An Ecological Approach for Reviewing CWA Section 404 Compensatory Mitigation Projects in EPA Region 4

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Executive Summary

The planning and implementation of wetland and stream compensatory mitigation proposals is complex and fraught with uncertainty and risk due to natural and anthropogenic factors. This uncertainty and risk have been highlighted by various scientific studies dating back to the 1980's. In 2001, the National Research Council (NRC) in their study entitled *Compensating for Wetland Losses Under the Clean Water Act* concluded that the Clean Water Act (CWA) Section 404 Program was not achieving the goal of No Net Loss of wetland functions through the use of compensatory mitigation and provided a series of recommendations to improve project and program performance. Although the NRC did not address stream mitigation, other studies done subsequently indicate similar challenges for stream mitigation projects and program performance (ELI et al., 2016).

To address shortcomings and update aspects of aquatic resource compensatory mitigation in the CWA Section 404 program, the USACE and EPA jointly promulgated the *Compensatory Mitigation for Losses of Aquatic Resources; Final Rule* (Mitigation Rule) in 2008. These regulations provide a sound regulatory basis for establishing policies and equivalent information requirements for compensatory mitigation provided by mitigation banks, in lieu fee programs, and permittee-responsible mitigation proposals. However, despite improvements in the mitigation proposals, there is still a considerable amount of natural and programmatic variability which continues to contribute to uncertainty and risk associated with wetland and stream compensatory mitigation projects throughout the country. This document outlines an approach (referred to herein as the Approach) which attempts to lower uncertainty and risk associated with compensatory mitigation projects by recommending more detailed and focused information during the mitigation project review in the form of aquatic resource classification, specific identification of stressors, quantifiable objectives, explicit design criteria connected to the quantifiable objectives, and post-project monitoring and long-term management.

<u>Central themes of this Approach:</u>

- Focusing on appropriate site selection,
- Incorporating goals and objectives connected to an explicit target condition,
- Monitoring specific, objective ecological performance standards,
- Developing sustainable and resilient wetland and stream mitigation projects, and
- Using reference data or discrete sites in project planning and evaluation.

This Approach represents a distillation of the 12 elements found in the Planning and Documentation, Ecological Performance Standards, and Monitoring and Management sections (40 CFR §230.94-230.97) of the Mitigation Rule into six basic questions to facilitate regulatory review of wetland and stream mitigation proposals. The objectives of the Approach are to frame the 12 elements in a logical and ecologically meaningful way, and to provide reviewers a consistent, ecologically based approach to mitigation project reviews so they can effectively evaluate any given wetland and/or stream project proposal for its sustainable ecological potential. The goal is to promote ecological sustainability and resilience of compensatory mitigation projects and enhance EPA's role as a member of USACE District Interagency Review Teams (IRTs). It is not the intent, or within the ability of this document, to provide a complete treatise on the detailed technical and policy aspects of reviewing aquatic resource compensatory mitigation plans. Nor is it our intent to supersede USACE District templates for presenting information in mitigation banking, in-lieu fee and permittee-responsible mitigation documents.

The structure of this document follows the sequence of questions, or steps, that are proposed to provide an ecological perspective on compensatory mitigation plan review and the links of those steps to the Mitigation Rule. These questions consider regional variations in conditions, functions, and services, and address how to apply equivalent standards and criteria to compensatory mitigation in streams and wetlands. The questions focus on classification, baseline and target condition, implementation plans, monitoring, performance and long-term management. Each section of the Approach addresses one of the six questions for both wetlands and streams, and includes detailed rationale, links to the Mitigation Rule, and recommended technical information and resources to help frame and provide useful information in answering each question.

To efficiently utilize this document, Figure ES-1 provides a breakdown of each question, the section it is in, and the essential wetland and stream information recommended to address each question. In addition, composite lists of all the information recommended by the Approach can be found in **Appendix A** for wetlands and **Appendix B** for streams.

As outlined in Figure ES-1, the six questions that frame the review of any potential compensatory mitigation site are:

(1) What is the current class?
(2) What is the baseline condition?
(3) What is the target condition?
(4) How will the mitigation design achieve the target condition?
(5) How will progress toward the target condition be assessed?
(6) How will the site be managed to sustain the target condition?

Question 1: What is the current class? (Aquatic resource classification)

For the purposes of this Approach, classification is a means of organizing and understanding complex information about streams and wetlands to bring a semblance of order to natural variability, to promote better communication in the management of aquatic resources, to focus information gathering and ensure appropriate ecological site context. To this end, classification is a critical first step in the mitigation project review process to provide a conceptual understanding of wetland and stream ecological processes, and fundamentally set the stage for the effective implementation of the proposed mitigation project.

Aquatic resource classification should be provided early on in mitigation project planning, as it supports site selection, goals and objectives and other required elements. For wetlands, a project proposal should identify the appropriate wetland class(es) on site, preferably using the Hydrogeomorphic (HGM) wetland classification, as it establishes a link between landscape position and hydrology to wetland processes and functions and is widely recognized as an appropriate wetland functional classification upon which to base assessment and mitigation planning. Classification should be supported by hydrogeomorphic (i.e., geomorphic position in the landscape, water sources, and hydrodynamics) and soils data, including landscape information, Web Soil Survey data, current HGM regional guidebook descriptions and keys, and any other available information.

For streams, project proposals should classify/characterize streams using a combination of approaches to focus information for mitigation planning. Given that fluvial systems are constantly adjusting and evolving in response to changes in sediment supply, channel and floodplain geometry, floods, groundwater hydrology, vegetation, woody debris, fauna (both natural (e.g.,

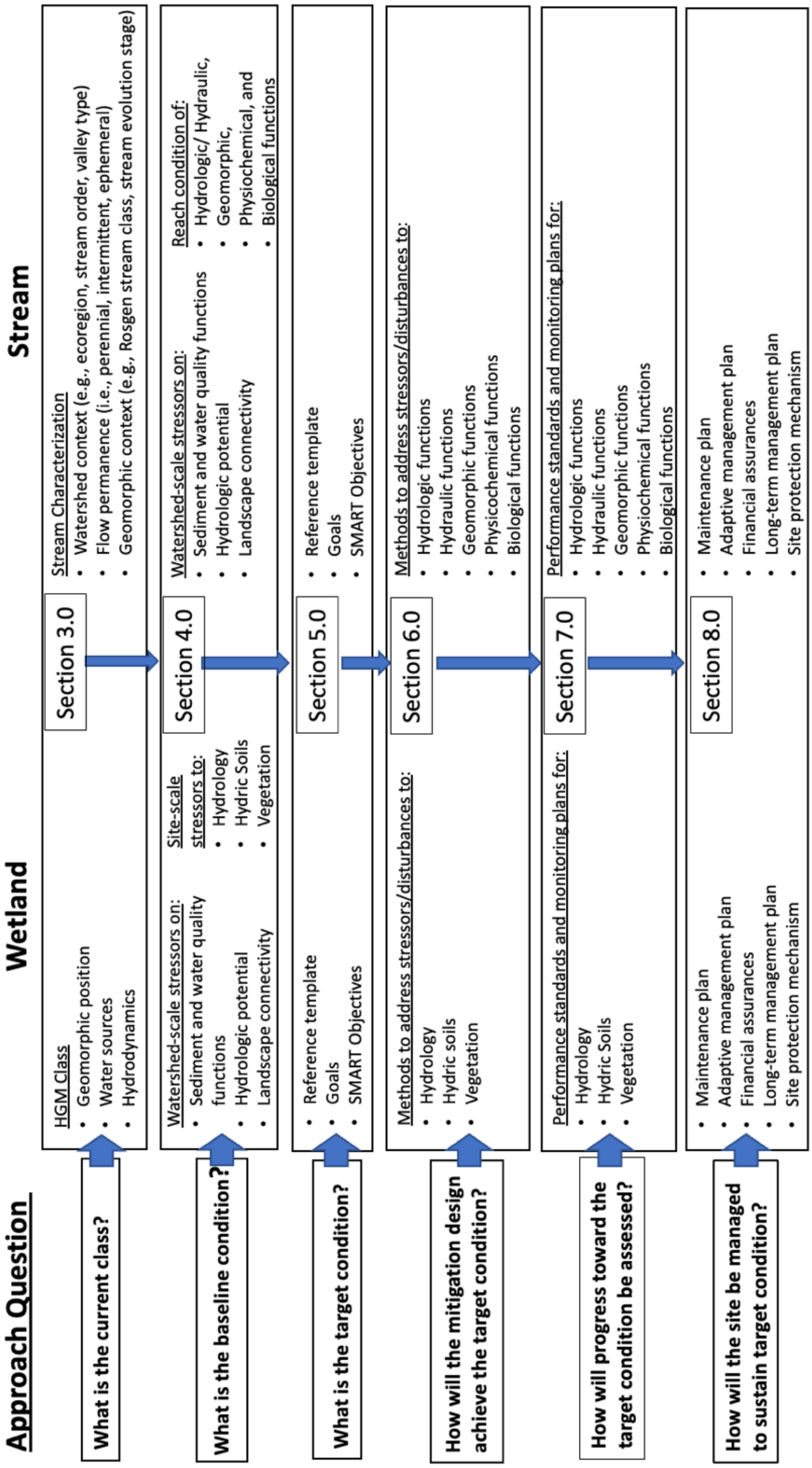

Figure ES-1. Information needed to address the six questions in the Approach for wetlands and streams, with the relevant section in the document discussing background and rationale.

beaver) and introduced (e.g., livestock)), as well as other historic and contemporary natural and anthropogenic factors that affect the stream system, one or more classification approaches will be needed to provide ecological context. This Approach outlines several methods for characterizing streams, including ecoregion, valley type, Strahler stream order, flow permanence, Rosgen classification, and stream evolutionary stage. Flow permanence provides information on water source and flow duration while valley type, stream order and ecoregion provide information about landscape position in the watershed, and geology. Rosgen stream class provides information about the reach's geomorphic condition, and stream evolution stage conveys information about a channel's response to disturbance and/or where that channel is along a geomorphic and ecologic disturbance gradient.

Question 2: What is the baseline condition? (Baseline assessment/monitoring)

This question focuses on the information needed to characterize the baseline condition and the level and source of stressors affecting the proposed mitigation site. Establishing the baseline condition and identifying stressors acting on the proposed site provides insight into factors requiring amelioration to re-establish function. These factors would then need to be addressed and/or considered as limitations in the mitigation project.

A site's baseline condition, or current functional capacity, is affected by factors operating at a watershed scale as well as those operating at the site or reach scale. Evaluating information at a watershed scale considers stressors and land uses outside the project boundaries that can affect the site's restoration potential, including surrounding land uses, landscape connectivity, and hydrologic potential (i.e., frequency, duration, magnitude, and timing of flows).

Stressors acting at a site-specific scale can also affect the condition and restoration potential for a mitigation site, and the level and sources of degradation should be assessed as part of baseline characterization. Site specific rapid assessments could be used in the baseline assessment but should be able to link current condition and/or function to the stressors impacting those functions and should be supplemented by site specific and watershed data.

Important elements of a baseline assessment include evaluation of watershed and reach or site-scale stressors, and any necessary measurements to characterize the existing conditions on site and inform project design/performance standards. For wetlands, baseline assessments should include site-specific vegetation, soils and hydrologic data. For streams, baseline assessments should include characterization of site-scale hydrologic, hydraulic, geomorphic, physicochemical and biological processes. Baseline data represent the starting condition of the site that will be compared to monitoring data in the future to ascertain the degree to which site conditions improve as a result of the mitigation project (i.e., level of performance). This information should also be compared to either existing reference data or reference data collected by the mitigation provider to establish the site's relationship with a reference population.

Question 3: What is the target condition? (Goals and objectives/reference)

The intent of this question is to understand the target condition of a site. Target condition, or the projected endpoint, establishes the functional expectations for the site (goals), specific actions (measurable objectives) which will be implemented and tracked to assess progress towards achieving goals, and identifies the reference(s) used to inform target condition. Goal statements are used as the enunciation of the vision for the project, and are broad statements of the intended outcome, or expectations of the mitigation project, including a list of the functions to be provided by the mitigation site. Objectives represent the actions needed to achieve the goal. Objectives should be SMART (i.e., Specific, Measurable, Achievable, Relevant, and Time bound) so that progress on the project can be effectively tracked. These objectives should then be tied to the performance standards. Reference comparisons are used to provide a benchmark for the end point, and reference standard condition data are often derived from analog comparisons with high quality sites, regional curves or other empirical equations, analytical models, and regional indices that correspond to the appropriate aquatic resource class and/or landscape setting.

Important elements to inform target condition include clear, function-based expectations for the outcome of the project (goals) given aquatic resource class(es) and the level of disturbance and stressors acting upon the site, quantifiable actions (objectives) needed to ameliorate the stressors and achieve target condition, and relevant reference comparisons. Establishing target condition is highly dependent on identifying the watershed and/or site-scale problems that may be affecting functional capacity. For example, in streams, watershed-scale stressors may affect hydrology and sediment routing that may explain changes in stream condition; and this information needs to be translated into goals and objectives that inform an appropriate design (Roni and Beechie, 2013).

Question 4: How will the mitigation design achieve target conditions? (Mitigation workplans)

This step ensures mitigation work plan/designs describe the proposed actions that will alleviate the impact of stressors and improve ecosystem functions at the mitigation site consistent with the stated goals and objectives and within site and watershed constraints. Details of any mitigation work plan will vary on a case-by-case basis and should be tailored to address the identified objectives.

Important elements of an effective mitigation plan include appropriate consideration of site conditions, landscape context, and site constraints due to surrounding land use and watershed conditions; and an understanding of the causes and levels of degradation, the effects a particular restoration method or approach might induce, as well as how to make modifications or refinements to the plan (i.e., adaptive management). Specific methods or approaches proposed in the workplan should be informed by baseline conditions and function-based goals and objectives that are appropriate given the aquatic resource class, landscape potential, watershed and site constraints, and logistics and have the potential to move the site from its current condition to the proposed target condition. Some restoration approaches are more commonly used than others (e.g., Natural Channel Design (NCD), planting specific forested species), and some providers utilize methods because of their familiarity with the method as opposed to the ability of the method to address a stressor. All methods, or sets of methods, should be considered so long as they have the potential to achieve the desired result.

