Journal of Environmental Management 80: 148-155. DOI: 10.1016/j.jenvman.2005.08.021

Medeiros, S., S. Hagen, J. Weishampel, and J. Angelo. 2015. Adjusting Lidar-derived digital terrain models in coastal marshes based on estimated aboveground biomass density. *Remote Sensing* 7(4):3507–3525.

Miller, A., M. Tabarestani, and J. Isaacs. 2014. A Survey of Recreational Shrimpers in the Northern U.S. Gulf of Mexico. Gulf States Marine Fisheries Commission Publication, Ocean Springs, MS.

Minello, T.J. 2000. Temporal development of salt marsh value for nekton and epifauna: Utilization of dredged material marshes in Galveston Bay, Texas, USA. *Wetlands Ecology and Management* 8(5):327–342.

Monz, C. 2000. Recreation resource assessment and monitoring techniques for mountain regions. *Tourism and Development in Mountain Regions* 255–274.

Monz, C. and Y.F. Leung. 2003a. National Park Service Coastal Visitor Impact Monitoring Phase 1 Report. National Park Service.

Monz, C. and Y.F. Leung. 2003b. National Park Service Coastal Visitor Impact Monitoring Phase 2 Report. National Park Service.

Monz, C. and Y.F. Leung. 2006. Meaningful measures: Developing indicators of visitor impact in the National Park Service inventory and monitoring program. In *The George Wright Forum* 23(2):17–27. Available: http://www.georgewright.org/232monz.pdf.

Moore, L.J. 2000. Shoreline mapping techniques. *Journal of Coastal Research* 111–124.

Morton, R.A. 1991. Accurate Shoreline Mapping: Past, Present, and Future. Paper presented at the Coastal Sediments.

Morton, R.A., T. Miller, and L. Moore. 2005. Historical shoreline changes along the US Gulf of Mexico: A summary of recent shoreline comparisons and analyses. *Journal of Coastal Research* 21(4):704–709. doi: 10.2112/04-0230.1.

Moscardo, G. and J. Ormsby. 2004. A Social Indicators Monitoring System for Tourist and Recreational Use of the Great Barrier Reef. Research Publication No. 80. Great Barrier Reef Maine Park Authority. Available: http://www.gbrmpa.gov.au/__data/assets/pdf_file/0018/5580/gbrmpa_RP80_A_Social_Indicators_Monitoring_System_2004.pdf.

NAS. 2017. Effective Monitoring to Evaluate Ecological Restoration in the Gulf of Mexico. National Academies of Sciences, Engineering, and Medicine. The National Academies Press, Washington, DC. DOI: 10.17226/23476

Neckles, H. and M. Dionne. 2000. Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine. Wells National Estuarine Research Reserve Technical Report, Wells, ME.

Neckles, H.A., M. Dionne, D.M. Burdick, C.T. Roman, R. Buchsbaum, and E. Hutchins. 2002. A monitoring protocol to assess tidal restoration of salt marshes on local and regional scales. *Restoration Ecology* 10(3):556–563.

Neckles H.A., B.S. Kopp, B.J. Peterson, and P.S. Pooler. 2012. Integrating scales of seagrass monitoring to meet conservation needs. *Estuaries and Coasts* 35: 23-46. DOI: 10.1007/s12237-011-9410-x.

Olson, S.A. and J.M. Norris. 2007. U.S. Geological Survey Streamgaging...from the National Streamflow Information Program. U.S. Geological Survey Fact Sheet 2005-3131. Available: http://pubs.usgs.gov/fs/2005/3131.

Opfer, S., C. Arthur, and S. Lippiatt. 2012. *NOAA Marine Debris Shoreline Survey Field Guide*. U.S. National Oceanic and Atmospheric Administration Marine Debris Program.

Patton, C.J. and J.R. Kryskalla. 2003. Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory – Evaluation of Alkaline Persulfate Digestion as an Alternative to Kjeldahl Digestion for Determination of Total and Dissolved Nitrogen and Phosphorus in Water. USGS Water-Resources Investigations Report 03.-4174. Available: https://nwql.usgs.gov/WRIR-03-4174.shtml.

Ramsey III, E.W., G.A. Nelson, and S.K. Sapkota. 2001. Coastal change analysis program implemented in Louisiana. *Journal of Coastal Research* 53–71.

Rangoonwala, A., C.E. Jones, and E. Ramsey. 2016. Wetland shoreline recession in the Mississippi River Delta from petroleum oiling and cyclonic storms. *Geophysical Research Letters* 43(22).

Rantz, S.E., and others. 1982. *Measurement and Computation of Streamflow. Volume 2. Computation of Discharge*. U.S. Geological Survey, Water Supply Paper 2175. Available: http://pubs.usgs.gov/wsp/wsp2175/html/wsp2175_vol2.html.

Rodusky A.J., B. Sharfstein, T.L. East, and R.P. Maki. 2005. A comparison of three methods to collect submerged aquatic vegetation in a shallow lake. *Environmental Monitoring and Assessment* 110: 87-97. DOI: 10.1007/s10661-005-6338-2

Roegner, G.C., H.L. Diefenderfer, A.B. Borde, R.M. Thom, E.M. Dawley, A.H. Whiting, S.A. Zimmerman, and G.E. Johnson. 2008. Protocols for Monitoring Habitat Restoration Projects in the Lower Columbia River and Estuary. Final Report. PNNL-15793. Prepared for the U.S. Army Corps of Engineers, Portland, OR. Available: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-15793.pdf.

Rozas, L.P. 1992. Bottomless lift net for quantitatively sampling nekton on intertidal marshes. *Marine Ecology Progress Series* 287–292.

Rozas, L.P. and T.J. Minello. 1997. Estimating densities of small fishes and decapod crustaceans in shallow estuarine habitats: A review of sampling design with focus on gear selection. *Estuaries* 20(1):199–213.

Rufe, P.P. 2014. Digital Orthoimagery Base Specification V1.0. Chapter 5 of Section B, U.S. Geological Survey Standards, Book 11, Collection and Delineation of Spatial Data. Available: https://pubs.usgs.gov/tm/11/b5/pdf/tm11-B5.pdf.

Ryan, P.G., C.J. Moore, J.A. van Franeker, and C.L. Moloney. 2009. Monitoring the abundance of plastic debris in the marine environment. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 364(1526):1999–2012.

Rydlund, P.H. and B.K. Densmore. 2012. *Methods of Practice and Guidelines for Using Survey-Grade Global Navigation Satellite Systems (GNSS) to Establish Vertical Datum in the United States Geological Survey*. Chapter 1 of Section D, Field Survey Methods, Book 11, Collection and Delineation of Spatial Data. Available: https://pubs.usgs.gov/tm/11d1/.

Sallenger, A., W. Krabill, R. Swift, J. Brock, J. List, M. Hansen, R. Holman, S. Manizade, J. Sontag, and A. Meredith. 2003. Evaluation of airborne topographic lidar for quantifying beach changes. *Journal of Coastal Research* 125–133.

Samiappan, S., G. Turnage, L.A. Hathcock, and R. Moorhead. 2017. Mapping of invasive Phragmites (common reed) in Gulf of Mexico coastal wetlands using multispectral imagery and small unmanned aerial systems. *International Journal of Remote Sensing* 38(8–10):2861–2882.

Sauer, V.B. and D.P. Turnipseed. 2010. *Stage Measurement at Gaging Stations*. U.S. Geological Survey. Available: https://pubs.usgs.gov/tm/tm3-a7/.

Schmid, K.A., B.C. Hadley, and N. Wijekoon. 2011. Vertical accuracy and use of topographic lidar data in coastal marshes. *Journal of Coastal Research* 27(6A):116–132.

Short F.T., L.J. McKenzie, R.G. Coles, K.P. Vidler, and J.L. Gaeckle. 2006. SeagrassNet Manual for Scientific Monitoring of Seagrass Habitat, Worldwide Edition. University of New Hampshire Publication 75 pp.

Smart, M.M., F.A. Reid, and J.R. Jones. 1981. A comparison of a persulfate digestion and the Kjeldahl procedure for determination of total nitrogen in freshwater samples. Water Research 15(7): 919-921. DOI: 10.1016/0043-1354(81)90148-2

Smith, M. and D. Vericat. 2015. From experimental plots to experimental landscapes: Topography, erosion and deposition in sub-humid badlands from structure-from-motion photogrammetry. *Earth Surface Processes and Landforms* 40(12):1656–1671.

Smith, M., J. Carrivick, and D. Quincey. 2016. Structure from motion photogrammetry in physical geography. *Progress in Physical Geography* 40(2):247–275.

Soniat, T.M., E.E. Hoffman, J.M. Klinck., and E.N. Powell. 2009. Differential modulation of eastern oyster (Crassostrea virginica) disease parasites by the El-Niño-Southern Oscillation and the North Atlantic Oscillation. International Journal of Earth Sciences: Geologische Rundschau 98(1) 99-114. DOI: 10.1007/s00531-008-0364-6

Steyer, G.D. and D.W. Llewellyn. 2000. Coastal wetlands planning, protection, and restoration act: A programmatic application of adaptive management. *Ecological Engineering* 15(3):385–395.

Stockdon, H.F., K.S. Doran, and A.H. Sallenger. 2009. Extraction of Lidar-based dune-crest elevations for use in examining the vulnerability of beaches to inundation during hurricanes. *Journal of Coastal Research* 59–65.

Stoner, N.K. 2011. Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions. U.S. Environmental Protection Agency March 16 Memorandum from Nancy K. Stoner, Acting Assistant Administrator, to Regional Administrators, Regions 1–10.

Suir, G.M., D.E. Evers, G.D. Steyer, and C.E. Sasser. 2013. Development of a reproducible method for determining quantity of water and its configuration in a marsh landscape. *Journal of Coastal Research* Special Issue 62: Understanding and Predicting Change in the Coastal Ecosystems of the Northern Gulf of Mexico. pp.110–117.

Thayer, G.W., T.A. McTigue, R.J. Salz, D.H. Merkey, F.M. Burrows, and P.F. Gayaldo (eds.). 2005. Science-Based Restoration Monitoring of Coastal Habitats, Volume Two: Tools for Monitoring Coastal Habitats. NOAA Coastal Ocean Program Decision Analysis Series No. 23. NOAA National Centers for Coastal Ocean Science, Silver Spring, MD. 628 pp. plus appendices.

Thieler, E.R., E.A. Himmelstoss, J.L. Zichichi, and A. Ergul. 2009. The Digital Shoreline Analysis System (DSAS) Version 4.0 – An ArcGIS Extension for Calculating Shoreline Change. Open-File Report 20008-1278. U.S. Geological Survey. Available: https://pubs.er.usgs.gov/publication/ofr20081278.

Tiner, R.W. 1999. Wetland Monitoring Guidelines. Operational Draft. E. Services, Trans. U.S. Fish and Wildlife Service, Hadley, MA.

Turnipseed, D.P. and V.B. Sauer. 2010. Discharge Measurements at Gaging Stations. U.S. Geological Survey Techniques and Methods Book 3, Chap. A8. Available: http://pubs.usgs.gov/tm/tm3-a8/.

U.S. Census Bureau, U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce. 2011. *2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation*.

U.S. EPA. 2002. *Method 1604: Total Coliforms and Escherichia Coli in Water by Membrane Filtration Using a Simultaneous Detection Technique (MI Medium).* EPA-821-R-02-024. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

U.S. EPA. 2011. *National Wetland Condition Assessment: Field Operations Manual.* EPA-843-R-10-001. U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 2014. *National Coastal Condition Assessment: Field Operations Manual*. EPA-841-R-14-007. U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 2017. Clean Water Act Methods Update Rule – Final Rule. Table 1H – List of Approved Microbiological Methods for Ambient Water. Federal Register, Vol. 82, No. 165, August 28. pp. 40867–408768.

USGS. 2011. *Channel Cross-Section Standard Operating Procedure*. U.S. Geological Survey, Western Ecological Research Center, San Francisco Bay Estuary Field Station, Vallejo, CA.

USGS. 2013. National Field Manual for the Collection of Water-Quality Data. U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Chap. A6.2 "Dissolved Oxygen."

Wagner, R.J., R.W. Boulger Jr., C.J. Oblinger, and B.A. Smith. 2006. Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting. U.S. Geological Survey. Available: http://pubs.water.usgs.gov/tm1d3.

Walker, R. 2014. Total Nitrogen Methods Fact Sheet. South Florida Water Management District, Technical Oversight Committee, West Palm Beach, Florida. Available: https://www.sfwmd.gov/sites/default/files/documents/tn_methods_fact_sheet.pdf.

Wildish, D.J. and D.D. Kristmanson. 1997. Benthic Suspension Feeders and Flow. Cambridge University Press, New York. 409 pp.

Zimmerman, R.J., T.J. Minello, and G. Zamora. 1984. Selection of vegetated habitat by brown shrimp, *Penaeus aztecus*, in a Galveston Bay salt marsh. *Fishery Bulletin* 82(2):325–336.

Zweig, C.L., M.A. Burgess, H.F. Percival, and W.M. Kitchens. 2015. Use of unmanned aircraft systems to delineate fine-scale wetland vegetation communities. *Wetlands* 35(2):303–309.