Question 5: How will progress toward the target condition be assessed? (Performance standards and monitoring)

This question highlights information needed to determine the ecological success of a mitigation project, including performance standards and monitoring plans. Performance standards are based on the specific goals and objectives of the mitigation project, and monitoring is used to determine if a project is meeting its performance standards. Each mitigation project will have a potentially unique set of specific performance standards that are applicable for the class or subclass of aquatic resource and are tied to the specific mitigation project goals and objectives. Generally, performance standards reflect a range of wetland functions (e.g., wetland hydrologic storage, biogeochemical cycling and plant and animal habitat) and/or stream functions (e.g., stream hydrologic connection, hydraulic maintenance, geomorphologic form) by measuring field parameters which are sensitive to changes brought about by the mitigation plan and tied directly to a project objective.

To help determine the effectiveness of a provider's performance standards, reviewers should evaluate whether they generally address the questions of: *"what is measured"; "how is it measured"; "when is the level of performance required met"* and *"Does the proposed performance standard effectively represent a target condition or function?"* Performance standards are appropriate when they are informed by a reference comparison, described using clear and concise wording, scientifically defensible, and supported by data collection methods that are appropriately timed, repeatable and with clearly defined error rates.

Given the inherent variability and highly dynamic nature of streams, it is difficult to establish a static set of performance standards for a given point in time (e.g., achieve reference planform by year five). The choice of performance standards depends on the results of the classification, baseline assessment, the objectives of the project, and the actions required to achieve the objectives. The ultimate goal of any stream compensatory mitigation project is to enhance, establish, or re-establish hydrologic, hydraulic, geomorphic, physicochemical, and biological function to the stream proposed as compensatory mitigation. Again, there are a wide variety of methods which can be brought to bear on problems a stream may be having. Therefore, measuring the ability of any method(s) to improve stream functions will depend on the information collected previously in this Approach, the parameters chosen, and the availability of comparable reference stream information for each function.

Monitoring can be split into three phases: baseline, implementation, and effectiveness monitoring. Baseline monitoring is addressed during the baseline condition assessment for both wetlands and streams. Implementation monitoring is typically accomplished by comparing as-built plans with the 100% design drawings and design criteria presented in the mitigation plan to verify the project was actually constructed as designed and approved by applicable permitting authorities. Effectiveness monitoring evaluates the project's effect on resource indicators (e.g., wetland habitat conditions or stream geomorphology) and whether the project achieved its goals and objectives and target condition. Effectiveness monitoring is directly related to performance standards, and will inform credit releases, project closeout and whether adaptive management measures are needed.

Generally, monitoring plans should clearly and concisely describe the parameters to be assessed; where and how often each will be measured; specific methods and/or protocols for measuring each parameter; the resources (e.g., time, money, equipment, and expertise) needed; how data will be analyzed and interpreted with respect to objectives and performance standards; the level of statistical rigor to determine treatment effectiveness; and how data will be made accessible and understandable for decision-making regarding achievement of performance and/or adaptive management. Clarity in the monitoring plan is important since different parties may be involved in monitoring a site over the long-term. Personnel changes, on both the provider's team as well as among the IRT, dictate that monitoring plans be clearly written and organized to promote accurate interpretation at any point during the life of the project. A 10-year monitoring period may be warranted for aquatic resource compensatory mitigation projects that develop more slowly (e.g., forested wetlands and/or riparian areas), unless performance can be demonstrated in a shorter period of time.

Question 6: How will the site be managed to sustain the target condition? (Maintenance plans, adaptive management plans, financial assurances, long-term management plans, and site protection instruments)

This question outlines administrative components of a mitigation plan, including site protection mechanisms and financial assurances, as well as maintenance plans, long-term management plans and adaptive management plans.

The **maintenance plan** accounts for activities that will need to take place on the project site for the duration of the monitoring period and should support the goal of making the compensatory mitigation site ecologically sustainable and resilient. Maintenance plans describe and outline a schedule of maintenance requirements (e.g., maintain or replace monitoring equipment, replant dead vegetation, maintain access routes to monitoring stations, and those required for field inspections) to ensure the continued viability of the resource once initial construction is completed. Reviewers should ensure that the maintenance plan is included and complete.

Preparing for **adaptive management** means developing a management strategy that anticipates likely challenges, but provides flexibility to accommodate unforeseen changes, associated with the project and provides for the implementation of actions to address those challenges. Adaptive management is considered a hedge against the risk, uncertainty, and dynamic nature of compensatory mitigation projects (i.e., will what the provider is undertaking work?), and guides the process by which modifications to those projects are implemented to optimize performance. Plans should be linked both to a provider's and reviewer's experience with potential problems and/or monitoring results indicating that attainment of performance standards has been impeded, and how such problems could be rectified. Adaptive management plans should address a range of issues, including but not limited to climate (e.g., flood, drought, and hurricanes), trespass, invasive species issues, and beaver.

Financial assurances require providers to set money aside for contingencies and are an important mechanism for managing risk of project failure, including failure to complete the project, to meet performance standards, or to maintain the project. Holding all forms of compensatory mitigation to equivalent standards, these financial assurance plans are typically worked out between the mitigation provider and the USACE and cannot be modified without prior notice to the USACE.

Long-term management plans outline and describe how the compensatory mitigation project will be managed after performance standards have been achieved to ensure the long-term sustainability of the resource. This is a very important aspect of the compensatory mitigation program since many ecosystem functions will likely not fully develop within the typical monitoring period. Therefore, the long-term management plan should account for the continued maturation of the compensatory mitigation site and development of stream and/or wetland functions.

The **site protection mechanism** is a description of the legal arrangements and instrument, including site ownership, that will be used to ensure the long-term protection of the compensatory mitigation project site (40 CFR §230.97(a)). The long-term protection of compensation sites should be arranged through appropriate real estate instruments, such as conservation easements, restrictive covenants, or transfer of title to public or private land managers. The real estate instrument should restrict or prohibit incompatible uses (e.g., clear cutting, mineral extraction, all-terrain vehicle access).

1.0 Introduction

Underlying this Approach is EPA Region 4's commitment to the Section 404 (b)(1) Guidelines (40 CFR §230) and the sequential requirement to first avoid, and then minimize impacts to aquatic resources to the maximum extent practicable before proposing compensatory mitigation (40 CFR §230.91).

Aquatic resource compensatory mitigation is seldom straightforward. Ecosystem restoration projects have been characterized as exercises in approximation (NRC, 1992). Many, if not all projects are burdened with uncertainty due to vagaries in project implementation and the inherent complexity, dynamics, and variability of natural ecosystems. Project implementation can vary as a result of the methods used to carry out the project, as well as the implementation procedures unique to each U.S. Army Corps of Engineers (USACE) District (e.g., Standard Operating Procedures (SOPs), credit calculations, and service area assignments) and State. This document outlines an approach (herein referred to as the Approach) to address general aspects of ecological requirements within the context of the Mitigation Rule to provide a consistent means of guiding EPA's ecological review of Clean Water Act (CWA) Section 404 compensatory mitigation plans. This Approach was initially developed for use in EPA Region 4 (Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama and Mississippi), and contains regionally specific references and examples. The questions in the Approach, however, can be applied nationally with appropriate consideration of regionally specific references, policies and resource constraints.

This document describes an ecological approach intended to assist EPA staff in their role as contributing members of Interagency Review Teams (IRT), and lays out a technical, objective framework based on the purpose, goals, and requirements of the CWA and the Section 404(b)(1) Guidelines, as clarified and enhanced by the Mitigation Rule. The Approach provides a process by which EPA staff can and should consider the watershed context and site-specific elements spelled out in 40 CFR §230.93(c) in an ecological context and will aid the consistent review of mitigation proposals in regulatory settings, including mitigation banking prospectus and instruments, in-lieu fee (ILF) instruments and compensation planning frameworks, ILF mitigation plans, and permittee-responsible mitigation plans. In addition, the Approach may support the compilation of EPA comments on individual CWA Section 404 permit actions, development of regional conditions for Nationwide Permits and/or regional general permits, and formulation and review of mitigation plans for enforcement actions. Finally, this Approach could also be used to inform development and/or improvement of (SOPs, guidelines, or agreements at the USACE District, state, or local level for compilation and evaluation of mitigation proposals.

Specific objectives of this Approach are to:

- Evaluate stream and wetland projects using the same review process;
- Use aquatic resource classification to inform appropriate mitigation site selection;
- Ensure that mitigation project designs incorporate important ecological processes;
- Ensure that mitigation project designs account for hydrologic and ecologic landscape connections, (i.e., the watershed context); and
- Ensure that mitigation plans include performance standards and monitoring tied directly to project objectives.

Neither this document, nor the Approach itself, establish new requirements in addition to those of the CWA and regulations promulgated thereunder, or any other applicable statute. Nothing herein shall be deemed to expand or restrict the authorities of EPA. The Approach does not create or alter any legal rights, requirements, or benefits, nor is it intended to address all factual scenarios that may arise on a case-by-case basis. This ecological approach is presented as an effort to improve the outcomes of compensatory mitigation for aquatic resources, and as such will likely be revised as more experience is gained. It is our intent that this will improve compensatory mitigation approximations and lead to the design of more successful and sustainable projects that lessen impacts associated with the Section 404 program, and better address the uncertainty associated with those projects.

2.0 Overview of the Approach

2.1 Background

In 1990, with the signing of the Mitigation Memorandum of Agreement, EPA and USACE agreed to define mitigation as avoidance, minimization and compensation, although the focus since that time has been primarily on compensation (Hough and Robertson, 2008). A report on the status of the science behind wetland creation and restoration in 1989 concluded, among other things that: project goals were often unclear; monitoring was uncommon; success varied with the type of wetland and target functions; site conditions were often improper for the anticipated aquatic resource; and problems with site success were often due to off-site impacts (Kusler and Kentula, 1989). Although this report is over 30 years old, the issues raised continue to persist.

In 2001, the National Research Council (NRC) published a review and critique of the CWA Section 404 wetland compensatory mitigation program's record in meeting the No Net Less goal originally set by the interagency National Wetlands Policy Forum in 1988 and adopted by the President George H.W. Bush administration in 1990. Their report summarized existing studies of wetland compensatory mitigation sites nationwide and concluded that the program had not been successful in meeting the No Net Loss goal. The NRC outlined numerous concerns with the CWA Section 404 compensatory mitigation program and determined that many compensatory mitigation sites failed to adequately replace wetland functions lost as a result of impacts authorized by the CWA Section 404 program.

Generally, implementation of wetland mitigation projects in the southeastern U.S. has not been effective at replacing lost wetland functions and could be improved by injecting more ecologically based siting, design, and performance standards into the process; and by using reference sites to help assess the development of conditions on compensatory mitigation sites (NRC, 2001; Morgan and Roberts, 1999; Rheinhardt and Brinson, 2000; Reiss et al., 2007). Moreno-Mateos et al. (2012) undertook an analysis of wetland restoration projects across the globe and found that many had failed to restore functions, some even after decades of recovery time.

This Approach is predicated upon a number of central themes that emerged from the 2001 NRC report, as well as wetland and stream restoration literature. These themes are:

- A focus on appropriate site selection,
- Incorporation of specific goals and objectives connected to an explicit target condition,
- Adequate monitoring of specific, objective ecological performance standards,
- Development of sustainable and resilient wetland and stream mitigation projects, and
- Use of reference data or discrete sites in project planning and evaluation.

While the NRC was not charged to evaluate stream restoration as a part of the CWA Section 404 compensatory mitigation program, more recent efforts by the Environmental Law Institute, Stream Mechanics and the Nature Conservancy (ELI et al., 2016) identified several gaps in implementing stream mitigation programs, including the need to integrate functional lift into the mitigation program, more guidance on the watershed approach and linking project goals to watershed goals, the need for improved data for site selection, more guidance on monitoring for adaptive management and improving program success, aligning flexibility versus prescribed approaches, and a need to better align regulator and ecological goals. Bernhardt et al. (2005) compiled data on over 37,000 stream restoration projects nationwide in a National River Restoration Science Synthesis database. Subsequent review and assessment of that data found that 20% of the projects had no stated goals and only 10% of project records included any form of assessment or monitoring (Bernhardt et al., 2007). The authors concluded that a comprehensive assessment of stream restoration progress in the U.S. was not possible with the piecemeal information currently available- an assessment also reached by the Government Accountability Office in reports to the U.S. Congress in 2002 and 2003 (GAO, 2002; 2003).

2.2 The Mitigation Rule

In their 2001 report, the NRC made several technical, programmatic, and policy recommendations aimed at enhancing compensatory mitigation proposals, which lead to more ecologically successful mitigation projects and improved project tracking. Many of these recommendations informed the promulgation of a new CWA regulation in 2008 to address compensatory mitigation.

In 2008, the USACE and EPA promulgated regulations at 33 CFR §320 and 40 CFR §230, respectively, to improve the CWA Section 404 compensatory mitigation program (*Compensatory Mitigation for the Losses of Aquatic Resources; Final Rule;* Mitigation Rule). The Mitigation Rule lays out the policy and information required by the USACE and EPA when determining the appropriateness of compensatory mitigation for the CWA Section 404 program. It also sets policy for ensuring that the sequencing provisions of the Section 404(b)(1) Guidelines are followed (i.e., avoid, minimize, and compensate), and it provides a preferential hierarchy of mitigation types or mechanisms to satisfy mitigation requirements: mitigation banks (banks), in-lieu fee (ILF) programs, and permittee-responsible mitigation (PRM) projects. The Mitigation Rule also establishes equivalent requirements, performance standards and criteria for use by all types of compensatory mitigation to improve the quality and success of mitigation projects.

The Mitigation Rule discusses general compensatory mitigation requirements, including location, type, and amount of compensation, the use of preservation, buffers, and riparian areas as compensation, and the relationship with other federal programs (33 CFR §332.3; 40 CFR §230.93). Further, the Mitigation Rule incorporates the recommendation of the NRC report, and other scientific literature to use a watershed approach for selecting compensatory mitigation sites. Fundamental considerations in a watershed approach include watershed scale; landscape position and resource type; habitat requirements of important species; trends in habitat loss or conversion, sources of watershed impairment; and current development trends.

In addition, the Mitigation Rule adopts recommendations that compensatory mitigation projects have measurable, enforceable ecological performance standards and requires regular monitoring for all types of compensation to verify achievement of stated objectives. Detailed mitigation plans must be provided for both wetland and stream mitigation projects, and all projects must include provisions for long-term management, long-term site protection mechanisms, financial assurances, and identification of the parties responsible for specific project tasks.

The Mitigation Rule establishes 12 items, or elements, that must be included in every mitigation plan, regardless of whether it is a bank, ILF project, or PRM site (40 CFR §230.94(c)). These 12 elements comprise the substantive information that the permittee (often a proposed Bank Sponsor or ILF Sponsor) must provide in order to explain and justify their plan for a proposed mitigation project and serve as the basis for project review by the USACE District Engineer and the Interagency Review Team (IRT) agencies (Table 1).

Table 1. Twelve elements required by the Mitigation Rule to be included in a mitigation plan.

Element	Description
Objectives §230.94(c)(2)	A description of resource type and amount to be provided; the method of provision; and the manner in which the resource functions of the compensatory mitigation project address the needs of the geographic area of interest (i.e., watershed, ecoregion, physiographic province, or other geographic area of interest).
Site Selection §230.94(c)(3)	Description of factors considered during the site selection process.
Site Protection Instrument §230.94(c)(4)	Description of the legal arrangements and instrument, including site ownership, to be used to ensure long-term protection of the site.
Baseline Information §230.94(c)(5)	Description of the ecological characteristics of the proposed compensatory mitigation site and, in the case of an individual permit application, the impact site.
Determination of Credits §230.94(c)(6)	Description of the number of credits to be provided by the mitigation site, along with a brief explanation and rationale for the determination.
Mitigation Work Plan §230.94(c)(7)	Detailed written specifications and work descriptions for the compensatory mitigation project, including but not necessarily limited to the geographic boundaries of the project; construction methods, timing, and sequence; source(s) of water, including connections to existing waters and uplands; methods for establishing the desired plant community; plans to control invasive species; grading plan, including elevations and slopes; soil management; and erosion control measures. Mitigation work plans are required for both wetland and stream projects, and additional relevant information may be required for stream projects (e.g., planform geometry, channel form, and design discharge).
Maintenance Plan §230.94(c)(8)	Description and schedule of maintenance requirements to ensure continued viability of the resource once construction is complete.
Performance Standards §230.94(c)(9) and §230.95	Ecologically-based standards that will be used to determine whether the compensatory mitigation project is achieving its objectives.
Monitoring Requirements §230.94(c)(10) and §230.96	Description of the parameters to be monitored to determine if the compensatory mitigation project is on track to meet its performance standards and whether adaptive management is needed.
Long-Term Management Plan §230.94(c)(11) and §230.97(d)	Description of how the compensatory mitigation project will be managed once the performance measures have been achieved to ensure long-term sustainability of the resource, including financial mechanisms to appropriately manage the site.
Adaptive Management Plan §230.94(c)(12) and §230.97(c)	Management strategy to address unforeseen changes to site conditions or other components of the compensatory mitigation project. The adaptive management plan will guide decisions for revising compensatory mitigation plans and implementing measures to address both foreseeable and unforeseen circumstances that adversely affect compensatory mitigation success.
Financial Assurances §230.94(c)(13) and §230.93(n)	Description of the financial assurances that will be provided, and how they are sufficient to ensure a high level of confidence that the compensatory mitigation will be completed in accordance with its performance standards.

2.3 The Six Questions Every Mitigation Reviewer Should Ask

The Approach re-arranges, and in some cases re-sequences, the 12 elements required under the Mitigation Rule into a series of six questions to facilitate a more logical sequence and progression for project review and to frame the elements in an ecological context (Figure 1). For example, the first element to consider in the Mitigation Rule is the objective(s) of the project. However, understanding the type of aquatic resource, its current condition, and the impairments contributing to that current condition are needed to identify and evaluate project objectives. Thus, these questions are presented first in the Approach. Only then can the objectives of the mitigation plan be considered. The Approach aims to account for watershed context and regional variability while providing objective and consistent comments between multiple USACE Districts and among all mitigation types (banks, ILF, and PRM).

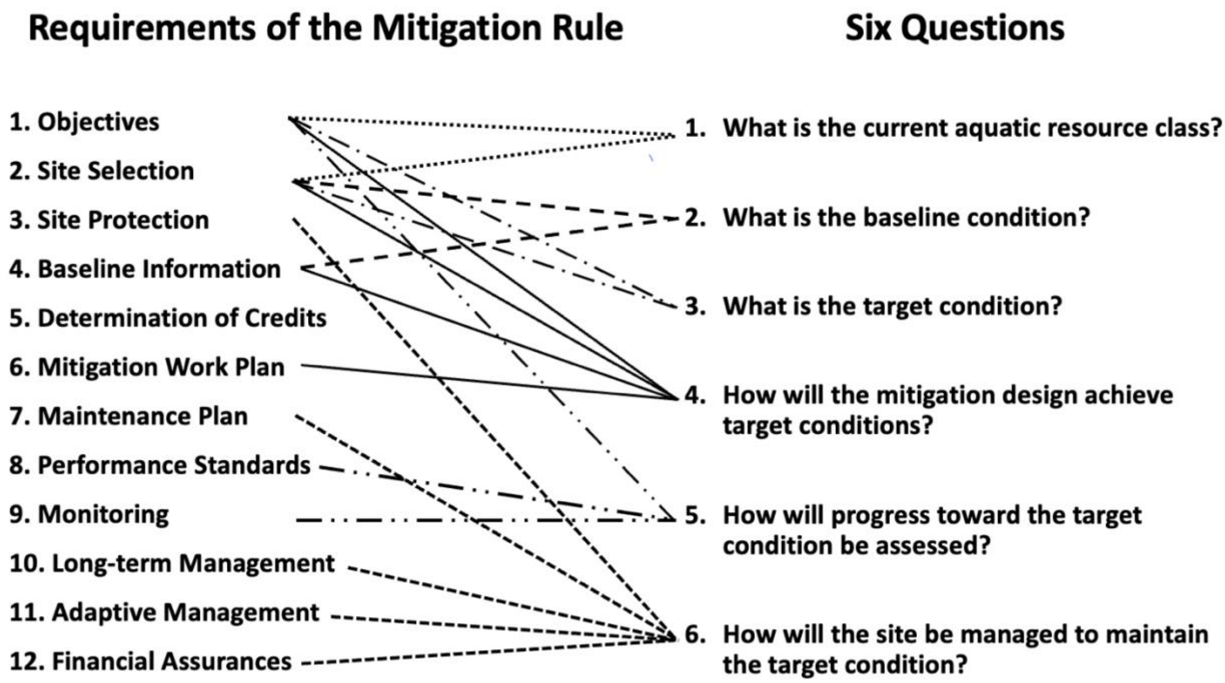

Figure 1. Relationship of the twelve elements required by the Mitigation Rule for a complete mitigation plan with the six basic questions fundamental to the Approach. Note that the determination of credits (Element #5) is not directly addressed in the Approach.

The Approach is an amalgamation of current ecological concepts and techniques drawn from the scientific literature and current practice, with an emphasis on application in aquatic resources in the southeastern U.S. (EPA Region 4). The Approach is rooted in six basic questions to be asked of all proposed mitigation projects:

(1) What are the current aquatic resource class(es) within the proposed mitigation site?
(2) What is the baseline condition of these resources?
(3) What is the site's projected target condition?
(4) How will the mitigation design achieve the target condition (i.e., what key interventions are necessary to achieve the target condition)?
(5) How will progress toward the target condition be assessed?
(6) How will the site be managed to sustain the target condition in perpetuity?

Gardner et al. (2009) noted that while the Mitigation Rule represents significant progress in implementing compensatory mitigation in the CWA Section 404 program, its effectiveness will depend on implementation in the field. By focusing the information required by the Mitigation Rule in a more resource-type context and connecting the information provided by proposed mitigation project providers and/or IRT agencies in a series of logical steps, the Approach could provide consistency to project reviews, and lead to improved aquatic ecosystem enhancement, establishment and restoration within the context of CWA Section 404 compensatory mitigation. By first classifying the aquatic resources on site, the subsequent questions build on the classification and expand the understanding of watershed and site scale functions and stressors and how they may influence project design and ecological success.

The fundamental construct of the Approach is illustrated in Figure 2. Essentially, when a site is proposed, reviewers will want to first understand its current aquatic resource type, which provides information about aquatic resource functions that should be assessed as part of the baseline assessment and also provide the basis for goal and objective setting. Methods used for assessing baseline condition should identify site impairments and stressors relative to appropriate reference conditions, which affect the restoration potential of the proposed site and inform the development of project-specific goals and objectives. A mitigation plan is devised to address project goals and objectives, such as to alleviate impairments and stressors, and improve or return the expected functions characteristic of the aquatic resource type given the watershed constraints. Within the mitigation plan, a monitoring plan should be provided which identifies the methods and intensity of sampling to establish that the target conditions, as measured by performance standards, have been met and to verify the site has achieved its ecological objectives (e.g., that impairments and stressors have been remedied or alleviated). If performance standards have not been met, then adaptive management is implemented to correct the aspect of the original plan which proved ineffective. Once the site has achieved, or is on a trajectory to achieve, the target condition, long-term management to maintain the site can begin.

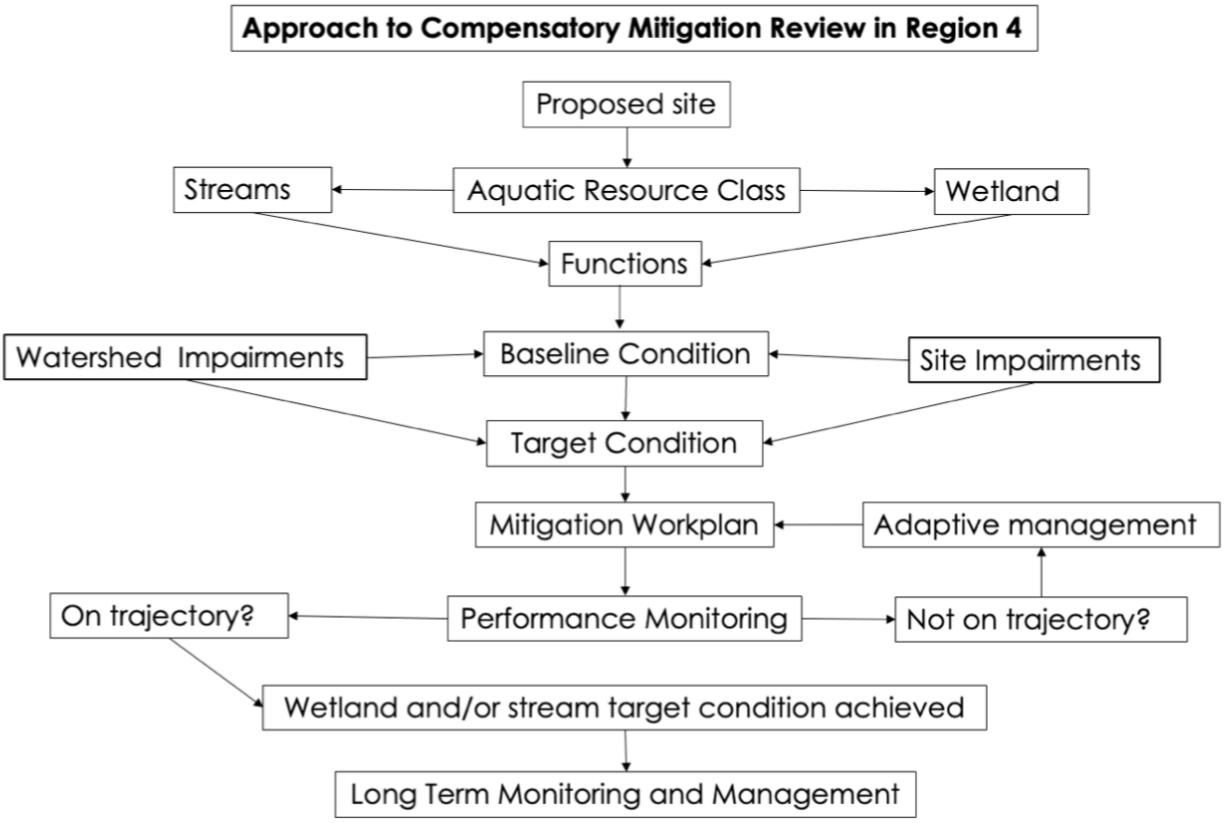

Figure 2. Approach for reviewing CWA Section 404 compensatory mitigation projects in Region 4.

It is important to not only ask a question, but also to understand the basis, or rationale for asking. The latter enables interpretation of the information presented to answer the question. Given the variability between stream and wetland sites, watershed conditions, effects of perturbations, experience of the mitigation provider, etc., a great deal of information will likely be needed to fully and adequately answer the six basic questions in the Approach and assess the adequacy of that information to support any given proposal. Understanding the rationale for why a question is being asked (Table 2) will help to discern what information is appropriate to address the question/elements of the Mitigation Rule. Each of the six questions is posed not only to consolidate information from the Mitigation Rule, but also to explicitly establish an ecological basis for compensatory mitigation review of both wetland and stream compensatory mitigation projects.

Table 2. Summary of review objectives of each of the six questions in the Approach.