E.4. Create, Restore, and Enhance Coastal Wetlands: Monitoring Guidance

This guidance is intended to promote consistency in data collection among similar types of projects and allow for future analysis across TIGs and Restoration Types, (Section 10.6.2 of SOP; DWH NRDA Trustees, 2016). This guidance may also assist the TIGs by providing recommended methodologies for monitoring restoration projects, saving time and money spent developing suitable monitoring protocols for individual restoration projects. If adjustments from this monitoring guidance are needed for a particular project, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016). Project teams within each TIG will identify parameters applicable to the objectives for each individual restoration project when developing the project MAM Plan. In addition to the project monitoring guidance identified in this Manual, specific monitoring may be required to comply with permits granted by regulatory agencies. The TIGs are not restricted from adding additional parameters, and other project monitoring that may be needed for specific projects should be determined by the TIGs.

The Cross-TIG MAM work group developed this monitoring guidance by following the process described in the Monitoring and Adaptive Management Procedures and Guidelines Manual Version 1.0 (MAM Manual Version 1.0; DWH NRDA Trustees, 2017).

This guidance is intended to assist the TIGs in developing MAM Plans for restoration projects, as appropriate. Specifically, it provides:

- Examples of Restoration Techniques
- Guidance on example restoration objectives, example drivers, and example uncertainties
- Guidance on core performance monitoring parameters for projects within the Restoration Approach
- Guidance on supplemental performance monitoring parameters for specific restoration objectives.

The monitoring parameters identified within a project MAM Plan should be consistent with the recommended monitoring defined within this guidance document, wherever appropriate. Depending on the nature of the restoration project, TIGs may also choose not to include some of the elements described in this guidance document (e.g., drivers, uncertainties). If adjustments from the monitoring guidance are needed, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). The guidance provided should not be considered exhaustive. Therefore, TIGs may develop project-level objectives, drivers, uncertainties, and monitoring parameters that have not been previously identified. The TIGs will develop MAM objectives and monitoring parameters that pertain to their restoration activities; and will determine the frequency and duration of monitoring, and the associated budget they deem appropriate. Finally, this section is subject to

change as new monitoring parameters, methods, and technologies are identified and/or developed.

The monitoring parameters recommended in this guidance document are further detailed in Attachment E Section E.3, which includes a complete list of core- and objective-specific monitoring parameters identified by the Cross-TIG MAM work group and guidance on measurement unit(s) and monitoring methods. Guidance on monitoring locations, frequencies, durations of sampling and potential analyses is also provided where appropriate.

E.4.1. Restoration Techniques

Restoration Techniques are specific restoration actions the Trustees identified for each of the Restoration Approaches. Restoration Techniques may be used individually or in combination. See Appendix 5.D of the PDARP/PEIS (DWH NRDA Trustees, 2016a). The following are example Restoration Techniques included in the PDARP/PEIS for this Restoration Approach. This list should not be considered exhaustive; additional Restoration Techniques may be developed and/or identified.

1. Create or enhance coastal wetlands through placement of dredged material
2. Backfill canals
3. Restore hydrologic connections to enhance coastal habitats
4. Construct breakwaters.

E.4.2. Example Project-Level Restoration Objectives

Project-level restoration objectives should be specific to the resource injuries and clearly specify the desired outcome(s) of the restoration project (15 CFR § 990.55(b)(2)). See Section 2.4.1 of the MAM Manual Version 1.0 for guidance on establishing restoration objectives. The following are example project-level restoration objectives that may apply to one or more of the above-mentioned Restoration Techniques. This list should not be considered exhaustive; additional objectives may be developed and/or identified.

- Create or restore intertidal wetland elevations
- Restore targeted coastal wetland hydrology
- Increase or maintain native coastal wetland vegetation
- Restore targeted salinity regime
- Reduce shoreline erosion rate
- Restore hydrologic connectivity
- Provide habitat for fish and invertebrates
- Provide habitat for resident and migratory birds
- Increase habitat connectivity
- Increase the abundance of targeted species
- Remove invasive species.

E.4.3. Example Drivers

Drivers are outside forces, natural or anthropogenic, that have the potential to influence the outcome(s) of a restoration project. Drivers tend to be large-scale, long-term forces that are not easily controlled at the scale of a single restoration project (Harwell et al., 2016). See Section 2.4.2 of the MAM Manual Version 1.0 for guidance on establishing the conceptual setting for a MAM Plan, including identifying drivers. The following are example drivers that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional drivers may be identified.

- Hydrologic regime
- Freshwater inflow
- Precipitation
- Sediment input/load
- Subsidence
- Nutrients
- Sea level rise
- Storms/wave energy
- Sediment accretion/erosion
- Grazing/herbivory
- Invasive species
- Hard-freeze events
- Physical impacts
- Boat wakes
- Adjacent development/land use
- Chemical impacts (e.g., oil spills).

E.4.4. Example Uncertainties

Uncertainties or information gaps have the potential to affect adaptive management decisions for individual or multiple restoration projects. These decisions may include how to improve the likelihood of achieving favorable project outcomes or selecting corrective actions in the event a project is not performing as intended. See Section 2.4.3 of the MAM Manual Version 1.0 for guidance on identifying potential sources of uncertainty for a MAM Plan. The following are example uncertainties that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional uncertainties may be identified.

- Local subsidence and accretion rates (e.g., organic, mineral)
- Optimal hydrologic conditions (e.g., depth, duration, frequency of flooding) for sustainability of the created/restored/enhanced marsh
- Long-term precipitation trends
- Frequency, duration, and severity of freeze events
- Sediment and nutrient inputs
- Vegetation stress due to herbivory, disease, competition by invasive species
- Appropriate habitat characteristics for targeted species, whether the habitat is a limiting factor for the species
- Use of the habitat by targeted species
- Predation on targeted species
- Land use changes
- Construction of new hydrologic barriers (e.g., roads, canals, berms)
- Wetland buffer conversion/management.

E.4.5. Guidance on Developing Parameters for Project-Level Performance

This section includes two types of monitoring parameters for consideration under the Create, Restore, and Enhance Coastal Wetlands Restoration Approach:

1. Core performance monitoring parameters applicable to projects within a Restoration Approach (core performance monitoring parameters are those used consistently across projects in order to facilitate the aggregation of project monitoring results and the evaluation of restoration progress for each Restoration Type; Appendix 5.E.4 of PDARP/PEIS; DWH NRDA Trustees, 2016a).

2. Objective-specific performance monitoring parameters that are only applicable to projects with a particular restoration objective.

Additional adaptive management and/or validation monitoring parameters for consideration have also been identified. These additional parameters may be helpful for resolving uncertainties, explaining outside drivers, optimizing project implementation, supporting decisions about corrective actions and other adaptive management of the project, and informing the planning of future DWH NRDA restoration projects. Tables E.4.1 and E.4.2 should not be considered exhaustive, and other parameters may be considered, as appropriate. See the complete list of core- and objective-specific monitoring parameters, Section E.3 above, for details on the core performance monitoring parameters including definitions, units, and other guidance.

Table E.4.1. Core performance monitoring parameters and additional parameters for consideration under the Create, Restore, and Enhance Coastal Wetlands Restoration Approach

Core performance monitoring parameters	Parameters for consideration (as appropriate)
• Area • Elevation • Vegetation survival[a] • Vegetation percent cover and composition	• Water level • Vegetation height (emergent) • Vegetation density (emergent) • Aboveground biomass • Belowground biomass • Salinity (surface water) • Salinity (porewater) • Subsidence • Accretion • Sediment texture • Soil bulk density • Soil moisture content • Soil organic matter • Consolidation of constructed features

[a] If project is planted with vegetation.

Table E.4.2. Performance monitoring parameters and additional parameters for consideration for projects with specific restoration objectives. These would be collected in addition to the parameters listed in Table E.4.1.

Project-specific objective	Objective-specific performance monitoring parameters	Parameters for consideration (as appropriate)
Restore targeted salinity regime	• Salinity (surface water)	• Salinity (porewater)
Reduce shoreline erosion rate	• Shoreline position • Structural integrity and function of constructed features	• Sediment consolidation • Elevation • Wave height • Wave energy • Wave attenuation • Fetch • Longshore drift and currents

Project-specific objective	Objective-specific performance monitoring parameters	Parameters for consideration (as appropriate)
Restore hydrologic connectivity	• Channel dimensions[a, b] • Structural integrity and function of constructed features	• Sediment deposition • Salinity (surface water) • Surface water nutrients • Dissolved oxygen • Soil nutrients • Soil moisture • Velocity (water) in channels, culverts[a, b] • Discharge[a, b]
Provide habitat for fish and invertebrate species	• Channel dimensions[a] • Wetland edge • Nekton/epibenthos abundance, density, and composition • Nekton diversity	• Nekton length/width • Nekton biomass • Infauna/epifauna composition • Infauna/epifauna density • Infauna/epifauna biomass • Abundance/density of predators for targeted species • Salinity (surface water) • Temperature • Dissolved oxygen • Velocity (in channels, culverts)[a, b] • Abundance of preferred food/prey species for targeted species
Provide habitat for birds	• Area (by targeted habitat types) • Bird abundance/density and species composition	• Bird habitat utilization (staging, loafing, feeding, etc.) • Bird nest density • Nest success • Nest predation rate • Abundance/density of predators for targeted species • Abundance/density of preferred food/prey species for targeted species
Increase the abundance of targeted injured species	• Targeted injured species abundance/density	• Reproductive capacity of targeted species • Abundance of preferred food/prey species for targeted species • Abundance/density of competing species, invasives, or predators for targeted species

[a] If channels are included in the project design.
[b] If culverts are included in the project design.

References

DWH NRDA Trustees. 2016a. *Deepwater Horizon* Oil Spill: Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS). Available: http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan.

DWH NRDA Trustees. 2016b. Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the *Deepwater Horizon* (DWH) Oil Spill. Originally approved May 4, 2016; revised November 15, 2016.

Harwell, M.A., J.H. Gentile, L.D. McKinney, J.W. Tunnell Jr., W.C. Dennison, and R.H. Kelsey. 2016. A New Framework for the Gulf of Mexico EcoHealth Metrics. Available: http://www.harteresearchinstitute.org/sites/default/files/resources/Framework%20for%20the%20Gulf%20EcoHealth%20Metric.pdf.

E.5. Create, Restore, and Enhance Barrier and Coastal Islands and Headlands: Monitoring Guidance

This guidance is intended to promote consistency in data collection among similar types of projects and allow for future analysis across TIGs and Restoration Types, (Section 10.6.2 of SOP; DWH NRDA Trustees, 2016). This guidance may also assist the TIGs by providing recommended methodologies for monitoring restoration projects, saving time and money spent developing suitable monitoring protocols for individual restoration projects. If adjustments from this monitoring guidance are needed for a particular project, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016). Project teams within each TIG will identify parameters applicable to the objectives for each individual restoration project when developing the project MAM Plan. In addition to the project monitoring guidance identified in this Manual, specific monitoring may be required to comply with permits granted by regulatory agencies. The TIGs are not restricted from adding additional parameters, and other project monitoring that may be needed for specific projects should be determined by the TIGs.

The Cross-TIG MAM developed this monitoring guidance by following the process described in the Monitoring and Adaptive Management Procedures and Guidelines Manual Version 1.0 (MAM Manual Version 1.0; DWH NRDA Trustees, 2017).

This guidance is intended to assist the TIGs in developing MAM Plans for restoration projects, as appropriate. Specifically, it provides:

- Examples of Restoration Techniques
- Guidance on example restoration objectives, example drivers, and example uncertainties
- Guidance on core performance monitoring parameters for projects within the Restoration Approach
- Guidance on supplemental performance monitoring parameters for specific restoration objectives.

The monitoring parameters identified within a project MAM Plan should be consistent with the recommended monitoring defined within this guidance document, wherever appropriate. Depending on the nature of the restoration project, TIGs may choose not to include some of the elements described in this guidance document (e.g., drivers, uncertainties). If adjustments from the monitoring guidance are needed, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). The guidance provided should not be considered exhaustive. Therefore, TIGs may develop project-level objectives, drivers, uncertainties, and monitoring parameters that have not been previously identified. The TIGs will develop MAM objectives and monitoring parameters that pertain to their restoration activities; and will determine the frequency and duration of monitoring, and the associated budget they deem appropriate. Finally, this section is subject to change as new monitoring parameters, methods, and technologies are identified and/or developed.

The monitoring parameters recommended in this guidance document are further detailed in Attachment E Section E.3, which includes a complete list of core- and objective-specific monitoring parameters identified by the Cross-TIG MAM work group and guidance on measurement unit(s) and monitoring methods. Guidance on monitoring locations, frequencies, durations of sampling and potential analyses is also provided where appropriate.

E.5.1. Restoration Techniques

Restoration Techniques are specific restoration actions the Trustees identified for each of the Restoration Approaches. Restoration Techniques may be used individually or in combination. See Appendix 5.D of the PDARP/PEIS (DWH NRDA Trustees, 2016a). The following are example Restoration Techniques included in the PDARP/PEIS for this Restoration Approach. This list should not be considered exhaustive; additional Restoration Techniques may be developed and/or identified.

1. Restore or construct barrier and coastal islands and headlands via placement of dredged sediments
2. Plant vegetation on dunes and back-barrier marsh.

E.5.2. Example Project-Level Restoration Objectives

Project-level restoration objectives should be specific to the resource injuries and clearly specify the desired outcome(s) of the restoration project (15 CFR § 990.55(b)(2)). See Section 2.4.1 of the MAM Manual Version 1.0 for guidance on establishing restoration objectives. The following are example project-level restoration objectives that may apply to one or more of the above-mentioned Restoration Techniques. This list should not be considered exhaustive; additional objectives may be developed and/or identified.