Question	Rationale (i.e., why are we asking?)
What is the current aquatic resource class?	Organize natural variability; facilitate communication; focus information gathering; and ensure appropriate placement of site in landscape.
What is the baseline condition?	Identify landscape- and site-scale stressors affecting site; and understand existing site condition and functional capacity within the context of reference aquatic resources.
What is the target condition?	Establish vision/goals for the site and objectives outlining how to achieve those goals; place target condition in the context of existing condition, reference aquatic resources, and appropriate reference standard resources.
How will the mitigation design achieve the target condition?	Design projects to ameliorate landscape- and site-scale stressors affecting the site and be sustainable (recognizing that some stressors may not be able to be addressed).
How will progress toward the target condition be assessed?	Monitor efficient measures of performance that indicate functional lift; ensure sample locations and timing of sampling is representative of the whole site, the processes acting on the site, and the effects of the mitigation action; and ensure monitoring approaches can inform ecological performance standards and the need for adaptive management.
How will the site be managed to sustain the target condition?	Managing site conditions after mitigation plan implementation to allow site to mature, be sustainable and continue to contribute ecological function to the watershed; and adaptively manage if needed.

This Approach does not specifically address the production, value, costs, release, approval, or accounting of credits. The determination of credits is a significant aspect of the Mitigation Rule (see 40 CFR §230.98(o)) and the current CWA Section 404 compensatory mitigation program. There is wide variation in credit determination methods among USACE Districts, with some using area/length-based ratios to determine the amount of compensatory mitigation needed to offset impacts and others incorporating condition and/or functional assessments and/or estimates of functional lift (ELI et al. 2016). These approaches are largely determined and established by USACE District policy, with input from the IRTs, and are typically standardized within a District to decrease uncertainty for the regulated community and increase consistency among District project managers. Because this Approach focuses on determining ecological suitability, evaluating site and watershed ecological conditions and site-specific planning, it only becomes relevant to credit determination where District-specific approaches incorporate information on existing and/or proposed site conditions or estimates of functional lift in their credit determination methods.

2.4 Addressing Uncertainty and Risk

This document attempts to lower uncertainty and risk associated with compensatory mitigation projects by recommending more detailed and focused information from the mitigation providers in the form of better resource classification, specific identification of stressors, quantifiable objectives, explicit design criteria connected to the

> This approach recommends more ecologically focused information about the site's aquatic resource class, stressors, mitigation objectives, plans, monitoring and performance, and long-term management.

quantifiable objectives, and post-project monitoring and long-term management. An important aspect of the Mitigation Rule, and aquatic resource restoration in general, is adaptive management. In the context of uncertainty and risk, adaptive management may help to relieve the providers of some of the responsibility to foresee and guard against possible adverse outcomes at the project planning and design stage. Monitoring, assessment, and adaptive management make it possible to identify and evaluate unexpected developments before they become problems and take the steps necessary to control or prevent the risk of project failure.

Uncertainty is inherent in all mitigation projects. Despite the number of times a particular resource type is mitigated, or a particular method is used, there will always be uncertainty surrounding the outcomes of a project. Uncertainty is divided into natural variability, referring to the randomness observed in nature, and knowledge uncertainty, which refers to our limited understanding of a physical system and our ability to measure and model it (Skidmore et al., 2011).

Natural variability is inherent to natural systems and therefore will be difficult to reduce. With this in mind, the reviewer should recognize that there will always be a certain level of uncertainty in all mitigation projects and should discuss ways to accommodate this uncertainty with the mitigation provider. Some examples of ways a project might reduce uncertainty and risk associated with natural variability include:

- Using reference sites to better characterize the natural variability of the aquatic resource.
- Providing additional space within a riparian corridor for hydrological and morphological adjustments without damaging or destroying valuable habitats, species, ecosystems, people, or property;
- Removing or redesigning any artificial constraints (roads, bridges, culverts, and bank protection works, etc.) in the project area/reach with additional capacity to allow for unpredicted changes in the site’s hydrodynamics, flow, or sediment regimes due to, for example, climate or land use changes; and
- Including post-project monitoring and adaptive management of unforeseeable developments if and when they occur (Skidmore et al., 2011).

Knowledge uncertainty can be reduced by paying careful attention to:

- Precision and accuracy of field measurements (i.e., measurement error);
- Gaining in-depth understanding of the operating processes and functions of the aquatic system (i.e., uncertainty decreases as knowledge of the system increases);
- Adequately characterizing the symptoms and causes of problems manifested in the aquatic system (e.g., is the aquatic resource suffering from watershed-, or site-scale stressors?);
- Selecting appropriate monitoring parameters to represent current condition, identify design criteria, and objectively document project success; and
- Understanding the limitations (i.e., limited representativeness of natural processes and limited predictive capacity) of models and indicators used in the project. It is important for the reviewer to understand, and have thorough discussions with the provider and others, about the level of uncertainty in input data, analyses, and outputs of models. Many models include error estimates which should be understood and accommodated in the mitigation planning process.

Risk is broadly defined as the product of the chance a particular event will occur (probability), and the impact the event would cause (consequence), if it did occur. Risk and uncertainty are not the same thing: uncertainties may be large, but many of them pose little risk to outcomes of the project. Therefore, reviewers should consider whether risks are unacceptable before asking the provider to reduce uncertainty. For example, not calculating the changes in velocities and shear stresses as a result of channel reconfiguration and placement of instream structures may result in failing structures or the stream abandoning the structures. The reviewer may consider these anticipated results unacceptable and ask for the provider to address the uncertainties. For wetlands, restoring hydrology to former riverine wetlands requires reasonable certainty in predicting the hydrology in adjacent channels and shallow groundwater levels. If the risks associated with a project appear unacceptable, the reviewer needs to request that the provider include information, like that listed above, in the mitigation and the adaptive management plans to lower the risk.

3.0 What is the Current Aquatic Resource Class?

For the purposes of this Approach, classification is a means of organizing and understanding complex information about streams and wetlands to bring a semblance of order to natural variability, to promote better communication in the management of aquatic resources, to focus information gathering and ensure appropriate ecological site context. To this end, classification is a critical first step in the mitigation project planning process to focus conceptual understanding of wetland and stream ecological processes, and fundamentally set the stage for the effective review of the proposed mitigation project. By first understanding the functional class(es) of aquatic resources on a potential mitigation site, the provider can better understand and communicate the site-specific and watershed characteristics/processes that exert the most influence on the functions being performed, or capable of being performed by that resource type on that site.

Aquatic resource classification should be provided early on in mitigation project reviews, as it supports site selection, development of mitigation goals and objectives, and other required elements. When reviewing and commenting on early stages of mitigation plans or proposals, for example during pre-application meetings or at the prospectus stage, reviewers should consider whether the appropriate aquatic resource class(es) has been identified, and, if not, whether sufficient information is available to inform aquatic resource classification. Data to inform classification should be requested as early as possible. For wetlands, this information includes hydrogeomorphic (i.e., geomorphic position, water sources and hydrodynamics), soils and vegetation data. For streams, this information may include stream order, valley type, flow regime, and/or classification via established methods (e.g., Rosgen, stream evolution models). This section provides the reviewer with background information on recommended classification approaches in wetlands and streams and the underlying data and information used to inform these classification approaches.

3.1 Regulatory Context

While there is not a specific regulatory requirement for classifying aquatic resources, using a functional approach to determine aquatic resource type informs rule requirements for objectives (40 CFR §230.94(c)(2)) and site selection (40 CFR §230.94(c)(3)) as well as informing ecological performance standards (40 CFR §230.95) and monitoring (40 CFR §230.96). The Mitigation Rule requires a description of the resource type(s) when developing objectives for the project, specifically stating that objectives should include "[a] description of the resource type(s) and amount(s) that will be provided, the method of compensation (i.e., restoration, establishment, enhancement, and/or preservation), and the manner in which the resource functions of the compensatory mitigation project will address the needs of the watershed, ecoregion, physiographic province, or other geographic area of interest."

Further, the Mitigation Rule stipulates that selected sites must be ecologically suitable for providing the desired aquatic resource functions (40 CFR §230.93(d)). Using a functional classification to identify aquatic resource types informs a number of ecological suitability factors, including characterizing the "hydrologic conditions, soil characteristics, and other physical and chemical characteristics;" as well as "watershed-scale features, such as aquatic habitat diversity, connectivity and other landscape functions," (40 CFR §230.93(d)(1)). Ecological performance standards may be based on reference aquatic resources that represent the range of variability exhibited by the "regional class of aquatic resources" (40 CFR §230.95(b)); and the content and level of monitoring must be commensurate with not only the scale and scope of the mitigation project but also to inform whether the project is meeting its performance standards.

The biotic and abiotic variability in aquatic resource conditions presents a challenge for IRTs to isolate the most applicable technical considerations necessary to effectively review mitigation plans. Addressing this challenge can be aided by taking a functional approach to classifying wetlands and streams. Classifying wetland and stream types in ways that make connections to ecological functions is advantageous to the planning, implementation, and review of compensatory mitigation proposals, informs site selection and ecological suitability, and facilitates development of relevant, function-based objectives.

3.2 Wetland Classification

Key Points of Classification:

- Classification aids communication between provider and reviewer and focuses review on key processes and functional attributes.
- HGM is the recommended wetland classification due to its consideration of landscape position, water source and hydrodynamics.
- For streams, a combination of classification approaches may be needed to characterize a stream's watershed and landscape context, flow permanence and geomorphic context.

When a potential mitigation site is proposed, the review process should begin by considering the site's landscape context, what (if any) water sources affect the site and how water moves through the site (Box A). Wetland classification schemes that describe ecological units based on similar characteristics are useful, as they can link a specific site to a wetland class with known ecological functions using site-specific information on landscape position, hydrologic sources, soils, and vegetation. For this, the hydrogeomorphic (HGM) classification of wetlands (Brinson, 1993) is particularly well-suited and is the preferred method in this Approach. HGM classification combines site-specific landscape, hydrologic, and soil information and places a site into a broader ecological context that can inform baseline assessment, setting target conditions, monitoring, and performance standards. Soils data support classification by providing the relationship between landforms, hydrology and wetland soil development, a key element of successful wetland restoration or enhancement efforts (see Section 3.2.3 below).

Ideally, reviewers should ensure the provider classifies a proposed wetland mitigation project hydrogeomorphically to at least the class level and in many cases the subclass level, where possible (see Tables 3 and 4 below, as well as local regional HGM guidebooks). This classification should be supported by landscape information, Web Soil Survey data (e.g., Soil Web online, or Soil Web.kml in Google Earth), current HGM regional guidebook descriptions and keys, and any other available information. Additional information on technical resources for HGM and soils are provided in the Sections 3.2.2 and 3.2.3 below. However, despite the preference for HGM classification, other wetland classification methods (see below) could be used if available information for HGM is insufficient and the alternate method is well documented and provides information on how the site functions.

Box A. Recommended information to inform HGM wetland classification

Hydrogeomorphic classification:

- What is the HGM classification of the existing wetlands on site?
    - Geomorphic position. Data source?
    - Water sources. Data source?
    - Hydrodynamics. Data source?
    - Applicable HGM regional guidebook? Rationale?
- Does the site classification suggest that a different wetland type would be appropriate?

Soils information to support classification:

- Geomorphic position
- Flooding (frequency, timing and duration)
- Ponding (timing, frequency and duration)
- Seasonal high-water table (depth and timing)

3.2.1 Rationale

The following section provides the rationale for functionally classifying wetlands using the HGM classification (Brinson, 1993) and discusses other potential classification methods which could be used to augment, or in lieu of, HGM. HGM establishes a link between landscape position and hydrology to wetland functions and is widely recognized as an appropriate wetland functional classification upon which to base assessment and mitigation planning (Smith et al., 1995). It has been shown to be effective in differentiating wetland types based on geomorphic setting and hydrology (Cole et al., 1997; Gwin et al., 1999; Shaffer et al., 1999; Cole and Brooks, 2000; Cole et al., 2002). In addition, the basic premise of the HGM classification is a useful construct for wetland restoration (e.g., Bedford, 1999; Gwin et al., 1999; NRC, 2001; Zedler, 2006; Galatowitsch and Zedler, 2014) and is a wetland functional classification designed for use in the CWA Section 404 program (Clairain, 2002). There are currently numerous HGM regional guidebooks applicable to the southeastern U.S. that discuss prevalent wetland subclasses, the functions they perform, and the common impairments affecting those functions. Further HGM classifications are based on reference data (see Section 4.4). Using HGM classification focuses information on landscape setting (e.g., floodplains, slopes, depressions) and the hydrologic sources and processes that drive wetland function (e.g., overbank flooding, surface ponding, and shallow groundwater saturation), making it particularly useful to categorize and communicate wetland types for wetland mitigation planning.

Other wetland classification systems can also provide information on landscape position and hydrology and may be useful in the review of wetland mitigation proposals. The Cowardin classification (Cowardin et al., 1979), perhaps the most widespread wetland classification system in the country, is used by the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) to periodically inventory and monitor trends affecting wetland resources in the U.S. The classification is hierarchical and described by the Federal Geographic Data Committee as being primarily based on systems or complexes "that share the influence of similar hydrologic, geomorphic, chemical, or biological factors," (FGDC, 2013).

However, the NWI lacks descriptors needed for estimating wetland functions. To address this, an enhancement to include hydrogeomorphic-type modifiers for landscape position, landform, water flow path, and waterbody type (LLWW) has been developed and utilized for mapping in some parts of the U.S. (Tiner, 2010; 2013). These enhanced modifiers require remote sensing or aerial photo interpretation to incorporate into existing NWI maps (hence the term NWI+). There have been efforts to develop keys to the LLWW modifiers and apply them to NWI maps in some parts of the country, although not in the southeast U.S. However, where this enhanced NWI (NWI+) is available, the keys and map products could provide useful information for supporting an aquatic resource type determination but would require site-specific data to verify conditions detected via remote sensing.

3.2.2 Determining Wetland HGM Class

HGM classification involves the determination of a wetland's geomorphic setting, the source(s) of water that supply the site's hydrologic regime, and the hydrodynamics of the water source(s), which indicate the power and direction of water movement entering and exiting the site. Geomorphic setting refers to the landform and position of the wetland in the landscape, while water source refers to the primary origin of the water that sustains wetland characteristics, such as precipitation, floodwater, or groundwater. Hydrodynamics refers to the level of energy with which water moves through the wetland and the direction of water movement. These three abiotic factors largely dictate the functions wetlands perform and the level to which they are performed.

Brinson (1993) identified five HGM wetland classes that were later expanded to the seven classes described by Smith et al. (1995) (Table 3). Classifying wetlands into one of the seven wetland classes differentiates wetlands based on function and reduces the range of natural variation in function compared to all wetlands generally. However, as it was intended for use as an impact assessment protocol for the CWA Section 404 program, HGM classification requires an additional level of resolution to adequately differentiate anthropogenic disturbances (i.e., impacts) from natural disturbances. Wetland subclasses are differentiated by applying the three HGM classification criteria along with other characteristics (e.g., geomorphic characteristics and/or plant communities) at finer geographic scales (Smith et al., 1995). For example, Wilder et al. (2013) classified alluvial forested wetlands of the Coastal Plain into four subclasses: riverine mid-gradient; riverine low-gradient; slope headwaters; and connected depressions. Smith and Klimas (2002) recognized seven subclasses in the Yazoo Basin of Mississippi, namely riverine overbank, riverine backwater, flats, connected and isolated depressions, isolated and connected fringe. Other major subclasses present in the southeastern U.S. include mineral soil wet pine flats (i.e., bunchgrass/ pine savanna, cypress/pine savanna, and switchcane/pine savanna (Rheinhardt et al., 2002)), headwater slopes (Noble et al., 2007), Tennessee flats and seasonally inundated depressions (Noble et al., 2013), Everglade flat wetlands (Noble et al., 2002) and Gulf of Mexico tidal fringe wetlands (Shafer et al., 2007).

<u>Functional aspects of the HGM wetland classification are:</u>

- Geomorphic position: Where a wetland sits in the landscape;
- Water source: Where the water comes from before it enters the wetland; and
- Hydrodynamics: How much energy the water carries when it enters the wetland.

The descriptions of HGM wetland classes in Table 3 point out the variety of conditions, particularly hydrologic, under which different wetland classes can occur. Using these descriptions alone makes differentiating wetland classes difficult, although Table 3 provides a beginning. In addition to wetland class descriptions in Table 3, a simplified key to HGM wetland classes in the southeastern U.S. is presented in Table 4, which can help determine wetland class. Keys and descriptions of wetland classes and subclasses for a number of reference domains can be found in HGM regional guidebooks (see Section 4.4.1. for a list of HGM regional guidebooks for the southeast).

Table 3. Hydrogeomorphic wetland classes at the continental scale (after Smith et al., 1995).

HGM Class	Definition
Depression	**Geomorphic setting**: Topographic depressions (i.e., closed elevation contours) allowing accumulation of surface water. May have any combination of inlets and outlets or lack them completely. **Water sources**: Precipitation, overland flow, streams, or groundwater/interflow from adjacent uplands. **Hydrodynamics**: Vertical fluctuations ranging from diurnal to seasonal. Water flows from higher elevations toward the lowest point of the depression. May lose water thru evapotranspiration, intermittent or perennial outlets, or infiltration to groundwater. **Examples**: Cypress domes.
Tidal Fringe	**Geomorphic setting**: Along coasts and estuaries, where influenced by sea level. **Water sources**: Primarily tides and secondarily groundwater discharge and precipitation. Seldom dry for significant periods. **Hydrodynamics**: Frequently flooded with water table elevations controlled mainly by sea surface elevation. At interface between tidal fringe and riverine classes, bidirectional flows from tides dominate over unidirectional flow controlled by riverine floodplain slope. Water is lost thru tidal exchange, overland flow to tidal creek channels, and evapotranspiration. **Examples**: *Spartina alterniflora* salt marshes.
Lacustrine Fringe	**Geomorphic setting**: Adjacent to lakes where lake water elevation maintains the water table in the wetland. In some cases, these wetlands consist of a floating mat attached to land. **Water sources**: Additional sources of water are precipitation and groundwater discharge, the latter dominating where lacustrine fringe wetlands intergrade with uplands or slope wetlands. **Hydrodynamics**: Surface water flow is bidirectional, usually controlled by water-level fluctuations resulting from wind or seiche. Water is lost through flow returning to the lake after flooding and by evapotranspiration.
Slope	**Geomorphic setting**: Normally occur on sloping land ranging from slight to steep but can occur in nearly flat landscapes if groundwater discharge to the wetland surface is dominant. Distinguished from depressional wetlands by lack of closed topographic depression and predominance of the groundwater/interflow water source. **Water sources**: Predominantly groundwater or interflow discharging at the land surface. Precipitation is often secondary. **Hydrodynamics**: Dominated by downslope unidirectional water flow and water lost primarily by saturated subsurface flows, via low-order streams, and/or by evapotranspiration. **Example**: Fens
Mineral Soil Flats	**Geomorphic setting**: Interfluves, extensive relic lake bottoms, or large floodplain terraces with poor vertical drainage due to impermeable layers. **Water sources**: Precipitation. Virtually no groundwater discharge, which distinguishes them from depressions and slopes. **Hydrodynamics**: Vertical fluctuations, slow lateral drainage, and low hydraulic gradients. Lose water by evapotranspiration, overland flow, and infiltration to underlying groundwater. **Example**: Pine flatwoods
Organic Soil Flats	**Geomorphic setting**: Flat interfluves, as well as where depressions have become filled with peat to form a relatively large flat surface. Organic soil flats, or extensive peatlands, differ from mineral soil flats in part because their elevation and topography are controlled by vertical accretion of organic matter. **Water source**: Dominated by precipitation. **Hydrodynamics**: Vertical fluctuations, slow lateral drainage, and low hydraulic gradients. Lose water by evapotranspiration, overland flow, and seepage/infiltration to underlying groundwater. **Example**: Portions of the Everglades and northern Minnesota peatlands.
Riverine	**Geomorphic setting**: Floodplains and riparian corridors in association with stream channels. **Water source**: Overbank flow from channel or subsurface hydraulic connections between the stream channel and wetlands. Additional sources may be interflow, overland flow from adjacent uplands, tributary inflow, and precipitation. **Hydrodynamics**: During overbank flows, surface flows down the floodplain may dominate hydrodynamics. Headwater riverine wetlands often intergrade with slope wetlands, depressions, poorly drained flats, or uplands as the channel (bed) and bank disappear. Perennial flow is not required. Lose surface water via floodwater return to channel and surface runoff to the channel during rainfall events. Subsurface water is lost by discharge to the channel, movement to deeper groundwater (for losing streams), and evaporation. **Example**: Bottomland hardwoods on floodplains.

Table 4. Key to typical HGM classes in the southeastern U.S (after Klimas et al., 2004 and Wilder et al., 2013).

1. Wetland is located on floodplain of a stream and principal water source is the stream flooding	Riverine
Wetland is not located on floodplain of a stream and principal water source is not the stream	2
2. Wetland is not in a topographic depression, nor is it impounded	4
Wetland is in a topographic depression or it is impounded	3
3. Wetland is associated with a water body that is ponded or less than 2-m deep in most years	Depression
Wetland is associated with a water body that has permanent water more than 2-m deep in most years	4
4. Wetland is associated with an estuarine system and subject to tidal influence	Estuarine Fringe
Wetland is not associated with an estuarine system and subject to tidal influence	5
5. Wetland is fringing a reservoir	Lacustrine Fringe
Wetland is not fringing a reservoir	6
6. Topography is sloping with upslope watershed; principal water source is groundwater discharge or subsurface flow	Slope
Topography is not sloping with no upslope watershed, and principal water source is not groundwater discharge or subsurface flow	7
7. Topography is flat (0-2% slope) with no upslope watershed, dominated by organic soils, principal water source is precipitation	Organic Flat
Topography is flat (0-2% slope) with no upslope watershed, dominated by soil indicators of vertical water movement, principal water source is precipitation	Mineral soil flat

3.2.3 Using Soil Information in HGM Classification

Soil information can be used to augment the classification key above and to better understand the relationship between landforms, hydrology and wetland soil development, the key elements of successful wetland restoration and enhancement efforts. The formation of wetland soils and the sources of water that maintain hydric soils and wetland hydrology are directly related to the depth, duration, and direction of movement of water in a wetland (Bruland and Richardson, 2005a). Landscape position, coupled with the frequency, duration, and timing at which water flows vertically or laterally through the soil profile, ponds, or flows on/across the surface of the soil, affects the formation and characteristics of the soil as well as the functions a wetland performs. Interpretating soil survey data not only helps with hydric soil determinations, but also corroborates HGM classification and places soil information into a context for understanding processes important to wetland ecological functions (USDA NRCS, 2011).

Valuable sources of information for understanding the hydrologic regime associated with hydric soils include:

- Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm);
- Soil Web online (https://casoilresource.lawr.ucdavis.edu/soilweb-apps/ or the SoilWeb.kml: https://casoilresource.lawr.ucdavis.edu/soil_web/kml/SoilWeb.kmz);
- Google Earth Pro

All three of these resources present data contained in the Soil Survey Geographic Database (SSURGO), which can be used to classify a wetland area to an appropriate HGM class or subclass (USDA NRCS, 2011). Data derived from SSURGO is particularly useful because of the objectivity of the database (i.e., it was not generated to determine wetland class); the ubiquity of soil map coverage; and the presence of information pertaining directly to geomorphic setting, water source and hydrodynamics.

Soil taxonomy, landform(s), groundwater saturation (depth to seasonal high-water table), ponding and flooding frequency and duration information are provided for the mapped soil units. Landform can be used to corroborate the wetland geomorphic position identified in Table 3, while the depth to seasonal high-water table and the duration and frequency of ponding and flooding are all indicators of predominant water source. For example, the Waverly soil series is a common wetland soil in western Kentucky and Tennessee. It is listed as a hydric soil on the Kentucky and Tennessee State Hydric Soil List due to its aquic suborder (Fluvaquentic Endoaquept), exhibiting hydric soil indicators (criteria 2) and due to being frequently flooded (criteria 4). It is typically found in a floodplain landform with a seasonally high-water table of approximately 10 in (23 cm), no ponding, but with a frequent flood regime. This information lends support and additional information to the classification of low gradient riverine wetlands described in the regional guidebooks developed for western Kentucky (Ainslie et al., 1999) and western Tennessee (Wilder and Roberts, 2002). Other examples and description of using soil interpretations to support HGM classification can be found in Technical Note 3, Soil Hydrodynamic Interpretations for Wetlands (USDA NRCS, 2011).

The use of dichotomous keys (e.g., Table 4; Smith et al., 1995; Brooks et al., 2011), and soil information from the Web Soil Survey can indicate if a site is located in a particular geomorphic setting (e.g., riverine, slope, flat) and has mapped hydric soils with associated water features that indicate predominant soil hydrodynamics (USDA 2011). This information could be used by the provider to assign HGM class(es) to the site and set functional expectations for the proposed mitigation project. For instance, in the example above, Waverly soils found along a floodplain indicate a riverine wetland setting. In addition, the water sources are expected from seasonal high-water tables and overbank flooding. By contrast, slope wetland soils would have saturated soils with no flooding or ponding and flats soils would tend to have high water tables, perhaps pond, but not flood. Although the soil information from the Web Soil Survey may be general and categorical for any particular soil series in the restoration context, it augments HGM classification by providing site level information on typical water sources and hydrodynamics expected with the mapped soil series. This is important information to have as the review process proceeds.

3.3 Stream Characterization

In like fashion to wetland classification, the expectation of the Approach is that stream mitigation sites will be classified to aid in understanding the site-specific and watershed characteristics and processes that exert the most influence on the functions being performed, or capable of being performed at that site. However, unlike HGM classification for wetlands, there is not a widely accepted functional classification for streams. Thus, the information below does not outline a discrete functional classification for streams, but rather lists several classification approaches that can provide pertinent information to characterize aspects of a site's watershed, hydrology and geomorphic context which will influence the assessment of stream function for baseline, target and reference condition assessment.

Reviewers should ensure a proposed stream project site is characterized using function-based approaches that provide the watershed, hydrologic and geomorphic information listed in Box B. Classification approaches, such as Rosgen stream class, stream order, flow regime, valley type, and stream evolution models (SEM), provide insight into important aspects of stream function at the beginning of the mitigation plan review process. Stream order and valley type provide information about landscape position in the watershed; ecoregion information provides landscape context; and flow permanence provides information on hydrology. Rosgen stream type provides information about the reach's current geomorphic condition, while SEM provides information about a channel's response to disturbance, its degradational status or where that channel is along a geomorphic and ecologic disturbance gradient. Characterization using these approaches provides landscape, geomorphic, water source, as well as disturbance-related information.

Each aspect of the stream characterization should be supported by the appropriate landscape information, field data, and other relevant information provided as part of the proposal. Information on flow permanence, morphology and slope, and watershed position of the project reach will provide context to subsequent baseline assessment and target condition steps of the Approach. Descriptions of several stream classification approaches are provided in the sections below as examples of useful information to characterize a stream mitigation site. However, any information which can provide watershed, hydrologic and geomorphic context to a stream mitigation proposal can be used in addition to, or in lieu of, the information outlined below.

Box B. Recommended information to address stream characterization.

What is the stream's watershed/landscape context?

- Where does the stream sit in the watershed?
    - e.g., determine Strahler stream order (ensure appropriate mapping resolution) and watershed size
- What is the current valley type (e.g., very confined, confined, partially confined, unconfined)?
    - Data sources? How was valley type determined?
- In what ecoregion does the site occur?

What is the flow permanence?

- Is the stream reach perennial, intermittent, or ephemeral? Data sources?

What is the geomorphic context?

- What classification approach(es) was/were used?
- Were all relevant data provided to support classification? (e.g., entrenchment ratio, width/depth ratio, sinuosity, bed materials, slope, number of channels)
- What are the stable stream types for the given valley type? How does that compare to the existing stream type?
- What is the Stream/Channel Evolution stage?
    - Model used?
    - Justification for stage?
    - Field indicators noted?