- Restore a barrier island that is sustained for the expected project lifespan to provide coastal habitat(s) important for the restoration of ecosystem functions and stability.
- Restore a barrier island structure to reduce potential storm damage impacts on coastal habitats.
- Promote establishment of beach dune and back-barrier marsh vegetation to:
- Stabilize marsh and beach sediments
- Stabilize the shoreline
- Promote longevity of the subaerial island
- Reduce erosion
- Encourage sediment deposition
- Contribute to the ecosystem function (habitat for birds and native species) of dunes and back-barrier marshes.
- Increase availability of high-quality beach and/or dune habitat in support of species utilization, foraging, and/or nesting activity.
- Promote recovery of Threatened and Endangered (T&E) Species.
- Improve the long-term littoral drift/sediment transport system to naturally sustain barrier systems.
- Enhance recreational use.
- Maintain a sand beach and dune system to improve the resilience and sustainability of coastal habitat by the capture or retention of sand. Reduce the rate of sediment loss and/or reduce erosion.

- Maintain beach, dune, back-barrier marsh elevation profile and area, as well as adjacent subtidal areas.
- Minimize habitat loss and fragmentation; reduce adverse human impacts (e.g., development, vehicular and pedestrian traffic) to protect the barrier or coastal island system.

E.5.3. Example Drivers

Drivers are outside forces, natural or anthropogenic, that have the potential to influence the outcome(s) of a restoration project. Drivers tend to be large-scale, long-term forces that are not easily controlled at the scale of a single restoration project (Harwell et al., 2016). See Section 2.4.2 of the MAM Manual Version 1.0 for guidance on establishing the conceptual setting for a MAM Plan, including identifying drivers. The following are example drivers that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional drivers may be identified.

- Adjacent development/land use
- Sediment availability
- Wave dynamics
- Storm events
- Sea level rise.

E.5.4. Example Uncertainties

Uncertainties or information gaps have the potential to affect adaptive management decisions for individual or multiple restoration projects. These decisions may include how to improve the likelihood of achieving favorable project outcomes or selecting corrective actions in the event a project is not performing as intended. See Section 2.4.3 of the MAM Manual Version 1.0 for guidance on identifying potential sources of uncertainty for a MAM Plan. The following are example uncertainties that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional uncertainties may be identified.

- Natural variability in ecological and physical processes, such as wave-driven transport or vegetation growth, and in the associated barrier island response (e.g., geomorphic variability and barrier island evolution)
- Short- and long-term fate of natural and/or placed material
- Climate variability, such as tropical cyclone frequency, intensity, and timing; and the impact on redistributing natural or placed sand on vegetation types, growth, and distribution
- Future rate of local relative sea level rise (e.g., subsidence plus eustatic variability), including if the rate of rise will be relatively constant or will accelerate the ecological and geomorphic response of the island to sea level rise
- Adequate availability of appropriate borrow sources
- Availability of property
- Timeframe for recolonization of native fauna species (e.g., year-round residential species, nesting species, T&E Species, migratory species, vegetation, invertebrates)
- Sustainability of long-term project management (e.g., continued funding)
- Permitting.

E.5.5. Guidance on Developing Parameters for Project-Level Performance

This section includes two types of monitoring parameters for consideration under the Create, Restore, and Enhance Barrier and Coastal Islands and Headlands Restoration Approach:

1. Core performance monitoring parameters applicable to projects within a Restoration Approach (core performance monitoring parameters are those used consistently across projects in order to facilitate the aggregation of project monitoring results and the evaluation of restoration progress for each Restoration Type; Appendix 5.E.4 of PDARP/PEIS; DWH NRDA Trustees, 2016a)
2. Objective-specific performance monitoring parameters that are only applicable to projects with a particular restoration objective.

Additional adaptive management and/or validation monitoring parameters for consideration have also been identified. These additional parameters may be helpful for resolving uncertainties, explaining outside drivers, optimizing project implementation, supporting decisions about corrective actions and other adaptive management of the project, and informing the planning of future DWH NRDA restoration projects. Tables E.5.1 and E.5.2 should not be considered exhaustive, and other parameters may be considered, as appropriate. See the complete list of core- and objective-specific monitoring parameters, Section E.3 above, for details on the core performance monitoring parameters including definitions, units, and other guidance.

Table E.5.1. Core performance monitoring parameters and additional parameters for consideration under the Create, Restore, and Enhance Barrier and Coastal Islands and Headlands Restoration Approach

Core performance monitoring parameters	Parameters for consideration (as appropriate)
• Area • Shoreline position • Elevation	• Width (beach, dune, island) • Classification of hardbottom and submerged habitats • Position of hardbottom and submerged habitats • Substratum type • Relief • Sediment distribution within hardbottom habitats • Persistence or exposure of hardbottom habitats • Habitat connectivity • Wave height/energy/attenuation • Velocity and patterns • Sediment budget and transport patterns • Frequency and extent of overtopping and overwash

Table E.5.2. Performance monitoring parameters and additional parameters for consideration for projects with specific restoration objectives. These would be collected in addition to the parameters listed in Table E.5.1.

Project-specific objective	Objective-specific performance monitoring parameters	Parameters for consideration (as appropriate)
Stabilize marsh and/or shoreline by promoting establishment of beach, dune, and back-barrier marsh vegetation	• Vegetation density or vegetation percent cover • Vegetation species composition	• Survival/mortality • Height

Project-specific objective	Objective-specific performance monitoring parameters	Parameters for consideration (as appropriate)
Reduce sediment loss and erosion and/or reduce adverse human impacts	• Structural integrity and function of constructed features	• Extent of shoreline armoring • Sediment depth data, texture, type, and consolidation rate • Number of protected habitat sites • Sediment budget and transport patterns • Visitor use and access • Vegetation density • Vegetation percent cover • Vegetation species composition • Species density/abundance • Species utilization
Living coastal marine resource or T&E Species habitat, utilization, foraging, nesting, or recovery	• Bird (or targeted injured species) abundance/density • Bird (or targeted injured) species composition	• Bird nest density • Bird habitat utilization • Bird nest success • Nekton diversity and/or abundance • Benthic abundance, biomass, diversity • Targeted injured species abundance/density • Targeted injured species utilization • Hardbottom mapping • Dissolved oxygen • Turbidity • Salinity (surface water) • Sediment depth data, texture, type, and consolidation rate
Enhance recreational use	• See Enhance Public Access to Natural Resources for Recreational Use Monitoring Guidance (Section E.11 of Attachment E of this manual) for core and objective-specific performance monitoring parameters	• See Enhance Public Access to Natural Resources for Recreational Use Monitoring Guidance (Section E.11 of Attachment E of this manual) for core and objective-specific performance monitoring parameters

References

DWH NRDA Trustees. 2016a. *Deepwater Horizon* Oil Spill: Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS). Available: http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan.

DWH NRDA Trustees. 2016b. Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the *Deepwater Horizon* (DWH) Oil Spill. Originally approved May 4, 2016; revised November 15, 2016.

Harwell, M.A., J.H. Gentile, L.D. McKinney, J.W. Tunnell Jr., W.C. Dennison, and R.H. Kelsey. 2016. A New Framework for the Gulf of Mexico EcoHealth Metrics. Available: http://www.harteresearchinstitute.org/sites/default/files/resources/Framework%20for%20the%20Gulf%20EcoHealth%20Metric.pdf.

E.6. Restore and Enhance Dunes and Beaches: Monitoring Guidance


This guidance is intended to promote consistency in data collection among similar types of projects and allow for future analysis across TIGs and Restoration Types, (Section 10.6.2 of SOP; DWH NRDA Trustees, 2016). This guidance may also assist the TIGs by providing recommended methodologies for monitoring restoration projects, saving time and money spent developing suitable monitoring protocols for individual restoration projects. If adjustments from this monitoring guidance are needed for a particular project, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016). Project teams within each TIG will identify parameters applicable to the objectives for each individual restoration project when developing the project MAM Plan. In addition to the project monitoring guidance identified in this Manual, specific monitoring may be required to comply with permits granted by regulatory agencies. The TIGs are not restricted from adding additional parameters, and other project monitoring that may be needed for specific projects should be determined by the TIGs.

The Cross-TIG MAM developed this monitoring guidance by following the process described in the Monitoring and Adaptive Management Procedures and Guidelines Manual Version 1.0 (MAM Manual Version 1.0; DWH NRDA Trustees, 2017).

This guidance is intended to assist the TIGs in developing MAM Plans for restoration projects, as appropriate. Specifically, it provides:

- Examples of Restoration Techniques
- Guidance on example restoration objectives, example drivers, and example uncertainties
- Guidance on core performance monitoring parameters for projects within the Restoration Approach
- Guidance on supplemental performance monitoring parameters for specific restoration objectives.

The monitoring parameters identified within a project MAM Plan should be consistent with the recommended monitoring defined within this guidance document, wherever appropriate. Depending on the nature of the restoration project, TIGs may choose not to include some of the elements described in this guidance document (e.g., drivers, uncertainties). If adjustments from the monitoring guidance are needed, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). The guidance provided should not be considered exhaustive. Therefore, TIGs may develop project-level objectives, drivers, uncertainties, and monitoring parameters that have not been previously identified. The TIGs will develop MAM objectives and monitoring parameters that pertain to their restoration activities; and will determine the frequency and duration of monitoring, and the associated budget they deem appropriate. Finally, this section is subject to

change as new monitoring parameters, methods, and technologies are identified and/or developed.

The monitoring parameters recommended in this guidance document are further detailed in Attachment E Section E.3, which includes a complete list of core- and objective-specific monitoring parameters identified by the Cross-TIG MAM work group and guidance on measurement unit(s) and monitoring methods. Guidance on monitoring locations, frequencies, durations of sampling and potential analyses is also provided where appropriate.

E.6.1. Restoration Techniques

Restoration Techniques are specific restoration actions the Trustees identified for each of the Restoration Approaches. Restoration Techniques may be used individually or in combination. See Appendix 5.D of the PDARP/PEIS (DWH NRDA Trustees, 2016a). The following are example Restoration Techniques included in the PDARP/PEIS for this Restoration Approach. This list should not be considered exhaustive; additional Restoration Techniques may be developed and/or identified.

1. Renourish beaches through sediment addition
2. Restore dune and beach systems through the use of passive techniques to trap sand
3. Plant vegetation on dunes
4. Construct groins and breakwaters or use sediment bypass methods
5. Protect dune systems through the use of access control.

E.6.2. Example Project-Level Restoration Objectives

Project-level restoration objectives should be specific to the resource injuries and clearly specify the desired outcome(s) of the restoration project (15 CFR § 990.55(b)(2)). See Section 2.4.1 of the MAM Manual Version 1.0 for guidance on establishing restoration objectives. The following are example project-level restoration objectives that may apply to one or more of the above-mentioned Restoration Techniques. This list should not be considered exhaustive; additional objectives may be developed and/or identified.

- Create, stabilize, protect, restore, and/or enhance the beach and/or dune system, to improve the resilience (e.g., to storm damage) and sustainability of coastal habitats.
- Promote establishment of beach dune and marsh vegetation to stabilize sediment, stabilize shoreline, reduce erosion, encourage sediment deposition, and contribute to the ecosystem function (e.g., habitat for birds and native species) of dunes and marshes.
- Increase availability of a high-quality specific beach and/or dune habitat for species utilization, including foraging and/or nesting activity.
- Promote recovery of T&E Species.
- Improve the long-term littoral drift/sediment transport system to promote more sustainable beach and dune systems.
- Enhance recreational use.
- Maintain a sand beach and dune system to improve the resilience and sustainability of coastal habitat by the capture or retention of sand. Reduce the rate of sediment loss and/or reduce erosion.
- Minimize habitat loss/fragmentation and reduce adverse human impacts (e.g., development, vehicular and pedestrian traffic) to protect system.

E.6.3. Example Drivers

Drivers are outside forces, natural or anthropogenic, that have the potential to influence the outcome(s) of a restoration project. Drivers tend to be large-scale, long-term forces that are not easily controlled at the scale of a single restoration project (Harwell et al., 2016). See Section 2.4.2 of the MAM Manual Version 1.0 for guidance on establishing the conceptual setting for a MAM Plan, including identifying drivers. The following are example drivers that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional drivers may be identified.

- Adjacent development/land use
- Sediment availability
- Wave dynamics
- Storm events
- Sea level rise.

E.6.4. Example Uncertainties

Uncertainties or information gaps have the potential to affect adaptive management decisions for individual or multiple restoration projects. These decisions may include how to improve the likelihood of achieving favorable project outcomes or selecting corrective actions in the event a project is not performing as intended. See Section 2.4.3 of the MAM Manual Version 1.0 for guidance on identifying potential sources of uncertainty for a MAM Plan. The following are example uncertainties that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional uncertainties may be identified.

- Natural variability in ecological and physical processes, such as wave-driven transport or vegetation growth, and in the associated dune and beach response (e.g., geomorphic variability and evolution)
- Short- and long-term fate of natural and/or placed material
- Climate change variability, such as tropical cyclone frequency, intensity, and timing; and the impact on redistributing natural and/or placed sand on vegetation types, growth, and distribution
- Future rate of local relative sea level rise (e.g., subsidence plus eustatic variability), including if the rate of rise will be relatively constant or will accelerate how the island will respond
- Adequate availability of appropriate borrow sources
- Willingness of landowners to sell property or otherwise allow restoration activities
- Timeframe for re-establishment/recolonization of native flora and fauna species (e.g., year-round resident, nesting species, migratory species, T&E Species, invertebrates/prey base, vegetation).

E.6.5. Guidance on Developing Parameters for Project-Level Performance

This section includes two types of monitoring parameters for consideration under the Restore and Enhance Dunes and Beaches Restoration Approach:

1. Core performance monitoring parameters applicable to projects within a Restoration Approach (core performance monitoring parameters are those used consistently across projects in order to facilitate the aggregation of project monitoring results and the evaluation of restoration progress for each Restoration Type; Appendix 5.E.4 of PDARP/PEIS; DWH NRDA Trustees, 2016a)

2. Objective-specific performance monitoring parameters that are only applicable to projects with a particular restoration objective.

Additional adaptive management and/or validation monitoring parameters for consideration have also been identified. These additional parameters may be helpful for resolving uncertainties, explaining outside drivers, optimizing project implementation, supporting decisions about corrective actions and other adaptive management of the project, and informing the planning of future DWH NRDA restoration projects. Tables E.6.1 and E.6.2 should not be considered exhaustive, and other parameters may be considered, as appropriate. See the complete list of core- and objective-specific monitoring parameters, Section E.3 above, for details on the core performance monitoring parameters including definitions, units, and other guidance.

Table E.6.1. Core performance monitoring parameters and additional parameters for consideration under the Restore and Enhance Dunes and Beaches Restoration Approach

Core performance monitoring parameters	Parameters for consideration (as appropriate)
• Area • Shoreline position • Elevation	• Width (beach, dune, island) • Classification of hardbottom and submerged habitat types • Position of hardbottom and submerged habitats • Substratum type • Relief • Distribution of sediment within hardbottom habitats • Hardbottom persistence or exposure • Habitat connectivity • Wave height/energy/attenuation • Flow magnitude and patterns • Sediment budget and transport patterns • Frequency and extent of overtopping and overwash

Table E.6.2. Performance monitoring parameters and additional parameters for consideration for projects with specific restoration objectives. These would be collected in addition to the parameters listed in Table E.6.1.

Project-specific objective	Objective-specific performance monitoring parameters	Parameters for consideration (as appropriate)
Promote establishment of beach dune and back-barrier marsh vegetation	• Vegetation density • Vegetation percent cover • Vegetation species composition	• Survival/mortality • Height
Reduce sediment loss and erosion and/or reduce adverse human impacts	• Structural integrity and function of constructed features (beach and dune protection features, including groins, breakwater, sand fencing and/or access control)	• Extent of shoreline armoring • Sediment depth data, texture, type, consolidation rate • Number of protected habitat sites • Visitor use and access • Vegetation density • Vegetation percent cover • Vegetation species composition • Species density/abundance • Species utilization

Project-specific objective	Objective-specific performance monitoring parameters	Parameters for consideration (as appropriate)
Living coastal marine resource or T&E Species habitat, utilization, foraging, nesting, or recovery	• Bird (or targeted injured species) abundance/density • Bird (or targeted injured) species composition	• Bird nest density • Bird habitat utilization • Bird nest success • Nekton diversity and or abundance • Benthic abundance, biomass, diversity • Targeted injured species abundance/density • Targeted injured species utilization • Hardbottom mapping • Dissolved oxygen • Turbidity • Salinity (surface water) • Sediment depth data, texture, type, and consolidation rate
Enhance recreational use	• See Enhance Public Access to Natural Resources for Recreational Use Monitoring Guidance (Section E.11 of Attachment E of this manual) for core and objective-specific performance monitoring parameters	• See Enhance Public Access to Natural Resources for Recreational Use Monitoring Guidance (Section E.11 of Attachment E of this manual) for core and objective-specific performance monitoring parameters

References

DWH NRDA Trustees. 2016a. *Deepwater Horizon* Oil Spill: Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS). Available: http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan.

DWH NRDA Trustees. 2016b. Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the *Deepwater Horizon* (DWH) Oil Spill. Originally approved May 4, 2016; revised November 15, 2016.

Harwell, M.A., J.H. Gentile, L.D. McKinney, J.W. Tunnell Jr., W.C. Dennison, and R.H. Kelsey. 2016. A New Framework for the Gulf of Mexico EcoHealth Metrics. Available: http://www.harteresearchinstitute.org/sites/default/files/resources/Framework%20for%20the%20Gulf%20EcoHealth%20Metric.pdf.

E.7. Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats: Monitoring Guidance

This guidance is intended to promote consistency in data collection among similar types of projects and allow for future analysis across TIGs and Restoration Types, (Section 10.6.2 of SOP; DWH NRDA Trustees, 2016). This guidance may also assist the TIGs by providing recommended methodologies for monitoring restoration projects, saving time and money spent developing suitable monitoring protocols for individual restoration projects. If adjustments from this monitoring guidance are needed for a particular project, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016). Project teams within each TIG will identify parameters applicable to the objectives for each individual restoration project when developing the project MAM Plan. In addition to the project monitoring guidance identified in this Manual, specific monitoring may be required to comply with permits granted by regulatory agencies. The TIGs are not restricted from adding additional parameters, and other project monitoring that may be needed for specific projects should be determined by the TIGs.

The Cross-TIG MAM work group developed this monitoring guidance by following the process described in the Monitoring and Adaptive Management Procedures and Guidelines Manual Version 1.0 (MAM Manual Version 1.0; DWH NRDA Trustees, 2017). This new guidance is being released as a supplement to MAM Manual Version 1.0.

This guidance is intended to assist the TIGs in developing MAM Plans for restoration projects, as appropriate. Specifically, it provides:

- Examples of Restoration Techniques
- Guidance on example restoration objectives, example drivers, and example uncertainties
- Guidance on core performance monitoring parameters for projects within the Restoration Approach
- Guidance on supplemental performance monitoring parameters for specific restoration objectives.

The monitoring parameters identified within a Protect and Conserve Marine, Coastal, Estuarine and Riparian project MAM Plan should be consistent with the recommended monitoring defined within this guidance document, wherever appropriate. Depending on the nature of the restoration project, TIGs may choose not to include some of the elements described in this guidance document (e.g., drivers, uncertainties). If adjustments from the monitoring guidance are needed, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). The guidance provided should not be considered exhaustive. Therefore, TIGs may develop project-level objectives, drivers, uncertainties, and monitoring parameters that have not been previously identified. The TIGs will develop MAM objectives and monitoring parameters that pertain to their restoration activities; and will determine the frequency and duration of monitoring, and the associated budget they deem appropriate. Finally, this guidance may change as new monitoring parameters, methods, and technologies are identified and/or developed.

The monitoring parameters recommended in this guidance document are further detailed in Attachment E Section E.3, which includes a complete list of core- and objective-specific monitoring parameters identified by the Cross-TIG MAM work group and guidance on measurement unit(s) and monitoring methods. Guidance on monitoring locations, frequencies, durations of sampling and potential analyses is also provided where appropriate.

E.7.1. Restoration Techniques

Restoration Techniques are specific restoration actions the Trustees identified for each of the Restoration Approaches. Restoration Techniques may be used individually or in combination. See Appendix 5.D of the PDARP/PEIS (DWH NRDA Trustees, 2016a). The following are example Restoration Techniques included in the PDARP/PEIS for this Restoration Approach. This list should not be considered exhaustive; additional Restoration Techniques may be developed and/or identified.

1. Acquire lands for conservation.
2. Develop and implement management actions in conservation areas and/or restoration projects.
3. Establish or expand protections for marine areas.

E.7.2. Example Project-Level Restoration Objectives

Project-level restoration objectives should be specific to the resource injuries and clearly specify the desired outcome(s) of the restoration project (15 CFR § 990.55(b)(2)). See Section 2.4.1 of the MAM Manual Version 1.0 for guidance on establishing restoration objectives. The following are example project-level restoration objectives that may apply to one or more of the above-mentioned Restoration Techniques. This list should not be considered exhaustive; additional objectives may be developed and/or identified.

- Acquire or conserve land to conserve target habitats for fish and wildlife; create connections between natural areas; provide protective buffers for existing protected lands, sensitive habitats, and/or water bodies; and /or to facilitate habitat management.
- Acquire or conserve land to prevent threats of development.
- Establish or expand protections for marine habitat to help maintain essential ecological processes, preserve genetic diversity, and/or ensure sustainable use of species and ecosystems.
- Acquire or conserve land to provide mechanisms for protected species management.
- Develop and/or implement management actions to enhance habitats to benefit target fish, wildlife and/or ecosystem services. Example actions include debris removal, invasive species control, vegetation management, and/or visitor access.
- Implement management actions to enhance nesting and foraging habitat for birds
- Acquire or conserve land to protect critical freshwater inflows to estuaries.

E.7.3. Example Drivers

Drivers are outside forces, natural or anthropogenic, that have the potential to influence the outcomes of a restoration project. Drivers tend to be large-scale, long-term forces that are not easily controlled at the scale of a single restoration project (Harwell et al., 2016). See Section 2.4.2 of the MAM Manual Version 1.0 for guidance on establishing the conceptual setting for a MAM Plan, including identifying drivers. The following are example drivers that may

be applicable to this Restoration Approach. This list should not be considered exhaustive; additional drivers may be identified.

- Anthropogenic development
- Sea level rise
- Regeneration of native vegetative communities
- Habitat degradation
- Storm impacts
- Ocean acidification

E.7.4. Example Uncertainties

Uncertainties or information gaps have the potential to affect adaptive management decisions for individual or multiple restoration projects. These decisions may include how to improve the likelihood of achieving favorable project outcomes or selecting corrective actions in the event a project is not performing as intended. See Section 2.4.3 of the MAM Manual Version 1.0 for guidance on identifying potential sources of uncertainty for a MAM Plan. The following are example uncertainties that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional uncertainties may be identified.

- Availability of land for protection or conservation
- Ability to identify willing sellers that own targeted habitats
- Ability to coordinate management of target habitats with existing management plans or agencies with management authority
- Lack of understanding of the threats affecting species targeted for restoration
- Future rate of local relative sea level rise
- Present or future visitor use patterns
- Time lag between management actions and response (e.g., protection actions and system response, interval of invasive plant regeneration through seedbank)
- Opportunities for or barriers to habitat migration
- Ability to enforce management actions

E.7.5. Guidance on Developing Parameters for Project-Level Performance

This section includes two types of monitoring parameters for consideration under the Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats Restoration Approach:

1. Core performance monitoring parameters applicable to projects within a Restoration Approach (core performance monitoring parameters are those used consistently across projects in order to facilitate the aggregation of project monitoring results and the evaluation of restoration progress for each Restoration Type; Appendix 5.E.4 of PDARP/PEIS; DWH NRDA Trustees, 2016a)
2. Objective-specific performance monitoring parameters that are only applicable to projects with a particular restoration objective.

Additional adaptive management and/or validation monitoring parameters for consideration have also been identified. These additional parameters may be helpful for resolving uncertainties, explaining outside drivers, optimizing project implementation, supporting decisions about corrective actions and other adaptive management of the project, and informing the planning of future DWH NRDA restoration projects. Tables E.7.1 and E.7.2 should not be considered exhaustive, and other parameters may be considered, as appropriate. See the complete list of core- and objective-specific monitoring parameters for details on the core performance monitoring parameters including definitions, units, and other guidance.

Table E.7.1. Core performance monitoring parameters and additional parameters for consideration under the Protect and Conserve Marine, Coastal, Estuarine, and Riparian Habitats Restoration Approach

Core performance monitoring parameters	Parameters for consideration (as appropriate)
• Area of Project Footprint • Terms of conservation/management plan are being met[a]	• Elevation • Habitat utilization by target species • Species abundance/diversity

[a]. If project includes a conservation/management agreement.

Table E.7.2. Performance monitoring parameters and additional parameters for consideration for projects with specific restoration objectives. These would be collected in addition to the parameters listed in Table E.7.1.

Project-specific objective	Objective-specific performance monitoring parameters	Parameters for consideration (as appropriate)
Create connections between natural areas	• Area of Project Influence	• None identified
Management of invasive species and enhancement of native plantings	• Vegetation survival • Vegetation percent cover • Vegetation species composition	• Vegetation density
Management, control, and removal of debris	• Debris	• None identified.
Enhance habitat for targeted species (e.g. sea turtles, birds)	• Targeted Injured Species Abundance/Density	• Abundance of preferred food/prey species for targeted species • Abundance/density of competing species, invasives, or predators for targeted species • Reproductive capacity of targeted species
Improve coastal water quality[a]	• Dissolved oxygen (DO) • pH • Temperature • Salinity (surface water) • Specific conductance • Discharge • Turbidity	• Nutrients • Pathogens (bacteria) • Sediments

[a] See the “Reduce Nutrient Loads to Coastal Watershed & Reduce Pollution and Hydrologic Degradation to Coastal Watersheds: Monitoring Guidance” for additional details (DWH NRDA Trustees 2017).

References

DWH NRDA Trustees. 2016a. *Deepwater Horizon* Oil Spill: Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS). Available: http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan.

DWH NRDA Trustees. 2016b. Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the *Deepwater Horizon* (DWH) Oil Spill. Originally approved May 4, 2016; revised November 15, 2016.

DWH NRDA Trustees. 2017. Monitoring and Adaptive Management Procedures and Guidelines Manual Version 1.0. Appendix to the Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the DWH Oil Spill. December. Available: http://www.gulfspillrestoration.noaa.gov/.