3.3.1 Rationale

There are a wide variety of stream classification systems developed to address various scientific and management purposes. David et al. (2021) provides a summary of classification approaches, including classification by flow regime, drainage network, geomorphology, riparian vegetation, other ecological factors, as well as approaches that integrate several of these together. In an effort to communicate effectively with IRT agencies and mitigation providers while also considering classifications useful to the mitigation of streams, it is recommended that a combination of approaches be used to characterize the watershed and landscape context (e.g., Strahler stream order, valley type, ecoregion), flow permanence, and geomorphic context (e.g., Rosgen classification, and stream evolution stage) and to focus further review considerations. Any stream classification system must be used with an understanding that fluvial systems are constantly adjusting and evolving in response to changes in sediment supply, channel and floodplain geometry, floods, groundwater hydrology, vegetation, woody debris, fauna (e.g., beaver, livestock), as well as other historic and contemporary natural, and anthropogenic factors that affect the stream system. Streams will respond differently to stressors and restoration approaches depending on underlying processes.

Process-based approaches to stream classification could also be considered, although there are few that are widely used, perhaps in part due to the lack of agreement on which spatial, temporal, structural, and functional attributes are most important for classification. Gordon et al. (2004) provides an overview of ecological, geomorphological, hydrological, water quality-based, and combined physical-chemical-ecological classification models which are used in different parts of the world to address different physical, chemical, biological, and ecological aspects of streams. Examples of process-based stream classifications in the U.S. include Whiting and Bradley (1993), who developed a classification of headwater streams based on dominant physical processes; Woolfe and Balzary (1996), who developed a channel classification to predict sedimentation and erosion regimes; Schumm et al. (1984), who identified straight, meandering, and braided channels and related both channel pattern and stability to modes of sediment transport in alluvial channels; and Montgomery and Buffington (1997), who proposed a similar classification system for alluvial, colluvial, and bedrock streams in the Pacific Northwest that addresses channel response to sediment inputs throughout the drainage network.

3.3.2 Watershed and Landscape Context

Functional aspects of stream classification are:

- What is watershed/landscape context?
- What is the flow permanence?
- What is the geomorphic context?

Strahler stream order (Strahler, 1952) is a widely accepted classification that provides insight into the position of the stream in the watershed. In this system, the first intermittent or perennial streams in a drainage area are assigned order one; ephemeral streams are not counted. First order streams have no tributaries, with subsequent stream orders proceeding downgradient and increasing in order as tributaries of equal order join to form larger order streams. Assigning Strahler stream order is typically done from maps, which show the stream network of any given watershed. Thus, the method is dependent on the level or resolution of mapping to precisely determine the extent of, particularly, first order streams whose channel features may not show up on larger scale maps. Typically, 1:24,000 scale maps or information at better resolution, should be used to determine stream order. Stream order not only places a mitigation site in a watershed context, but also informs mitigation site selection by recognizing the distribution of stream orders where impacts and compensatory mitigation occur within watershed drainage networks (i.e., mitigating for impacts within a given stream order with streams of the same order and in similar watershed positions).

Valley type will affect the relative contribution of materials to the stream from hillslope processes. Thus, the shape, or confinement, of a valley can be used to predict stream type (particularly entrenchment), the extent of the floodplain and riparian zones, and the connectivity of valley side slopes to the stream, which may all affect the interpretation of baseline assessment and target condition information. Rosgen (1994) includes 22 valley types categorized by morphology and geology. However, for the purposes of reviewing stream mitigation projects, valley types can be organized into four categories of valley confinement (Johnson et al., 2015):

- **Very confined:** Valleys are so narrow that only the fully entrenched stream types can exist. In these valleys, there is no room for an appreciable floodplain to develop, and the streams are intimately associated with the steep side slopes that define their edges. Valley bottom width is less than 1.4 times the bankfull width of the stream.
- **Confined:** Valleys at more moderate levels of confinement, where the side slopes tend to be more gradual or spaced farther apart, and there is room for narrow floodplains and riparian strips alongside the channel. Valley bottom width is between 1.4 and 2.2 times the bankfull width of the stream.
- **Partially confined:** Valleys that can be defined as those in which the belt width of the stream is constrained on one side or the other by either bedrock or the valley wall. Valley bottom width is between 2.2 and 7.0 times the bankfull width of the stream.
- **Unconfined:** Valleys are wide enough to accommodate broad floodplains and riparian wetlands; streams in these valleys are generally buffered from hillslope processes. They are generally lower-gradient than confined valleys and composed of finer-grained material including alluvial or lacustrine fill. In unconfined valleys, lateral migration is not limited on either side, and the natural stream encounters valley bottom edges only occasionally. Valley bottom width exceeds 7 times the bankfull width of the stream.

Ecoregions are areas of similar climate, landform, soil, potential natural vegetation, hydrology or other ecologically relevant parameters. Ecoregions represent areas where similar aquatic biotic assemblages (e.g., fish, macroinvertebrates, algae, riparian birds) are likely to occur (Stoddard, 2004). Ecoregions have been used in federal and state efforts to assess and monitor biological and water quality conditions in streams and wetlands. Reviewers should consider at least the Level 3 Ecoregion in which the project site occurs. This level of resolution provides a landscape description of the site and a means of accessing existing federal and state biological and water quality databases that could serve as a potential basis of comparison during the baseline assessment (Question 2), targeting (Question 3) and performance monitoring (Question 5). In some cases, differences in Level 4 ecoregions are important, as they have been shown to support statistically different macroinvertebrate community structure in headwater streams (Somerville and Pond, 2022), and the ambient monitoring programs in numerous southeastern states base their macroinvertebrate bioassessment indices on Level 4 ecoregions (e.g., Alabama, Georgia, Tennessee).

3.3.3 Flow Permanence

Flow permanence is the degree to which flow and water persist in the channel. It is an important ecological characteristic of streams because of its effect on stream water quality and biota. Stream reaches that flow continuously (perennial) often support much different fauna than those where flow is discontinuous for portions of the year (intermittent). Another major change in fauna occurs not only when flow is discontinuous, but also in stream channels where pools dry for part of the year. Ephemeral channels are those which only flow for a period of days in response to runoff, are dry much of the year and tend to only sporadically support aquatic organisms.

For the purposes of this Approach, flow permanence should be characterized as: **perennial** for streams that flow continuously during a year of normal rainfall, often with a streambed located below the water table for most of the year; **intermittent** for streams that flow for only part of the year, typically during a wet season when the streambed may be below the water table or when melt water from snow provides sustained flow; or **ephemeral** for streams that flow only in direct response to precipitation including rainstorms, rain on snow events, or snowmelt (Nadeau et al., 2015). These definitions coincide with those used by EPA in the development of regional stream duration assessment methods (SDAMs) (https://www.epa.gov/streamflow-duration-assessment).

SDAMs can be used in lieu of long-term hydrologic records of streamflow duration, and rely on regionally specific field indicators to determine streamflow duration. Regional SDAMs consider differences in climate, geology and topography in developing robust regional hydrologic, geomorphic and biological indicators that reflect a streamflow duration classification of perennial, intermittent, or ephemeral. As these methods are developed, they can be used to characterize flow permanence for this Approach and may be useful in the baseline assessment (Question 2). Links to existing SDAMs, including local and regional SDAMs, and status of federal regionalization efforts can be found at the EPA website listed above. Reviewers should consider how streamflow permanence was determined and encourage the use of SDAMs when and where available.

3.3.4 Geomorphic Context

The **Rosgen classification** of streams (Rosgen, 1994; 1996) is an example of classifying streams based on geomorphic channel patterns and has gained widespread use throughout the southeast and much of the country. The channel information collected for Rosgen classification can be useful to inform the review process and as a communication tool between mitigation providers, practitioners, and regulators. Generally speaking, the Rosgen classification is similar to the HGM classification in its description of geomorphic characteristics of the channel. However, unlike HGM, which incorporates hydrology and hydrodynamics into the classification, Rosgen does not explicitly incorporate hydrologic and hydraulic processes into the designation of classes; it has been described by some authors as a form-based or descriptive classification system (Goodwin, 1999; Buffington and Montgomery, 2013). Hence the recommendation to use in combination with other classification approaches to characterize valley type, stream order, flow permanence, and channel evolutionary stage.

In brief, the Rosgen system uses six morphological measurements (entrenchment, width/depth ratio, sinuosity, number of channels, slope, and bed material particle size) for classifying a stream reach into eight major Rosgen stream classes (Table 5). Entrenchment describes the relationship between a stream and its floodplain (i.e., how accessible a floodplain is to the stream) and is defined as the vertical containment of the stream and the degree to which it is incised in the active floodplain. The width/depth ratio can have a significant effect on the mechanics of secondary flows, sediment transport, and baseflow habitat, and is measured as the ratio of top width to mean depth for the bankfull channel. Sinuosity is the ratio of stream length to valley length or, alternatively, valley slope to stream slope. The bed material particle size used in the classification is the dominant bed surface particle size, determined in the field by a pebble-count procedure (Wolman, 1954) or as modified for sand and smaller sizes. Stream slope is measured over a channel reach of at least 20 bankfull widths in length (FISRWG, 2001). The number of channels differentiate single-thread streams from streams that are braided or anastomosed with multiple channels. Reviewers should be familiar with the general description and geomorphic aspects of the eight Rosgen stream classes (i.e., width/depth ratio, entrenchment ratio, sinuosity, and slope) and the valley type to effectively utilize or interpret the Rosgen classification.

Table 5. General descriptions of stream types and their criteria for Level 1 classification (Rosgen, 1996). Note that sinuosity and slope (provided as typical ranges) are secondary classification factors and should not limit the use of specific stream type.

Stream Type	General Description	Entrenchment Ratio (ER)	W/D Ratio	Sinuosity	Slope (ft/ft) (%)
A	High relief. High energy/ debris transport associated with depositional soils. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step/pool bed morphology. Very stable if bedrock or boulder dominated channel.	<1.4	<12	1.0 to 1.2	0.04 to 0.10 (4- 10%)
B	Moderate relief, colluvial deposition. Moderate ER and W/D ratio. Narrow, gently sloping valleys. Rapids predominate with scour pools. Very stable plan and profile. Stable banks.	1.4 to 2.2	>12	>1.2	0.02 to 0.039 (2-3.9%)
C	Low gradient. Broad valleys with terraces in association with broad floodplains, alluvial soils. Slightly entrenched with well-defined meandering channels. Riffle/pool morphology.	>2.2	>12	>1.4	<0.02 (<2%)
D	Low gradient. Broad valleys with alluvium, steeper fans. Depositional, braided channel with longitudinal and transverse bars. Active lateral adjustment, with abundant sediment supply. Convergent/ divergent bed features, aggradational processes, high bedload and bank erosion.	n/a	>40	n/a	<0.04 (<4%)
DA	Low gradient. Broad valleys with fine alluvium and/or lacustrine soils. Anastomosed (multiple channel) geologic control creating fine deposition with well vegetated bars that are laterally stable with broad wetland floodplains. Very low bedload, high wash load sediment.	>2.2	Highly variable	Highly variable	<0.005 (<0.5%)
E	Broad valley/meadows with alluvial materials and floodplains. Low gradient, highly sinuous with stable, well-vegetated banks. Riffle/pool morphology with very low W/D ratios.	>2.2	<12	>1.5	<0.02 (<2%)
F	Entrenched in highly weathered material. Gentle gradients with high W/D ratio. Meandering, laterally unstable with high bank erosion rates. Riffle/pool morphology.	<1.4	>12	>1.4	<0.02 (<2%)
G	Gullies, step/pool morphology with moderate slopes and low W/D ratio. Narrow valleys or deeply incised in alluvial or colluvial materials, i.e., fans or deltas. Unstable with grade control problems and high bank erosion rates.	<1.4	<12	>1.2	0.02 to 0.039 (2-3.9%)

An important aspect of Rosgen's classification is the determination of the bankfull geometry (i.e., channel width and depth required to contain the bankfull discharge which fills an alluvial channel up to the elevation of the active floodplain). The determination of bankfull geometry requires effective identification of indicators in the channel that correspond to the bankfull discharge. Bankfull indicators have been shown to be subjective and often difficult to accurately determine in the field, especially in rapidly changing channels, because field indicators are often subtle and are not valid if the stream is not stable and alluvial (FISRWG, 2001). In unstable streams, bankfull indicators are often missing entirely. Identifying bankfull indicators (e.g., the first flat depositional surface nearest in elevation to the baseflow water level in stable alluvial channels, and/or the average elevation of the highest surface of the channel bars) in the field and their correlation with the appropriate stream discharge requires training and experience.

For the reviewer, understanding how bankfull was determined is of critical importance in characterizing stream type both for existing condition and setting the target condition for design plans. When a stream is classified using the Rosgen classification, the indicators used to determine bankfull geometry and their correlation with appropriate flow conditions (i.e., bankfull flows) will need to be clearly explained by the mitigation provider and considered in the review. Bankfull discharge is often used in stream design as the design flow (see Section 6.3) upon which the modified or reconfigured channel is sized. For more information on determination of bankfull, see Rosgen (1996), FISRWG (2001), Harrelson et al. (1994), USDA NRCS (2007), and USACE (2020).

Stream evolution models (SEM) and channel evolution models (CEM) can also aid in conceptualizing how channel morphology responds to disturbance (FISRWG, 2001). The evolutionary trajectory of any given stream and floodplain system can be significantly different based on the magnitude and size of bedload and suspended load, local bed and bank controls, and repeated impacts (Table 6). These models add considerable benefit to any classification approach and should be included to lend insight into stream morphological responses to disturbance.