E.8. Reduce Nutrient Loads to Coastal Watersheds & Reduce Pollution and Hydrologic Degradation to Coastal Watersheds: Monitoring Guidance

This guidance is intended to promote consistency in data collection among similar types of projects and allow for future analysis across TIGs and Restoration Types, (Section 10.6.2 of SOP; DWH NRDA Trustees, 2016). This guidance may also assist the TIGs by providing recommended methodologies for monitoring restoration projects, saving time and money spent developing suitable monitoring protocols for individual restoration projects. If adjustments from this monitoring guidance are needed for a particular project, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016). Project teams within each TIG will identify parameters applicable to the objectives for each individual restoration project when developing the project MAM Plan. In addition to the project monitoring guidance identified in this Manual, specific monitoring may be required to comply with permits granted by regulatory agencies. The TIGs are not restricted from adding additional parameters, and other project monitoring that may be needed for specific projects should be determined by the TIGs.

The Cross-TIG MAM developed this monitoring guidance by following the process described in the Monitoring and Adaptive Management Procedures and Guidelines Manual Version 1.0 (MAM Manual Version 1.0; DWH NRDA Trustees, 2017).

This guidance is intended to assist the TIGs in developing MAM Plans for restoration projects, as appropriate. Specifically, this document provides:

- Examples of Restoration Techniques
- Guidance on example restoration objectives, example drivers, and example uncertainties
- Guidance on core performance monitoring parameters for projects within the Restoration Approaches
- Guidance on supplemental performance monitoring parameters for specific restoration objectives.

The monitoring parameters identified within a project MAM Plan should be consistent with the recommended monitoring defined within this guidance document, wherever appropriate. Depending on the nature of the restoration project, TIGs may choose not to include some of the elements described in this guidance document (e.g., drivers, uncertainties). If adjustments from the monitoring guidance are needed, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). The guidance provided should not be considered exhaustive. Therefore, TIGs may develop project-level objectives, drivers, uncertainties, and monitoring parameters that have not been previously identified. The TIGs will develop MAM objectives and monitoring parameters that pertain to their restoration activities; and will determine the frequency and duration of monitoring, and the associated budget they deem appropriate. Finally, this section is subject to change as new monitoring parameters, methods, and technologies are identified and/or developed.

The monitoring parameters recommended in this guidance document are further detailed in Attachment E Section E.3, which includes a complete list of core- and objective-specific monitoring parameters identified by the Cross-TIG MAM work group and guidance on measurement unit(s) and monitoring methods. Guidance on monitoring locations, frequencies, durations of sampling and potential analyses is also provided where appropriate.

E.8.1. Restoration Techniques

Restoration Techniques are specific restoration actions the Trustees identified for each of the Restoration Approaches. Restoration Techniques may be used individually or in combination. See Appendix 5.D of the PDARP/PEIS (DWH NRDA Trustees, 2016a). The following are example Restoration Techniques included in the PDARP for these Restoration Approaches. This list should not be considered exhaustive; additional Restoration Techniques may be developed and/or identified.

1. Agricultural conservation practices
2. Forestry management practices
3. Low-impact development practices
4. Traditional stormwater control measures
5. Erosion and sediment control practices
6. Hydrologic restoration practices.

E.8.2. Example Project-Level Restoration Objectives

Project-level restoration objectives should be specific to the resource injuries and clearly specify the desired outcome(s) of the restoration project (15 CFR § 990.55(b)(2)). See Section 2.4.1 of the MAM Manual Version 1.0 for guidance on establishing restoration objectives. The following are example project-level restoration objectives that may apply to one or more of the above-mentioned Restoration Techniques. This list should not be considered exhaustive; additional objectives may be developed and/or identified.

- Reduce nutrient, sediment, and/or pathogen (e.g., bacteria) concentrations and loadings
- Enhance dissolved oxygen concentration, turbidity, pH, salinity, and/or specific conductance.

E.8.3. Example Drivers

Drivers are outside forces, natural or anthropogenic, that have the potential to influence the outcomes of a restoration project. Drivers tend to be large-scale, long-term forces that are not easily controlled at the scale of a single restoration project (Harwell et al., 2016). See Section 2.4.2 of the MAM Manual Version 1.0 for guidance on establishing the conceptual setting for a MAM Plan, including identifying drivers. The following are example drivers that may be applicable to these Restoration Approaches. This list should not be considered exhaustive; additional drivers may be identified.

- Coastal development
- Changes in land use
- Land-use practices (e.g., application of fertilizer)

- Alterations to freshwater flows.

E.8.4. Example Uncertainties

Uncertainties or information gaps have the potential to affect adaptive management decisions for individual or multiple restoration projects. These decisions may include how to improve the likelihood of achieving favorable project outcomes or selecting corrective actions in the event a project is not performing as intended. See Section 2.4.3 of the MAM Manual Version 1.0 for guidance on identifying potential sources of uncertainty for a MAM Plan. The following are example uncertainties that may be applicable to these Restoration Approaches. This list should not be considered exhaustive; additional uncertainties may be identified.

- Willingness of landowners to participate
- Linkages between water quality improvements and ecosystem benefits
- Degree to which local improvements in water quality contribute to water quality improvements downstream
- Combination and placement of projects within a watershed to maximize benefits in receiving estuary
- Pollutant transport and freshwater flow through Gulf coastal watersheds
- Relationship between watershed pollutant loadings and occurrence of Gulf coastal ecosystem threats and human use impacts.

E.8.5. Guidance on Developing Parameters for Project-Level Performance

This section includes two types of monitoring parameters for consideration under the Reduce Nutrient Loads to Coastal Watersheds & Reduce Pollution and Hydrologic Degradation to Coastal Watersheds Restoration Approaches:

1. Core performance monitoring parameters applicable to projects within a Restoration Approach (core performance monitoring parameters are those used consistently across projects in order to facilitate the aggregation of project monitoring results and the evaluation of restoration progress for each Restoration Type; Appendix 5.E.4 of PDARP/PEIS; DWH NRDA Trustees, 2016a)
2. Objective-specific performance monitoring parameters that are only applicable to projects with a particular restoration objective.

Additional adaptive management and/or validation monitoring parameters for consideration have also been identified. These additional parameters may be helpful for resolving uncertainties, explaining outside drivers, optimizing project implementation, supporting decisions about corrective actions and other adaptive management of the project, and informing the planning of future DWH NRDA restoration projects. Tables E.8.1 and E.8.2 should not be considered exhaustive, and other parameters may be considered, as appropriate. See the complete list of core- and objective-specific monitoring parameters, Section E.3 above, for details on the core performance monitoring parameters including definitions, units, and other guidance.

Generally, in-situ water quality parameters will be collected at the same time as chemical (nutrients, sediments, pathogens, and others) and/or ecological/biological sampling; and at the same locations, frequencies, and depths.

Table E.8.1. Core performance monitoring parameters and additional parameters for consideration under the Reduce Nutrient Loads to Coastal Watersheds & Reduce Pollution and Hydrologic Degradation to Coastal Watersheds Restoration Approaches

Core performance monitoring parameters	Parameters for consideration (as appropriate)
• Number of water quality improvement practices implemented • Area of water quality improvement practices implemented (acres impacted)	• Ammonium nitrogen (NH_4-N) • Nitrite plus nitrate nitrogen (NO_2-N + NO_3-N) • Total Kjeldahl Nitrogen (TKN) • Loads (water level and flow)

Table E.8.2. Performance monitoring parameters and additional parameters for consideration for projects with specific restoration objectives. These would be collected in addition to the parameters listed in Table E.8.1.

Project-specific objective	Objective-specific performance monitoring parameters	Parameters for consideration (as appropriate)
Reduce nutrient concentrations and loadings	• Total nitrogen (TN) • Total phosphorus (TP)	• Soluble Reactive P (Orthophosphate phosphorus) • Chlorophyll *a* • Depth • Tidal cycle
Reduce sediment concentrations and loadings	• Total suspended solids (TSS) • Turbidity	• Suspended sediment concentration (SSC) • Loads (discharge and concentration) • Bedload/bed sediment • Water depth • Secchi depth
Reduce pathogen concentrations and/or exposures	• *E. coli* • Enterococci • Fecal coliform	• *Vibrio cholera* • *Vibrio vulnificus* • Coliphages
Improve in-situ water quality	• Dissolved oxygen (DO) • pH • Temperature • Salinity (surface water) • Specific conductance • Discharge or velocity (water flow) • Turbidity	• Chlorophyll *a* (biomass) • Phytoplankton (biomass and/or biovolume) • Pigments • Loading
Restore natural hydrology and/or reduce hydrologic degradation	• Salinity (surface water) • Discharge or velocity (water flow)	• Water level

References

DWH NRDA Trustees. 2016a. *Deepwater Horizon* Oil Spill: Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS). Available: http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan.

DWH NRDA Trustees. 2016b. Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the *Deepwater Horizon* (DWH) Oil Spill. Originally approved May 4, 2016; revised November 15, 2016.

Harwell, M.A., J.H. Gentile, L.D. McKinney, J.W. Tunnell Jr., W.C. Dennison, and R.H. Kelsey. 2016. A New Framework for the Gulf of Mexico EcoHealth Metrics. Available: http://www.harteresearchinstitute.org/sites/default/files/resources/Framework%20for%20the%20Gulf%20EcoHealth%20Metric.pdf.

E.9. Restore and Enhance Submerged Aquatic Vegetation: Monitoring Guidance

This guidance is intended to promote consistency in data collection among similar types of projects and allow for future analysis across TIGs and Restoration Types, (Section 10.6.2 of SOP; DWH NRDA Trustees, 2016). This guidance may also assist the TIGs by providing recommended methodologies for monitoring restoration projects, saving time and money spent developing suitable monitoring protocols for individual restoration projects. If adjustments from this monitoring guidance are needed for a particular project, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016). Project teams within each TIG will identify parameters applicable to the objectives for each individual restoration project when developing the project MAM Plan. In addition to the project monitoring guidance identified in this Manual, specific monitoring may be required to comply with permits granted by regulatory agencies. The TIGs are not restricted from adding additional parameters, and other project monitoring that may be needed for specific projects should be determined by the TIGs.

The Cross-TIG MAM work group developed this monitoring guidance by following the process described in the Monitoring and Adaptive Management Procedures and Guidelines Manual Version 1.0 (MAM Manual Version 1.0; DWH NRDA Trustees, 2017). This new guidance is being released as a supplement to MAM Manual Version 1.0.

This guidance is intended to assist the TIGs in developing MAM Plans for restoration projects, as appropriate. Specifically, it provides:

- Examples of Restoration Techniques
- Guidance on example restoration objectives, example drivers, and example uncertainties
- Guidance on core performance monitoring parameters for projects within the Restoration Approach
- Guidance on supplemental performance monitoring parameters for specific restoration objectives.

The monitoring parameters identified within a Restore and Enhance Submerged Aquatic Vegetation project MAM Plan should be consistent with the recommended monitoring defined within this guidance document, wherever appropriate. Depending on the nature of the restoration project, TIGs may choose not to include some of the elements described in this guidance document (e.g., drivers, uncertainties). If adjustments from the monitoring guidance are needed, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). The guidance provided should not be considered exhaustive. Therefore, TIGs may develop project-level objectives, drivers, uncertainties, and monitoring parameters that have not been previously identified. The TIGs will develop MAM objectives and monitoring parameters that pertain to their restoration activities; and will determine the frequency and duration of monitoring, and the associated budget they deem appropriate. Finally, this guidance may change as new monitoring parameters, methods, and technologies are identified and/or developed.

The monitoring parameters recommended in this guidance document are further detailed in Attachment E Section E.3, which includes a complete list of core- and objective-specific monitoring parameters identified by the Cross-TIG MAM work group and guidance on measurement unit(s) and monitoring methods. Guidance on monitoring locations, frequencies, durations of sampling and potential analyses is also provided where appropriate.

E.9.1. Restoration Techniques

Restoration Techniques are specific restoration actions the Trustees identified for each of the Restoration Approaches. Restoration Techniques may be used individually or in combination. See Appendix 5.D of the PDARP/PEIS (DWH NRDA Trustees, 2016a). The following are example Restoration Techniques included in the PDARP/PEIS for this Restoration Approach. This list should not be considered exhaustive; additional Restoration Techniques may be developed and/or identified.

1. Backfill scars with sediment
2. Revegetate SAV beds via propagation and/or transplanting
3. Enhance SAV beds through nutrient addition
4. Protect SAV beds with buoys, signage, and/or other protective measures
5. Protect and enhance SAV through wave attenuation structures

E.9.2. Example Project-Level Restoration Objectives

Project-level restoration objectives should be specific to the resource injuries and clearly specify the desired outcome(s) of the restoration project (15 CFR § 990.55(b)(2)). See Section 2.4.1 of the MAM Manual Version 1.0 for guidance on establishing restoration objectives. The following are example project-level restoration objectives that may apply to one or more of the above-mentioned Restoration Techniques. This list should not be considered exhaustive; additional objectives may be developed and/or identified.

- Restore sea floor elevation to promote SAV
- Promote regrowth of native SAV
- Increase or maintain native SAV
- Increase or maintain site-specific nutrient levels to enhance SAV beds (e.g., bird stakes)
- Improve or maintain water quality
- Reduce current velocity and wave action to protect or restore SAV
- Provide habitat for targeted species (e.g., fish, wildlife)
- Increase abundance of targeted injured species (e.g., fish, wildlife)

E.9.3. Example Drivers

Drivers are outside forces, natural or anthropogenic, that have the potential to influence the outcome(s) of a restoration project. Drivers tend to be large-scale, long-term forces that are not easily controlled at the scale of a single restoration project (Harwell et al., 2016). See Section 2.4.2 of the MAM Manual Version 1.0 for guidance on establishing the conceptual setting for a MAM Plan, including identifying drivers. The following are example drivers that may

be applicable to this Restoration Approach. This list should not be considered exhaustive; additional drivers may be identified.

- Hydrologic regime
- Freshwater inflow
- Precipitation
- Sediment input/load
- Burial
- Subsidence
- Nutrients
- Sea level rise
- Storms/wave energy
- Sediment accretion/erosion
- Grazing/herbivory
- Hard-freeze events
- Invasive species
- Physical impacts, including boat scarring
- Boat wakes
- Adjacent development/land use
- Chemical impacts (e.g., oil spills)

E.9.4. Example Uncertainties

Uncertainties or information gaps have the potential to affect adaptive management decisions for individual or multiple restoration projects. These decisions may include how to improve the likelihood of achieving favorable project outcomes or selecting corrective actions in the event a project is not performing as intended. See Section 2.4.3 of the MAM Manual Version 1.0 for guidance on identifying potential sources of uncertainty for a MAM Plan. The following are example uncertainties that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional uncertainties may be identified.

- Local subsidence and accretion rates (e.g., organic, mineral)
- Optimal hydrologic conditions (e.g., turbidity, wave energy) for sustainability of the SAV bed
- Sediment and nutrient inputs
- Vegetation stress due to herbivory, disease, competition by invasive species
- Best method to revegetate SAV bed (e.g., seed, propagule)
- Appropriate habitat characteristics for targeted species, whether the habitat is a limiting factor for the species
- Use of the habitat by targeted species
- Adjacent habitat conversion, management, and restoration activities
- Presence of floating aquatic vegetation (FAV)
- Germination or general reproductive triggers
- Frequency/intensity of tropical storms

E.9.5. Guidance on Developing Parameters for Project-Level Performance

This section includes two types of monitoring parameters for consideration under the Restore and Enhance Submerged Aquatic Vegetation Restoration Approach:

3. Core performance monitoring parameters applicable to projects within a Restoration Approach (core performance monitoring parameters are those used consistently across projects in order to facilitate the aggregation of project monitoring results and the evaluation

of restoration progress for each Restoration Type; Appendix 5.E.4 of PDARP/PEIS; DWH NRDA, 2016a).

4. Objective-specific performance monitoring parameters that are only applicable to projects with a particular restoration objective.

Additional adaptive management and/or validation monitoring parameters for consideration have also been identified. These additional parameters may be helpful for resolving uncertainties, explaining outside drivers, optimizing project implementation, supporting decisions about corrective actions and other adaptive management of the project, and informing the planning of future DWH NRDA restoration projects. Tables E.9.1 and E.9.2 should not be considered exhaustive, and other parameters may be considered, as appropriate. See the complete list of core- and objective-specific monitoring parameters, Section E.3 above, for details on the core performance monitoring parameters including definitions, units, and other guidance.

Table E.9.1. Core performance monitoring parameters and additional parameters for consideration under the Restore and Enhance Submerged Aquatic Vegetation restoration approach.

Core performance monitoring parameters	Parameters for consideration (as appropriate)
• Area • Vegetation percent cover • Vegetation species composition • Vegetation survival[a]	• Aboveground biomass • Accretion • Belowground biomass • Current velocity • Floating aquatic vegetation (FAV) percent cover • Photosynthetically active radiation (PAR) • Salinity (surface water) • Secchi depth • Sediment nutrients • Sediment organic matter • Sediment texture • Shoot density • Temperature • Turbidity • Water level • Wave energy

[a] If project is planted with vegetation.

Table E.9.2. Performance monitoring parameters and additional parameters for consideration for projects with specific restoration objectives. These would be collected in addition to the parameters listed in Table E.9.1.

Project-specific objective	Objective-specific performance monitoring parameters	Parameters for consideration (as appropriate)
Restore sea floor elevation to promote SAV (water depth)	• Elevation • Water Level	• Subsidence • Currents • Wave energy

Project-specific objective	Objective-specific performance monitoring parameters	Parameters for consideration (as appropriate)
Promote regrowth of native SAV	• Area of Scarring (length, number, depth, and/or area of scars) [a]	• Dissolved oxygen (DO) • Light availability • pH • Salinity (surface water) • Specific conductance • Temperature • TN (Total Nitrogen) • TP (Total Phosphorus) • Turbidity • Water Level
Increase or maintain nutrient levels to enhance SAV beds	• Structural integrity of constructed features (e.g., bird stakes, signage, and/or buoys)[b] • TN (Total Nitrogen) • TP (Total Phosphorus)	• Hydroperiod • Tidal regime
Increase or maintain water quality	• Dissolved oxygen (DO) • pH • Salinity (surface water) • Specific conductance • Temperature • Turbidity	• Cloud cover • Day length • Discharge or velocity (water flow) • Fetch • Frequency and duration of storms • Hydroperiod • Tidal regime
Reduce current velocity and wave action to protect or restore SAV	• Structural integrity and function of constructed features (e.g. oyster reefs) • Wave height, period, and direction	• Currents • Elevation • Fetch • Longshore drift and currents • Sediment consolidation
Increase the abundance of targeted injured species	• Targeted injured species abundance/density	• Abundance of preferred food/prey species for targeted species • Abundance/density of competing species, invasives, or predators for targeted species • Reproductive capacity of targeted species

[a] If project is addressing prop scars.

[b] If project includes the construction of structural features.

References

Thayer, Gordon W., Teresa A. McTigue, Ronald J. Salz, David H. Merkey, Felicity M. Burrows, and Perry F. Gayaldo, (eds.). 2005. Science-Based Restoration Monitoring of Coastal Habitats, Volume Two: Tools for Monitoring Coastal Habitats. NOAA Coastal Ocean Program Decision Analysis Series No. 23. NOAA National Centers for Coastal Ocean Science, Silver Spring, MD. 628 pp. plus appendices.

The National Academies of Sciences, Engineering, and Medicine. 2017. *Effective Monitoring to Evaluate Ecological Restoration in the Gulf of Mexico.* Washington, DC: The National Academies Press. Doi:10.17226/23476.

E.10. Restore Oyster Reef Habitat: Monitoring Guidance


This guidance is intended to promote consistency in data collection among similar types of projects and allow for future analysis across TIGs and Restoration Types, (Section 10.6.2 of SOP; DWH NRDA Trustees, 2016). This guidance may also assist the TIGs by providing recommended methodologies for monitoring restoration projects, saving time and money spent developing suitable monitoring protocols for individual restoration projects. If adjustments from this monitoring guidance are needed for a particular project, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016). Project teams within each TIG will identify parameters applicable to the objectives for each individual restoration project when developing the project MAM Plan. In addition to the project monitoring guidance identified in this Manual, specific monitoring may be required to comply with permits granted by regulatory agencies. The TIGs are not restricted from adding additional parameters, and other project monitoring that may be needed for specific projects should be determined by the TIGs.

The Cross-TIG MAM work group developed this monitoring guidance by following the process described in the Monitoring and Adaptive Management Procedures and Guidelines Manual Version 1.0 (MAM Manual Version 1.0; DWH NRDA Trustees, 2017). This new guidance is being released as a supplement to MAM Manual Version 1.0.

This guidance is intended to assist the TIGs in developing MAM Plans for restoration projects, as appropriate. Specifically, it provides:

- Examples of Restoration Techniques
- Guidance on example restoration objectives, example drivers, and example uncertainties
- Guidance on core performance monitoring parameters for projects within the Restoration Approach
- Guidance on supplemental performance monitoring parameters for specific restoration objectives

The monitoring parameters identified within a Restore Oyster Reef Habitat project MAM Plan should be consistent with the recommended monitoring defined within this guidance document, wherever appropriate. Depending on the nature of the restoration project, TIGs may also choose not to include some of the elements described in this guidance document (e.g., drivers, uncertainties). If adjustments from the monitoring guidance are needed, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). The guidance provided in this document should not be considered exhaustive. Therefore, TIGs may develop project-level objectives, drivers, uncertainties, and monitoring parameters that have not been previously identified. The TIGs will develop MAM objectives and monitoring parameters that pertain to their restoration activities, and will determine the frequency and duration of monitoring and the associated budget they deem appropriate. This guidance may change as new monitoring parameters, methods, and technologies are identified and/or developed. Additional guidance may be found in the Strategic Framework for Oyster Restoration Activities (DWH NRDA Trustees, 2017).

The monitoring parameters recommended in this guidance document are further detailed in Attachment E Section E.3, which includes a complete list of core- and objective-specific monitoring parameters identified by the Cross-TIG MAM work group and guidance on measurement unit(s) and monitoring methods. Guidance on monitoring locations, frequencies, durations of sampling and potential analyses is also provided where appropriate.

E.10.1. Restoration Techniques

Restoration Techniques are specific restoration actions the Trustees identified for each of the Restoration Approaches. Restoration Techniques may be used individually or in combination. See Appendix 5.D of the PDARP/PEIS (DWH NRDA Trustees, 2016a). The following are example Restoration Techniques included in the PDARP/PEIS for this Restoration Approach. This list should not be considered exhaustive; additional Restoration Techniques may be identified and/or developed.

1. Restore or create oyster reefs through placement of cultch in nearshore and subtidal areas.
2. Construct living shorelines.
3. Enhance oyster reef productivity through spawning stock enhancement projects such as planting hatchery raised oysters, relocating wild oysters to restoration sites, oyster gardening programs, and other similar projects.
4. Develop a network of oyster reef spawning reserves.

E.10.2. Example Project-Level Restoration Objectives

Project-level restoration objectives should be specific to the resource injuries and clearly specify the desired outcome(s) of the restoration project (15 CFR § 990.55(b)(2)). See Section 2.4.1 of the MAM Manual Version 1.0 for guidance on establishing restoration objectives. The following are example project-level restoration objectives that may apply to one or more of the above-mentioned Restoration Techniques. This list should not be considered exhaustive; additional objectives may be developed and/or identified.

- Increase reef height and/or area through cultch placement
- Establish new or increase capacity of existing shell recycling programs to increase amount of shell available for restoration
- Reduce wave energy reaching the shoreline
- Create substrate for colonization by oysters and other reef organisms
- Provide shelter for reef-dwelling organisms
- Re-establish ecological connections at the land-water interface
- Increase density of spawning-size oysters
- Create spawning reserves that are protected from harvest
- Enhance survival, growth, and reproduction of oysters

E.10.3. Example Drivers

Drivers are outside forces, natural or anthropogenic, that have the potential to influence the outcome(s) of a restoration project. Drivers tend to be large-scale, long-term forces that are not easily controlled at the scale of a single restoration project (Harwell et al., 2016). See Section 2.4.2 of the MAM Manual Version 1.0 for guidance on establishing the conceptual setting for a MAM Plan, including identifying drivers. The following are example drivers that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional drivers may be identified.

- Salinity
- Dissolved oxygen concentration
- Temperature
- Pollution
- Phytoplankton
- Harmful algal blooms
- pH
- Disease
- Larval transport (currents)
- Bottom hardness
- Sedimentation
- Wave exposure
- Tidal position
- Sea level rise
- Subsidence of cultch
- Commercial harvest
- Predation
- Competition for space or food
- Water management practices affecting local water quality
- Natural resource management policies

E.10.4. Example Uncertainties

Uncertainties or information gaps have the potential to affect adaptive management decisions for individual or multiple restoration projects. These decisions may include how to improve the likelihood of achieving favorable project outcomes or selecting corrective actions in the event a project is not performing as intended. See Section 2.4.3 of the MAM Manual Version 1.0 for guidance on identifying potential sources of uncertainty for a MAM Plan. The following are example uncertainties that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional uncertainties may be identified.

- Cultch availability and cost
- Freshet frequency and severity
- Illegal harvest
- Coastal acidification trends
- Adjacent land use
- Spatial (horizontal and vertical) effects from anoxia events
- Effects from local resource management, such as water or sediment diversions
- Most effective way to restore oysters

Guidance on Developing Parameters for Project-Level Performance

This section includes two types of monitoring parameters for consideration under the Restore Oyster Reef Habitat Approach:

1. Core performance monitoring parameters applicable to projects within a Restoration Approach (core performance monitoring parameters are those used consistently across projects in order to facilitate the aggregation of project monitoring results and the evaluation of restoration progress for each Restoration Type; Appendix 5.E.4 of PDARP/PEIS; DWH NRDA, 2016a).

2. Objective-specific performance monitoring parameters that are only applicable to projects with a particular restoration objective.

Additional adaptive management and/or validation monitoring parameters for consideration have also been identified. These additional parameters may be helpful for resolving uncertainties, explaining outside drivers, optimizing project implementation, supporting decisions about corrective actions and other adaptive management of the project, and informing the planning of future DWH NRDA restoration projects. Tables E.10.1 and E.10.2 should not be considered exhaustive, and other parameters may be considered, as appropriate. See the complete list of core- and objective-specific monitoring parameters for details on the core performance monitoring parameters including definitions, units, and other guidance.

Table E.10.1. Core performance monitoring parameters and additional parameters for consideration under the Restore Oyster Habitat Restoration Approach.

Category	Core performance monitoring parameters	Parameters for consideration (as appropriate)
Reef dimensions	• Project footprint (m^2) • Reef area (m^2) • Reef height (m) • Reef volume (m^3)	• Low tide exposure • Reef rugosity • Reef patchiness • Consolidation rate/subsidence of reef structure • Substrate type, amount, and condition
Oyster demography	• Density of live and dead oysters (# of oysters/m^2) • Size frequency distribution (shell height, mm) • Mortality (%)	• Growth rates • Recruitment • Shell volume (for determination of shell budget) • Dermo disease prevalence and intensity
Benthic predatory, pest, or competitive species		• Presence, density, or percent cover of predatory, pest, or competitive species
Environmental conditions		• Water temperature • Salinity • Dissolved oxygen • pH • Turbidity • Total suspended solids • Chlorophyll *a* • Flow rate

Table E.10.2. Performance monitoring parameters and additional parameters for consideration for projects with specific restoration objectives. These would be measured in addition to the parameters listed in Table E.10.1.