The most notable channel evolution models (Schumm et al., 1984; Simon and Hupp, 1986) have been in use since the 1980's to help inform management of impacts that have caused channel instability. However, as Cluer and Thorne (2014) point out, an unintended consequence of using CEM is the perpetuation of the assumption that single-thread meandering channels represent the natural configuration of dynamically stable alluvial streams and thus always represent appropriate target morphology for establishment or restoration. Cluer and Thorne (2014) instead maintain that many pre-European settlement streams were anastomosed (i.e., lower energy, low width/depth ratio channels comprised of cohesive bed and bank materials with lots of vegetation creating vegetated islands (not bars)), and that the multi-channel, frequently inundated floodplain stream configuration represents a natural and ecologically valuable stream-type. Such conditions in pre-colonial North America have been attributed largely to the former abundance and distribution of beaver (*Castor canadensis*) (Naiman et al., 1988; Wohl, 2021). As such, Cluer and Thorne (2014) proposed an update to the CEM concept, referred to as the Stream Evolution Model (SEM), which combines stages outlined in Schumm et al. (1984) and Simon and Hupp (1986) and inserts a multi-threaded anastomosed precursor stage to better represent pre-disturbance conditions in some contexts (Figure 3). This precursor stage is equivalent to a Rosgen DA channel and represents an ecologically rich stage of stream evolution where stream morphology and floodplain interactions make these stream types stable (i.e., as channel depth decreases and floodplain widens) and ecologically diverse (i.e., channel and floodplain become integrated habitat). Restoration of these stream systems has gained increased attention throughout the U.S. in recent years and has been referred to as valley restoration (e.g., Starr and Harman, 2015) or restoration using beaver dam analogues (e.g., Pollock et al., 2015; Goldfarb, 2018; Davee et al., 2019).

Table 6. Channel evolution model and stream evolution model stages with description of reach-averaged characteristics (Cluer and Thorne, 2014) and corresponding Rosgen classes (Johnson et al., 2015).

CEM (Schumm et al., 1984)	CEM (Simon and Hupp, 1986)	SEM (Cluer and Thorne, 2014)	Description	Rosgen Stream Type
		Anastomosing	Pre-disturbance, dynamically meta-stable network of anabranching channels and floodplain with vegetated islands supporting forested or herbaceous wetland;	Da, Db
		Single thread channels		
I. Undisturbed	I. Pre-modified	1. Sinuous	Dynamically stable and laterally active channel within a floodplain complex. Flood return interval 1-5 year range.	C, E
	II. Constructed	2. Channelized	Re-sectioned land drainage, flood control, or navigation channels.	Typically F, B
II. Degradation	III. Degradation	3. Degrading	Incising and abandoning its floodplain. Featuring head cuts, knick points or knick zones that incise into the bed, scour away bars and riffles, and remove sediment stored at bank toes. Banks geotechnically stable.	G
		3a. Arrested Degradation	Stabilized, confined or canyon-type channels. Incised channel in which bed lowering and channel evolution have been halted because non-erodible bed materials (bedrock, tight clays) have been encountered and banks remain largely stable.	F, G
III. Rapid Widening	IV. Degradation and Widening	4. Degradation and Widening	Incising with unstable, retreating banks that collapse by slumping and/or rotational slips. Failed material is scoured away and the enlarged channel becomes disconnected from its former floodplain which becomes a terrace.	G
		4-3. Renewed incision	Further head cutting within incised channel.	G
IV. Aggradation	V. Aggradation and Widening	5. Aggradation and Widening	Bed rising and aggrading, channel widening with unstable banks in which excess load from upstream, together with slumped bank material, build berms and silts bed. Banks stabilizing and berming.	F
V. Stabilization	VI. Quasi-Equilibrium	6. Quasi-equilibrium	Inset floodplain re-established, quasi-equilibrium channel with two-stage cross-section featuring regime channel inset within larger, degraded channel. Berms stabilize as pioneer vegetation traps fine sediment, seeds, and plant propagules.	C
	VII. Late-Stage evolution	7. Laterally active	Channel with frequent floodplain connection develops sinuous course, is laterally active and has symmetrical cross-section promoting bar accretion at inner margins and toe scour and renewed bank retreat along outer margins of expanding meander bends.	C, E
		Single thread channels		
		8. Anastomosing	Meta-stable channel network. Post disturbance channel featuring anastomosed planform connected to a frequently inundated floodplain that supports forested or herbaceous wetlands bounded by set-back terraces on one or both margins.	Da, Db

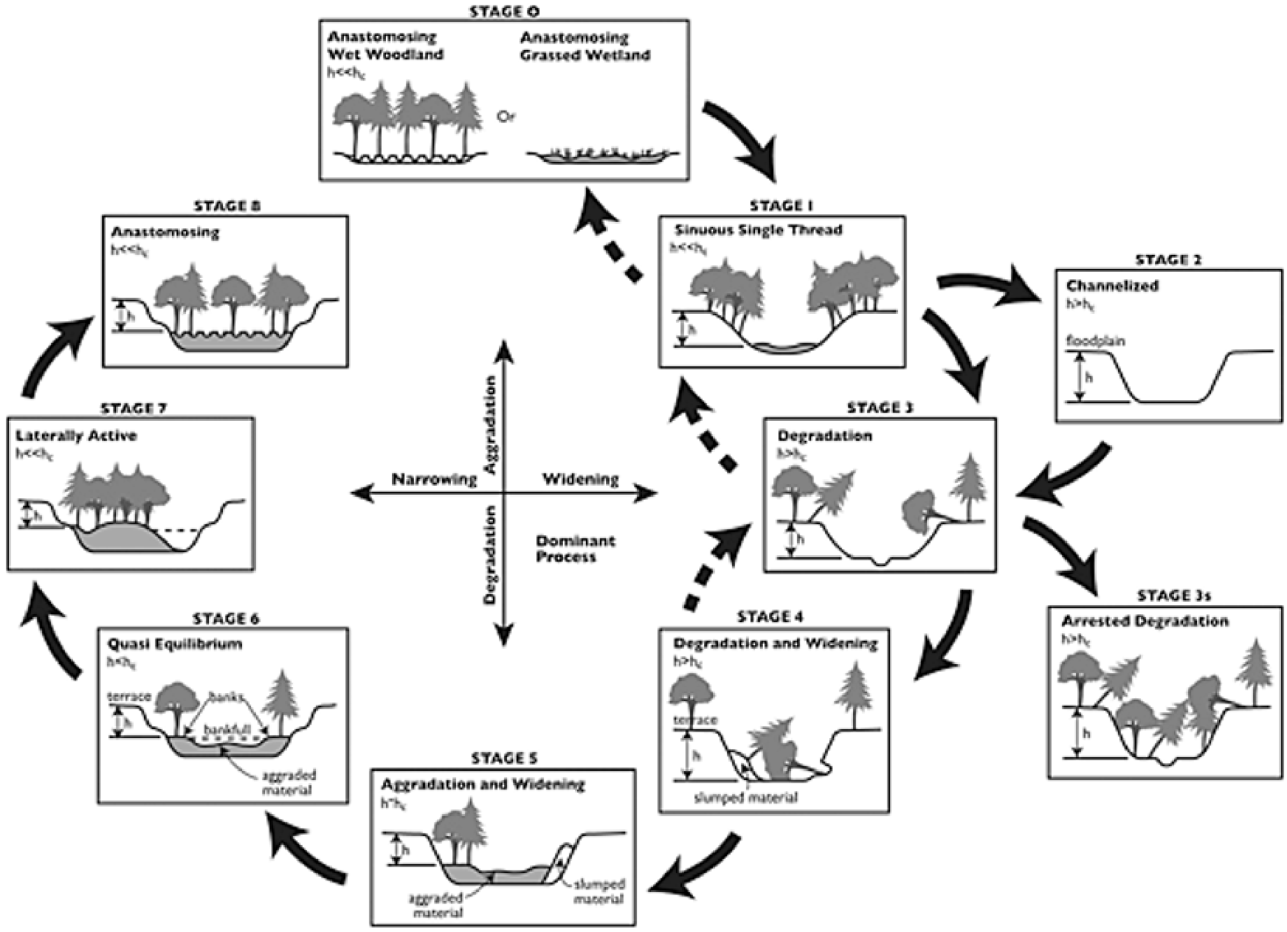

Figure 3. Stream Evolution Model (SEM) stages (reproduced from Cluer and Thorne, 2014).

The SEM, which is most applicable to low gradient (<2% slope), unconfined valleys, in humid forested regions (Bledsoe, pers comm), differs from the two previous channel evolution models by adding two successor stages to incorporate late-stage evolutionary changes (Table 6). This model also emphasizes that stream evolution in disturbed streams is not linear, but rather cyclical and explicitly recognizes that some streams may never evolve to some of these stages. For example, Stage 2 represents a maintained channel and Stage 3s is a channel that has downcut to a resistive layer at which degradation is either stopped (bedrock) or significantly slowed (cohesive clay).

Regardless of the model used, channel or stream evolution models aid in identifying the trajectory from current condition, whether that be a general tendency for a stream and its floodplain to progress toward a more stable configuration as the floodplain widens and the channel depth decreases to a point when it is difficult to know where the channel ends and floodplain begins, or whether degradation progresses until the channel functions completely separate from the floodplain (Cluer and Thorne, 2014). Adding the stream evolution model to the classification step is advantageous, because it (FISRWG, 2001; Cluer and Thorne, 2014):

- Provides a link between watershed land use change and reach scale morphology (see Section 4.5 on determining stream baseline condition).
- Recognizes multi-threaded channels resulting from channel aggradation as a natural channel form (Stages 0 and 8) which may only require minimal, if any, active work.
- Recognizes that a stream in an early degradational stage may be stabilized with grade control measures before they cross a geomorphic threshold of bank failure (e.g., banks too

high/ too steep; SEM stage 4) thus averting severe widening and massive sediment loading to downstream reaches and preventing further degradation of that reach, as well as those upstream.

- Recognizes that less intensive efforts may be required to improve stream reaches in Stages 6 and 7 than those in Stages 2 through 5 (see Section 6.5 on stream design and implementation).
- Recognizes the role lateral stability plays in accelerating degradation and bank stability problems in Stages 3s through 5, and that mitigation approaches must consider the lateral instability as well as vertical.

4.0 What is the baseline condition?

Baseline condition reflects the current functional capacity, or the degree to which a resource performs a suite of specific functions, and is influenced by the level and source of stressors affecting the proposed mitigation site. Establishing the baseline condition and identifying stressors acting on the proposed site provides insight into factors requiring amelioration to enhance, establish or re-establish functions. These factors would then need to be addressed and/or considered as limitations in the mitigation project. In essence, this step of the Approach provides information to evaluate site selection and the ecological suitability of a proposed mitigation site in relation to the level and source of stressors affecting the site. This step also identifies initial site data that will inform target condition and evaluate progress towards achieving performance standards.

Site-specific baseline information should be provided early on in mitigation project reviews, as it supports site selection, mitigation goals and objectives, workplans and other required elements. At the prospectus or pre-application stage, some baseline data should be provided, including an evaluation of both watershed and site-scale stressors and the results of any rapid assessments. At this stage, baseline information should be sufficient to support the ecological suitability of the mitigation site, inform project objectives and the mitigation activities proposed (e.g., what stressors should be addressed) and should indicate where more detailed data or additional analyses may be needed to inform design, performance standards and monitoring.

When reviewing and commenting on early stages of mitigation proposals, reviewers should provide comments to highlight areas where additional data collection may be needed to finalize the mitigation plan and should consider whether results of initial baseline analyses support site selection, project objectives and proposed mitigation activities. Reviewers should also consider requesting a site visit if one has not already been coordinated for the IRT. During review of complete draft mitigation plans, reviewers will want to ensure all necessary baseline information has been collected and included before the mitigation plans are finalized. The main opportunity to provide these comments will be during the Public Notice comment period for individual permits or during review of the draft prospectus and/or mitigation bank instrument or ILF project addendums.

Important elements of a baseline assessment include evaluation of watershed and reach or site-scale stressors, results from approved rapid assessment approaches, and any necessary measurements to characterize the existing conditions on site and inform project design and performance standards. Baseline data represent the starting condition of the site that will be compared to monitoring data in the future to ascertain level of performance (Questions 4 and 5). This information should also be compared to existing reference data or reference data collected by the provider to establish the site's relationship with a reference population (Question 4).

A site's baseline condition is affected by factors operating at a watershed scale as well as those operating at the site or reach scale. For wetlands, stressors are typically evaluated at the sub-watershed or catchment (i.e., area draining directly to the wetland) as well as at the site scale (Sections 4.2 and 4.4). Stream stressors can be evaluated at a landscape, valley segment/type, stream reach, and/or a site or habitat unit scale, all of which represent the spatial context for various stream functions (Figure 4). However, to simplify this Approach, essentially three scales (i.e., watershed, riparian, and reach) are described for streams (Sections 4.2 and 4.5), and all affect the potential of a site to be restored. Riparian scale refers to the area up- and down-stream of the project reach (reach scale) that encompasses the riparian area and is important for evaluating sediment dynamics that may influence the site being restored. Evaluation of information at multiple spatial scales is important since impairments or stressors at the watershed, catchment, riparian and/or site scale may limit the potential of a particular mitigation project to improve ecosystem functions. For example, depressional wetlands located in an active agricultural field may not support amphibians due to the input of sediment and chemicals, as well as being limited by the adjacent habitat needed by certain species for dispersal. Similarly, an incised, entrenched channel that will be maintained in a degraded stage due to active channel maintenance or watershed land uses is likely to have limited capacity to restore full functional capacity. Such limitations should be documented by the provider early and may limit the ecological suitability of a site for compensatory mitigation.