Project-specific objective	Objective-specific performance monitoring parameters	Parameters for consideration (as appropriate)
Habitat enhancement for fauna	• Species composition, density (# of individuals/m^2) or catch per unit effort (CPUE), and size (length (mm), biomass (g), etc.) of target faunal species/groups	• None identified
Living shorelines	• Shoreline position • Shoreline loss or gain (m^2/year, calculated)	• Shoreline elevation change • Marsh vegetation species composition, density, and percent cover • Wave height
Increased reef productivity	• Oyster larval settlement (# of spat/m^2 per day or # of spat/m^2) • Density of "large" (defined based on local conditions) oysters (# of large oysters/m^2)	• Gonad development status • Sex ratio

References

DWH NRDA Trustees. 2016a. *Deepwater Horizon* Oil Spill: Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS). Available: http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan.

DWH NRDA Trustees. 2016b. Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the *Deepwater Horizon* (DWH) Oil Spill. Originally approved May 4, 2016; revised November 15, 2016. Available: http://www.gulfspillrestoration.noaa.gov/sites/default/files/TC%20SOP%202.0%20with%20appendices.pdf

DWH NRDA Trustees. 2017. Deepwater Horizon Oil Spill Natural Resource Damage Assessment: Strategic Framework for Oyster Restoration Activities. June. Available: http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan.

Harwell, M.A., J.H. Gentile, L.D. McKinney, J.W. Tunnell Jr., W.C. Dennison, and R.H. Kelsey. 2016. A New Framework for the Gulf of Mexico EcoHealth Metrics. Available: http://www.harteresearchinstitute.org/sites/default/files/resources/Framework%20for%20the%20Gulf%20EcoHealth%20Metric.pdf.

E.11. Enhance Public Access to Natural Resources for Recreational Use: Monitoring Guidance


This guidance is intended to promote consistency in data collection among similar types of projects and allow for future analysis across TIGs and Restoration Types, (Section 10.6.2 of SOP; DWH NRDA Trustees, 2016). This guidance may also assist the TIGs by providing recommended methodologies for monitoring restoration projects, saving time and money spent developing suitable monitoring protocols for individual restoration projects. If adjustments from this monitoring guidance are needed for a particular project, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016). Project teams within each TIG will identify parameters applicable to the objectives for each individual restoration project when developing the project MAM Plan. In addition to the project monitoring guidance identified in this Manual, specific monitoring may be required to comply with permits granted by regulatory agencies. The TIGs are not restricted from adding additional parameters, and other project monitoring that may be needed for specific projects should be determined by the TIGs.

The Cross-TIG MAM developed this monitoring guidance by following the process described in the Monitoring and Adaptive Management Procedures and Guidelines Manual Version 1.0 (MAM Manual Version 1.0; DWH NRDA Trustees, 2017).

This guidance is intended to assist the TIGs in developing MAM Plans for restoration projects, as appropriate. Specifically, it provides:

- Examples of Restoration Techniques
- Guidance on example restoration objectives, example drivers, and example uncertainties
- Guidance on core performance monitoring parameters for projects within the Restoration Approach
- Guidance on supplemental performance monitoring parameters for specific restoration objectives.

The monitoring parameters identified within a project MAM Plan should be consistent with the recommended monitoring defined within this guidance document, wherever appropriate. Depending on the nature of the restoration project, TIGs may choose not to include some of the elements described in this guidance document (e.g., drivers, uncertainties). If adjustments from the monitoring guidance are needed, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). The guidance provided should not be considered exhaustive. Therefore, TIGs may develop project-level objectives, drivers, uncertainties, and monitoring parameters that have not been previously identified. The TIGs will develop MAM objectives and monitoring parameters that pertain to their restoration activities; and will determine the frequency and duration of monitoring, and the associated budget they deem appropriate. Finally, this section is subject to

change as new monitoring parameters, methods, and technologies are identified and/or developed.

The monitoring parameters recommended in this guidance document are further detailed in Attachment E Section E.3, which includes a complete list of core- and objective-specific monitoring parameters identified by the Cross-TIG MAM work group and guidance on measurement unit(s) and monitoring methods. Guidance on monitoring locations, frequencies, durations of sampling and potential analyses is also provided where appropriate.

E.11.1. Restoration Techniques

Restoration Techniques are specific restoration actions the Trustees identified for each of the Restoration Approaches. Restoration Techniques may be used individually or in combination. See Appendix 5.D of the PDARP/PEIS (DWH NRDA Trustees, 2016a). The following are example Restoration Techniques included in the PDARP/PEIS for this Restoration Approach. This list should not be considered exhaustive; additional Restoration Techniques may be developed and/or identified.[4]

1. Acquire land to serve as public access points
2. Enhance or construct infrastructure (e.g., boat ramps, piers, boardwalks, dune crossovers, camp sites, educational/interpretive spaces, navigational channel improvements and dredging, safe harbors, navigational aids, ferry services, rebuilding of previously damaged or destroyed facilities, promenades, trails, roads and bridges to access natural resources, and marina pump out stations).

E.11.2. Example Project-Level Restoration Objectives

Project-level restoration objectives should be specific to the resource injuries and clearly specify the desired outcome(s) of the restoration project (15 CFR § 990.55(b)(2)). See Section 2.4.1 of the MAM Manual Version 1.0 for guidance on establishing restoration objectives. The following are example project-level restoration objectives that may apply to one or more of the above-mentioned Restoration Techniques. This list should not be considered exhaustive; additional objectives may be developed and/or identified.

- Reduce or eliminate the potential for development to enhance access
- Increase access for recreational use through acquisition
- Enhance public access through infrastructure development
- Enhance public access by increasing visitor use of protected or enhanced lands
- Enhance public access by improving visitor satisfaction of the availability of recreational opportunities/protected lands
- Enhance public access by increasing access to wildlife-viewing opportunities by protecting wildlife habitat
- Minimize negative impacts on local community (e.g., noise, debris).

E.11.3. Example Drivers

Drivers are outside forces, natural or anthropogenic, that have the potential to influence the outcomes of a restoration project. Drivers tend to be large-scale, long-term forces that are not easily controlled at the scale of a single restoration project (Harwell et al., 2016). See Section 2.4.2 of the MAM Manual Version 1.0 for guidance on establishing the conceptual

4. An additional technique that could be utilized under this approach is artificial reefs.

setting for a MAM Plan, including identifying drivers. The following are example drivers that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional drivers may be identified.

- Development and changes in land use
- Seller motivation
- Public acceptance and use
- Frequency and intensity of hurricanes
- Infrastructure development
- Public interest or need.

E.11.4. Example Uncertainties

Uncertainties or information gaps have the potential to affect adaptive management decisions for individual or multiple restoration projects. These decisions may include how to improve the likelihood of achieving favorable project outcomes or selecting corrective actions in the event a project is not performing as intended. See Section 2.4.3 of the MAM Manual Version 1.0 for guidance on identifying potential sources of uncertainty for a MAM Plan. The following are example uncertainties that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional uncertainties may be identified.

- Ability to acquire the land (e.g., willingness of sellers)
- Increased use of the area
- Ability to attract public use of the area
- Potential need for ecological restoration (e.g., as a result of increased use of the area)
- Potential impact on local community (e.g., noise related to having too many visitors, trash).

E.11.5. Guidance on Developing Parameters for Project-Level Performance

This section includes two types of monitoring parameters for consideration under the Enhance Public Access to Natural Resources for Recreational Use Restoration Approach:

1. Core performance monitoring parameters applicable to projects within a Restoration Approach (core performance monitoring parameters are those used consistently across projects in order to facilitate the aggregation of project monitoring results and the evaluation of restoration progress for each Restoration Type; Appendix 5.E.4 of PDARP/PEIS; DWH NRDA Trustees, 2016a)
2. Objective-specific performance monitoring parameters that are only applicable to projects with a particular restoration objective.

Additional adaptive management and/or validation monitoring parameters for consideration have also been identified. These additional parameters may be helpful for resolving uncertainties, explaining outside drivers, optimizing project implementation, supporting decisions about corrective actions and other adaptive management of the project, and informing the planning of future DWH NRDA restoration projects. Tables E.11.1 and E.11.2 should not be considered exhaustive, and other parameters may be considered, as appropriate. See the complete list of core- and objective-specific monitoring parameters, Section E.3 above, for details on the core performance monitoring parameters including definitions, units, and other guidance.

Table E.11.1. Core performance monitoring parameters and additional parameters for consideration under the Enhance Public Access to Natural Resources for Recreational Use Restoration Approach

Core performance monitoring parameters	Parameters for consideration (as appropriate)
• Area (for land acquisition projects) • Visitor use/access	• Connectivity • Economic benefit

Table E.11.2. Performance monitoring parameters and additional parameters for consideration for projects with specific restoration objectives. These would be collected in addition to the parameters listed in Table E.11.1.

Project-specific objective	Objective-specific performance monitoring parameters	Parameters for consideration (as appropriate)
Enhance access through land acquisition, if lands may be closed for a period of time during the year (for various reasons such as beach closures)	• Right of entry	None identified
Enhance access through infrastructure	• Infrastructure or habitat constructed and/or enhanced and completed as designed	• Recreational activities utilized by public (nature and extent)
Increase visitor use of recreational activities	• Recreational activities utilized by public (nature and extent)	• Wildlife behavior response
Improve visitor satisfaction	• Visitor satisfaction • Recreational activities utilized by public (nature and extent)	• Wildlife behavior response
Enhance wildlife-viewing opportunities	• Recreational activities utilized by public (nature and extent)	• Wildlife behavior response • Physical disturbance (local)
Improve local citizen satisfaction	• Visitor satisfaction	• Economic benefit • Physical disturbance (local)

References

DWH NRDA Trustees. 2016a. *Deepwater Horizon* Oil Spill: Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS). Available: http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan.

DWH NRDA Trustees. 2016b. Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the *Deepwater Horizon* (DWH) Oil Spill. Originally approved May 4, 2016; revised November 15, 2016.

Harwell, M.A., J.H. Gentile, L.D. McKinney, J.W. Tunnell Jr., W.C. Dennison, and R.H. Kelsey. 2016. A New Framework for the Gulf of Mexico EcoHealth Metrics. Available: http://www.harteresearchinstitute.org/sites/default/files/resources/Framework%20for%20the%20Gulf%20EcoHealth%20Metric.pdf.

E.12. Enhance Recreational Experiences: Monitoring Guidance

This guidance is intended to promote consistency in data collection among similar types of projects and allow for future analysis across TIGs and Restoration Types, (Section 10.6.2 of SOP; DWH NRDA Trustees, 2016). This guidance may also assist the TIGs by providing recommended methodologies for monitoring restoration projects, saving time and money spent developing suitable monitoring protocols for individual restoration projects. If adjustments from this monitoring guidance are needed for a particular project, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016). Project teams within each TIG will identify parameters applicable to the objectives for each individual restoration project when developing the project MAM Plan. In addition to the project monitoring guidance identified in this Manual, specific monitoring may be required to comply with permits granted by regulatory agencies. The TIGs are not restricted from adding additional parameters, and other project monitoring that may be needed for specific projects should be determined by the TIGs.

The Cross-TIG MAM developed this monitoring guidance by following the process described in the Monitoring and Adaptive Management Procedures and Guidelines Manual Version 1.0 (MAM Manual Version 1.0; DWH NRDA Trustees, 2017).

This guidance is intended to assist the TIGs in developing MAM Plans for restoration projects, as appropriate. Specifically, this document provides:

- Examples of Restoration Techniques
- Guidance on example restoration objectives, example drivers, and example uncertainties
- Guidance on core performance monitoring parameters for projects within the Restoration Approach
- Guidance on supplemental performance monitoring parameters for specific restoration objectives.

The monitoring parameters identified within a project MAM Plan should be consistent with the recommended monitoring defined within this guidance document, wherever appropriate. Depending on the nature of the restoration project, TIGs may choose not to include some of the elements described in this guidance document (e.g., drivers, uncertainties). If adjustments from the monitoring guidance are needed, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). The guidance provided should not be considered exhaustive. Therefore, TIGs may develop project-level objectives, drivers, uncertainties, and monitoring parameters that have not been previously identified. The TIGs will develop MAM objectives and monitoring parameters that pertain to their restoration activities; and will determine the frequency and duration of monitoring, and the associated budget they deem appropriate. Finally, this section is subject to

change as new monitoring parameters, methods, and technologies are identified and/or developed.

The monitoring parameters recommended in this guidance document are further detailed in Attachment E Section E.3, which includes a complete list of core- and objective-specific monitoring parameters identified by the Cross-TIG MAM work group and guidance on measurement unit(s) and monitoring methods. Guidance on monitoring locations, frequencies, durations of sampling and potential analyses is also provided where appropriate.

E.12.1. Restoration Techniques

Restoration Techniques are specific restoration actions the Trustees identified for each of the Restoration Approaches. Restoration Techniques may be used individually or in combination. See Appendix 5.D of the PDARP/PEIS (DWH NRDA Trustees, 2016a). The following are example Restoration Techniques included in the PDARP/PEIS for this Restoration Approach to enhance experiences such as swimming, boating, bird watching, hiking, beach-going, snorkeling, or scuba diving. This list should not be considered exhaustive; additional Restoration Techniques may be developed and/or identified.[5]

1. Place stone, concrete, or permissible materials to create artificial reef structures
2. Enhance recreational fishing opportunities through aquaculture
3. Reduce and remove land-based debris.

E.12.2. Example Project-Level Restoration Objectives

Project-level restoration objectives should be specific to the resource injuries and clearly specify the desired outcome(s) of the restoration project (15 CFR § 990.55(b)(2)). See Section 2.4.1 of the MAM Manual Version 1.0 for guidance on establishing restoration objectives. The following are example project-level restoration objectives that may apply to one or more of the above-mentioned Restoration Techniques. This list should not be considered exhaustive; additional objectives may be developed and/or identified.

- Enhance fishing, snorkeling, and scuba-diving opportunities and experiences
- Enhance swimming opportunities and experiences
- Enhance beach-going experiences
- Enhance hiking opportunities and experiences
- Enhance bird watching opportunities and experiences
- Enhance coastal visitors' experiences by reducing land-based debris
- Protect coastal wildlife by reducing land-based debris.

E.12.3. Example Drivers

Drivers are outside forces, natural or anthropogenic, that have the potential to influence the outcome(s) of a restoration project. Drivers tend to be large-scale, long-term forces that are not easily controlled at the scale of a single restoration project (Harwell et al., 2016). See Section 2.4.2 of the MAM Manual Version 1.0 for guidance on establishing the conceptual setting for a MAM Plan, including identifying drivers. The following are example drivers that may

5. Due to the diverse nature of possible techniques under this Restoration Approach, we acknowledge that the specific methodologies and units used to collect monitoring information for the core parameter (i.e., visitor satisfaction surveys) may vary, and therefore visitor satisfaction surveys may not be used in all instances.

be applicable to this Restoration Approach. This list should not be considered exhaustive; additional drivers may be identified.

- Infrastructure development
- Human attachment to or interest in recreational activities
- Time and resources (e.g., income, transportation) available to participate in recreational activities
- Weather and climate events that limit time recreational activities
- State of economy
- Population trends.

E.12.4. Example Uncertainties

Uncertainties or information gaps have the potential to affect adaptive management decisions for individual or multiple restoration projects. These decisions may include how to improve the likelihood of achieving favorable project outcomes or selecting corrective actions in the event a project is not performing as intended. See Section 2.4.3 of the MAM Manual Version 1.0 for guidance on identifying potential sources of uncertainty for a MAM Plan. The following are example uncertainties that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional uncertainties may be identified.

- Ability to attract public use of the area
- Potential need for ecological restoration (e.g., as a result of increased use of the area)
- Potential negative impacts on wildlife resulting from recreational uses
- Potential impact on local community (e.g., noise related to having too many visitors, trash).

E.12.5. Guidance on Developing Parameters for Project-Level Performance

This section includes two types of monitoring parameters for consideration under the Enhance Recreational Experiences Restoration Approach:

1. Core performance monitoring parameters applicable to projects within a Restoration Approach (core performance monitoring parameters are those used consistently across projects in order to facilitate the aggregation of project monitoring results and the evaluation of restoration progress for each Restoration Type; Appendix 5.E.4 of PDARP/PEIS; DWH NRDA Trustees, 2016a)
2. Objective-specific performance monitoring parameters that are only applicable to projects with a particular restoration objective.

Additional adaptive management and/or validation monitoring parameters for consideration have also been identified. These additional parameters may be helpful for resolving uncertainties, explaining outside drivers, optimizing project implementation, supporting decisions about corrective actions and other adaptive management of the project, and informing the planning of future DWH NRDA restoration projects. Tables E.12.1 and E.12.2 should not be considered exhaustive, and other parameters may be considered, as appropriate. See the complete list of core- and objective-specific monitoring parameters, Section E.3 above, for details on the core performance monitoring parameters including definitions, units, and other guidance.

Table E.12.1. Core performance monitoring parameters and additional parameters for consideration under the Enhance Recreational Experiences Restoration Approach

Core performance monitoring parameters	Parameters for consideration (as appropriate)
• Visitor satisfaction	• Visitor use/access (especially for larger projects) • Economic benefit • Area

Table E.12.2. Performance monitoring parameters and additional parameters for consideration for projects with specific restoration objectives. These would be collected in addition to the parameters listed in Table E.12.1.

Project-specific objective	Objective-specific performance monitoring parameters	Parameters for consideration (as appropriate)
Enhancement through infrastructure	• Infrastructure or habitat constructed and/or enhanced and completed as designed	• Visitor use/access
Enhancement through marine debris removal	• Marine debris	• Visitor use/access • Area

References

DWH NRDA Trustees. 2016a. *Deepwater Horizon* Oil Spill: Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS). Available: http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan

DWH NRDA Trustees. 2016b. Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the *Deepwater Horizon* (DWH) Oil Spill. Originally approved May 4, 2016; revised November 15, 2016.

Harwell, M.A., J.H. Gentile, L.D. McKinney, J.W. Tunnell Jr., W.C. Dennison, and R.H. Kelsey. 2016. A New Framework for the Gulf of Mexico EcoHealth Metrics. Available: http://www.harteresearchinstitute.org/sites/default/files/resources/Framework%20for%20the%20Gulf%20EcoHealth%20Metric.pdf

E.13. Promote Environmental Stewardship, Education, and Outreach: Monitoring Guidance

This guidance is intended to promote consistency in data collection among similar types of projects and allow for future analysis across TIGs and Restoration Types, (Section 10.6.2 of SOP; DWH NRDA Trustees, 2016). This guidance may also assist the TIGs by providing recommended methodologies for monitoring restoration projects, saving time and money spent developing suitable monitoring protocols for individual restoration projects. If adjustments from this monitoring guidance are needed for a particular project, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016). Project teams within each TIG will identify parameters applicable to the objectives for each individual restoration project when developing the project MAM Plan. In addition to the project monitoring guidance identified in this Manual, specific monitoring may be required to comply with permits granted by regulatory agencies. The TIGs are not restricted from adding additional parameters, and other project monitoring that may be needed for specific projects should be determined by the TIGs.

The Cross-TIG MAM developed this monitoring guidance by following the process described in the Monitoring and Adaptive Management Procedures and Guidelines Manual Version 1.0 (MAM Manual Version 1.0; DWH NRDA Trustees, 2017).

This guidance is intended to assist the TIGs in developing MAM Plans for restoration projects, as appropriate. Specifically, this section provides:

- Examples of Restoration Techniques
- Guidance on example restoration objectives, example drivers, and example uncertainties
- Guidance on core performance monitoring parameters for projects within the Restoration Approach
- Guidance on supplemental performance monitoring parameters for specific restoration objectives.

The monitoring parameters identified within a project MAM Plan should be consistent with the recommended monitoring defined within this guidance document, wherever appropriate. Depending on the nature of the restoration project, TIGs may choose not to include some of the elements described in this guidance document (e.g., drivers, uncertainties). If adjustments from the monitoring guidance are needed, these adjustments should be described in the project-specific MAM Plan and agreed to by the TIG (Section 10.6.3 of SOP; DWH NRDA Trustees, 2016b). The guidance provided should not be considered exhaustive. Therefore, TIGs may develop project-level objectives, drivers, uncertainties, and monitoring parameters that have not been previously identified. The TIGs will develop MAM objectives and monitoring parameters that pertain to their restoration activities; and will determine the frequency and duration of monitoring, and the associated budget they deem appropriate. Finally, this section is subject to

change as new monitoring parameters, methods, and technologies are identified and/or developed.

The monitoring parameters recommended in this guidance document are further detailed in Attachment E Section E.3, which includes a complete list of core- and objective-specific monitoring parameters identified by the Cross-TIG MAM work group and guidance on measurement unit(s) and monitoring methods. Guidance on monitoring locations, frequencies, durations of sampling and potential analyses is also provided where appropriate.

E.13.1. Restoration Techniques

Restoration Techniques are specific restoration actions the Trustees identified for each of the Restoration Approaches. Restoration Techniques may be used individually or in combination. See Appendix 5.D of the PDARP/PEIS (DWH NRDA Trustees, 2016a). The following are example Restoration Techniques included in the PDARP/PEIS for this Restoration Approach. This list should not be considered exhaustive; additional Restoration Techniques may be developed and/or identified.

1. Create or enhance natural resource-related education facilities
2. Create or enhance natural resource-related education programs.

E.13.2. Example Project-Level Restoration Objectives

Project-level restoration objectives should be specific to the resource injuries and clearly specify the desired outcome(s) of the restoration project (15 CFR § 990.55(b)(2)). See Section 2.4.1 of the MAM Manual Version 1.0 for guidance on establishing restoration objectives. The following are example project-level restoration objectives that may apply to one or more of the above-mentioned Restoration Techniques. This list should not be considered exhaustive; additional objectives may be developed and/or identified.

- Increase access to environmental education and outreach opportunities
- Increase visitor use of educational resources and opportunities
- Improve visitors' satisfaction with the educational resources and opportunities provided
- Increase production and distribution of outreach materials
- Educate visitors about natural resources and restoration
- Increase public interest in and understanding of the natural science and environment of the Gulf coastal region.

E.13.3. Example Drivers

Drivers are outside forces, natural or anthropogenic, that have the potential to influence the outcomes of a restoration project. Drivers tend to be large-scale, long-term forces that are not easily controlled at the scale of a single restoration project (Harwell et al., 2016). See Section 2.4.2 of the MAM Manual Version 1.0 for guidance on establishing the conceptual setting for a MAM Plan, including identifying drivers. The following are example drivers that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional drivers may be identified.

- Lack of understanding of the natural science, resources, and environment of the Gulf coastal region
- Lack of understanding of marine ecosystems
- Human attachment to or interest in the environment
- Public opinion of environmental issues

- Time and resources (e.g., income, transportation) available to take advantage of educational or recreational opportunities
- State of economy
- Population trends
- Interest or need in the educational facilities and programs.

E.13.4. Example Uncertainties

Uncertainties or information gaps have the potential to affect adaptive management decisions for individual or multiple restoration projects. These decisions may include how to improve the likelihood of achieving favorable project outcomes or selecting corrective actions in the event a project is not performing as intended. See Section 2.4.3 of the MAM Manual Version 1.0 for guidance on identifying sources of uncertainty for a MAM Plan. The following are example uncertainties that may be applicable to this Restoration Approach. This list should not be considered exhaustive; additional uncertainties may be identified.

- Ability to attract public interest and use of the area
- Potential negative impacts on local community (e.g., noise related to having too many visitors, trash)
- Potential negative impacts to the surrounding environment
- Optimum location of outreach materials or opportunities to maximize public access or participation
- Optimum medium to communicate information (e.g., visual, written, oral materials, information)
- Weather and climate events that limit ability to travel to or access educational or recreational opportunities.

E.13.5. Guidance on Developing Parameters for Project-Level Performance

This section includes two types of monitoring parameters for consideration under the Promote Environmental Stewardship, Education, and Outreach Restoration Approach:

1. Core performance monitoring parameters applicable to projects within a Restoration Approach (core performance monitoring parameters are those used consistently across projects in order to facilitate the aggregation of project monitoring results and the evaluation of restoration progress for each Restoration Type; Appendix 5.E.4 of PDARP/PEIS; DWH NRDA Trustees, 2016a)
2. Objective-specific performance monitoring parameters that are only applicable to projects with a particular restoration objective.

Additional adaptive management and/or validation monitoring parameters for consideration have also been identified. These additional parameters may be helpful for resolving uncertainties, explaining outside drivers, optimizing project implementation, supporting decisions about corrective actions and other adaptive management of the project, and informing the planning of future DWH NRDA restoration projects. Tables E.13.1 and E.13.2 should not be considered exhaustive, and other parameters may be considered, as appropriate. See the complete list of core- and objective-specific monitoring parameters, Section E.3 above, for details on the core performance monitoring parameters including definitions, units, and other guidance.

Table E.13.1. Core performance monitoring parameters and additional parameters for consideration under the Promote Environmental Stewardship, Education, and Outreach Restoration Approach

Core performance monitoring parameters	Parameters for consideration (as appropriate)
• Visitor use and access • Nature and extent of educational materials or programs produced and distributed	• Visitor satisfaction

Table E.13.2. Performance monitoring parameters and additional parameters for consideration for projects with specific restoration objectives. These would be collected in addition to the parameters listed in Table E.13.1.

Project-specific objective	Objective-specific performance monitoring parameters	Parameters for consideration (as appropriate)
Enhancement through education-related infrastructure	• Infrastructure or habitat constructed and/or enhanced and completed as designed • Right of entry	• Visitor satisfaction
Increasing public's interest in and understanding of natural resources	• Visitor satisfaction	• Economic benefits

References

DWH NRDA Trustees. 2016a. *Deepwater Horizon* Oil Spill: Final Programmatic Damage Assessment and Restoration Plan (PDARP) and Final Programmatic Environmental Impact Statement (PEIS). Available: http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan.

DWH NRDA Trustees. 2016b. Trustee Council Standard Operating Procedures for Implementation of the Natural Resource Restoration for the *Deepwater Horizon* (DWH) Oil Spill. Originally approved May 4, 2016; revised November 15, 2016.

Harwell, M.A., J.H. Gentile, L.D. McKinney, J.W. Tunnell Jr., W.C. Dennison, and R.H. Kelsey. 2016. A New Framework for the Gulf of Mexico EcoHealth Metrics. Available: http://www.harteresearchinstitute.org/sites/default/files/resources/Framework%20for%20the%20Gulf%20EcoHealth%20Metric.pdf.