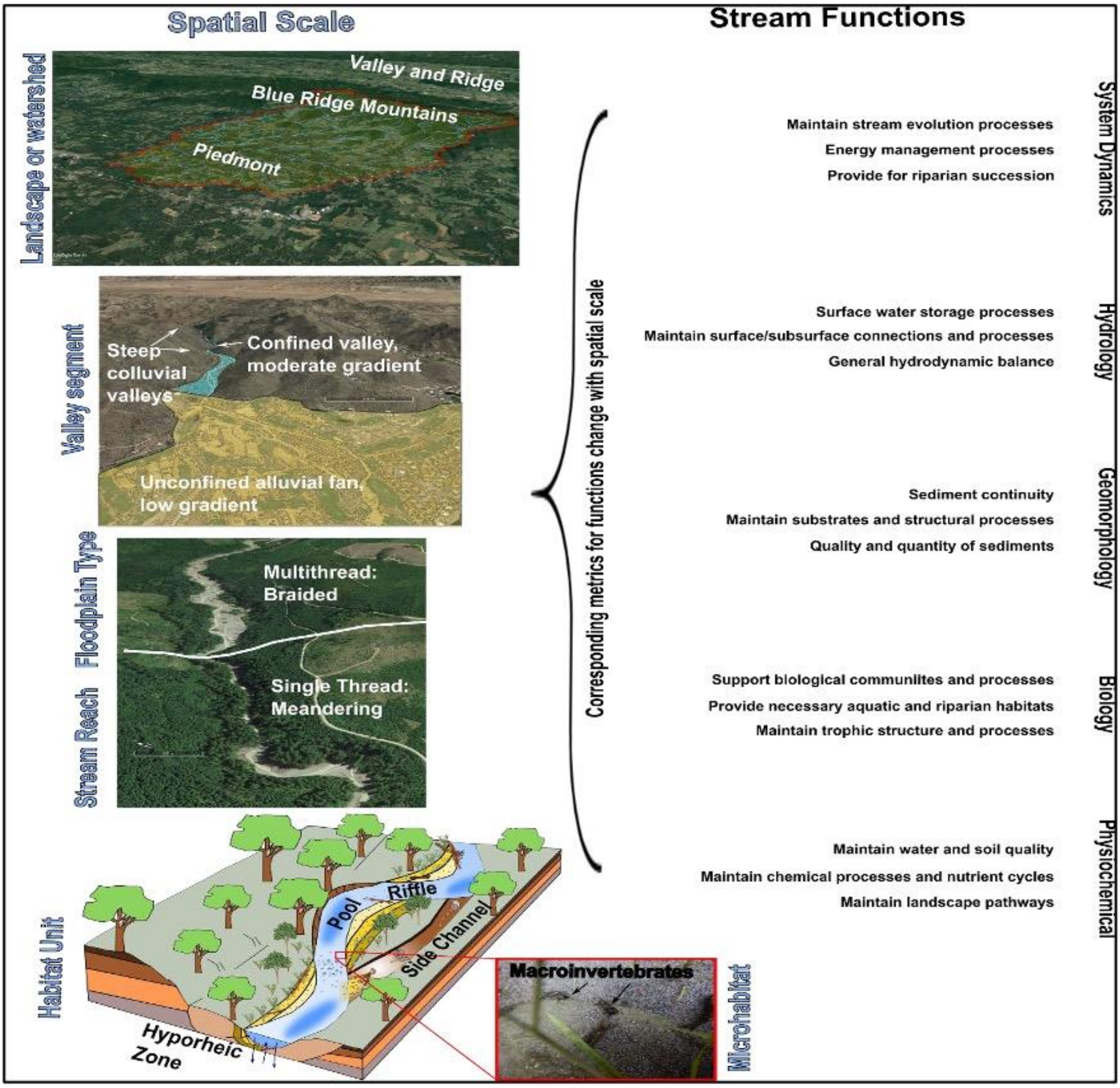

Figure 4. Spatial scales, relevant stream functions and corresponding indicator parameters for those functions. Stream functions and categories from Fischenich (2006); reproduced from David et al. (2021).

Sampling and analytical methods, to the extent possible, should be standard accepted protocols that lead to the consistent and repeatable production of data. The provider should identify these objective and repeatable methods in planning documents before data collection begins. These same methods should be used consistently throughout the life of the project to be comparable between the baseline stage (pre-project) and the monitoring of performance (i.e., post project). Likewise, the parameters measured during the baseline assessment should be the same as those used to measure performance (e.g., plant composition, plant cover, soil organic matter, depth to seasonal high-water table, and flood frequency). This section provides background information on evaluating watershed and site-scale stressors, as well as technical information on parameters and methods to assess condition in both wetlands and streams.

4.1 Regulatory Context

The Mitigation Rule explains that site selection should include consideration of watershed needs and the practicability of accomplishing self-sustaining aquatic resource restoration, enhancement, etc., at the proposed mitigation site (40 CFR §230.93(d)). Watershed-scale features, such as aquatic habitat diversity, habitat connectivity, stressors and other landscape-scale functions, as well as the size and location of the compensatory mitigation site relative to hydrologic sources and other ecological features, should also be considered. These factors are components of a watershed approach to site selection.

> The ultimate goal of a watershed approach is to maintain and improve the quality and quantity of aquatic resources within the watersheds through strategic site selection and reconnection of these resources to up-and downstream waters.

The Mitigation Rule explains that the goal of the watershed approach is to “maintain and improve the quality and quantity of aquatic resources within watersheds through strategic selection of compensatory mitigation sites,” (33 CFR §332.3(c); 40 CFR §230.93(c)(1)). The watershed approach, therefore, requires consideration of how the types and locations of potential compensatory mitigation projects will sustain aquatic resource functions in the watershed and how surrounding land uses will affect the ability of the potential site(s) to deliver those functions. Fundamental considerations in a watershed approach include: landscape/geomorphic position (i.e., for wetlands this refers to slope, depression, flat, etc.); resource type (i.e., wetland or stream); habitat requirements of important species; trends in habitat loss or conversion; sources of watershed impairment; and current development/land use trends. Gathering information at a watershed scale is intended to broaden the geographic extent of information considered during project planning to an area outside the project boundaries but within which land uses can affect the site’s restoration potential.

Baseline information is one of the 12 elements required in a mitigation plan. The Mitigation Rule describes baseline information as the ecological characteristics of the proposed compensatory mitigation project site including: historic and existing plant communities, historic and existing hydrology, soil conditions and other site characteristics appropriate to the type of resource proposed as compensation. Together, the Mitigation Rule requirements for baseline information and the watershed approach for site selection lay the groundwork for this question (Figure 1).

4.2 Watershed-scale Baseline Assessment (Wetlands and Streams)

This section of the Approach provides a summary of potential tools, resources, and datasets available to conduct a watershed-scale baseline assessment. A watershed assessment is intended to provide enough information to understand the existing condition of the watershed, how well it functions ecologically, and a site's mitigation potential. Ultimately, the information provided in the mitigation plan should identify potential causes of impairments and potential actions. The NRC (2001) noted that watershed structure governs the hydrologic and nutrient flows through the watershed. This structure also drives the hydrologic processes that develop and sustain streams and wetlands in the watershed, and thus establishes the relationship between wetland functions and watershed position, or stream function within the watershed (EPA, 2015). Understanding the linkages between the abiotic and biotic components of the ecosystem and the surrounding landscape serves as the basis for not only assessing ecosystem functions, but also attempting to replace/restore/enhance them (Richardson et al., 2011).

In light of the connection between wetland and stream ecosystems and their surrounding watersheds (EPA, 2015), as well as requirements in the Mitigation Rule to evaluate proposed compensatory mitigation sites in a watershed context, mitigation plans should include a watershed assessment that identifies watershed-scale stressors and their potential influence on the site's sediment and water quality functions, hydrologic potential and landscape connectivity (Box C). In addition, mitigation plans should assess the habitat potential of a site based on its proximity to biological refugia. Indicators, such as land use, hydrology, water quality, aquatic resources, habitat connectivity and landscape connectivity, can be used to characterize these functions, and should be assessed and reported by the mitigation provider.

Box C. Recommended information to evaluate watershed-scale stressors.

Watershed scale issues that must be addressed include:

Sediment and water quality functions

- Are land uses impacting sediment supply to the stream reach or wetland?
- Are land uses potentially impacting water quality from urban or agricultural runoff?
- Are any upstream or downstream impediments (e.g., dams, weirs, perched culverts, road crossings) affecting sediment/organic matter transport and/or timing?
- How much of the proposed site is contiguous to natural land cover, indicating adequate buffers?
- Are any water quality impairments occurring in the contributing catchment or watershed?

Hydrologic potential

- What is the propensity for site hydrology and wetness?
- Are land uses altering runoff processes (e.g., flashy hydrographs) to the stream reach or wetland?
- Are any upstream or downstream impediments (e.g., dams, weirs, perched culverts, road crossings) affecting flow characteristics (i.e., magnitude, duration, frequency, timing, rate of change)?
- Does soil data support wetland conditions?

Landscape connectivity

- Are land uses impacting the connectivity of stream and wetlands to adjacent habitats?
- Are any upstream or downstream impediments (e.g., dams, weirs, perched culverts, road crossings) limiting biota movement (i.e., longitudinal connectivity)?
- Are any impediments limiting flow access to floodplain (lateral connectivity) during flood events?
- Is the site located within an ecologically connected hub or corridor that identifies both aquatic and terrestrial connectivity?

Can the mitigation provider ameliorate adverse landscape-scale conditions with onsite management to reduce or remove the effects of those conditions on restoration site potential?

Given the availability of remote sensing data and GIS models and/or layers, it is feasible for mitigation providers to complete an evaluation of a proposed site's watershed, to identify the effect various land uses have on the frequency, timing, duration and magnitude of rainfall runoff, sediment, nutrients, organic material, and pollutants to the project site. Such an analysis may also locate natural areas providing ecological connections (e.g., corridors, buffers, refugia) to the project site and may indicate opportunities to reconnect relatively intact areas by restoring the connecting reach or wetland. GIS data layers are available nationally, but many states might have finer resolution or supplemental data available for use by providers to determine the level of watershed stressors affecting a proposed site.

Examples of datasets representing currently available data, which can be used to describe stressors on sediment and water quality, landscape connectivity, and hydrologic potential of proposed sites, are listed here and described in greater detail below.

- **Land Use:** National Land Cover Data (NLCD), USGS Gap Analysis Project (GAP);
- **Water Quality:** EPA's How's My Waterway (HMW), Water Quality Portal (WQP);
- **Hydrology:** National Hydrography Dataset (NHD), Topographic Wetness Index (TWI);
- **Aquatic Resources**: USDA NRCS SSURGO, National Wetland Inventory (NWI), Potential Wetland Soil Landscapes (PWSL);
- **Habitat Connectivity:** National Ecological Framework (NEF), Southeast Conservation Adaptation Strategy (SECAS) Blueprint;
- **Longitudinal Connectivity:** National Inventory of Dams (NID), Southeast Aquatic Resource Partnership (SARP) Barrier and Inventory Tool; and
- **Elevation or Terrain:** Light Detection and Ranging (LiDAR) remote sensing data.

Other resources to inform watershed assessments include:

- Various resources that describe the watershed approach specific to CWA Section 404, such as *The Watershed Approach Handbook: Improving outcomes and increasing benefits associated with wetland and stream restoration and protection projects* developed by the Environmental Law Institute and The Nature Conservancy (ELI and TNC, 2014).
- The Watershed Index Online (WSIO): developed by EPA as a national watershed data library and tool. The Indicator Library includes ecological and stressor indicators based on national datasets. While the WSIO was developed to compare across watersheds, there are state-specific Recovery Potential Screening tools that provide access to data across 300 indicators. The indicators are based on data that include land use, wetland inventories, protected lands, soils, road density, population density, runoff, and CWA NPDES data among many others.
- Historic and contemporary aerial photography, including GoogleEarth and EagleView.
- StreamCat (the Stream Catchment Database): assembled by EPA's Office of Research and Development (ORD) to support the National Rivers and Streams Assessment (NRSA) and publicly available (http://www2.epa.gov/national-aquatic-resource-surveys/streamcat). StreamCat greatly reduces the specialized geospatial expertise needed by providers and project managers to acquire landscape information for both catchments (i.e., the nearby landscape flowing directly into streams) and full upstream watersheds of specific stream reaches (Hill et al., 2016). Layers included in StreamCat representing natural components are: landcover, soils, lithology (surficial geology), runoff, and topography. Layers representing anthropogenic factors include roads, dams, mines, U.S. Census Data on population and housing density, urban and agricultural land use, imperviousness, and EPA Superfund sites.

- Water Resources Registry: state-specific preservation and restoration models displayed on an interactive online mapping tool created with the collaboration of a team of federal, state, and local partners. Spatial analyses and resulting models are generally developed for four main categories: wetlands, riparian areas, terrestrial areas, and stormwater management control.

CAVEAT: Use of these data sources is not completely diagnostic of a site's potential, nor will it be definitive for recommendations of concurrence or non-concurrence with mitigation proposals. Additional watershed-scale assessment should be undertaken to further review the factors identified by the above-referenced GIS data layers. Many states may have higher resolution data available that can help analyze watersheds within a particular geographic region (e.g., Water Resource Registry, LiDAR).

Sediment and water quality functions

Example of Landuse Data: NLCD categorizes land uses into broad categories that differentiate anthropogenic land uses (e.g., agriculture, residential, and urban) from natural cover (e.g., forest, meadows, and wetlands). The USGS GAP includes landcover data, protected areas data, and species data. The land cover data includes detailed vegetation and land cover patterns for the continental U.S. The protected areas, data and species data, have been incorporated into the NEF data described below to identify habitat connectivity.

Interpretation: Land use/land cover data represents the effects, or potential effects of anthropogenic activities on the site potential for a compensatory mitigation project. Anthropogenic cover types (e.g., high, medium and low development intensity, cultivated cropland, and developed open space) indicate conditions that affect the hydrologic and material balance into and out of the wetland and/or stream. Land uses typically increasing sediment supply include: upland drainage; deforestation; surface mining; urban development; and agricultural drainage. Decreases in sediment supply may result from dams and river regulation; reforestation; mine reclamation; and sediment management (Skidmore et al., 2011). Urban and agricultural areas typically decrease the ability of rainfall to infiltrate thus increasing the amount and velocity of runoff as well as affecting the timing of flows. Therefore, proposed compensatory mitigation sites adjacent to developed land covers will be at higher risk of not achieving full functional replacement. Similarly, for streams, the NLCD layer can be used to understand how surrounding land use might impact site potential by altering the hydrology and sediment supply, which in turn may affect the stream's ability to support reference quality biological communities. Many land uses reduce the hydrological resistance (i.e., surface roughness, storage, and infiltration) as water moves through the watershed, leading to more rapid runoff, increased peak flows and decreased low flows. Erosion and the discharge and volume of storm runoff in watersheds increase as rural or vegetated areas are converted to urban or agricultural uses. Reviewers should recognize these effects and ask how the mitigation provider intends to address these issues.

Example of Water Quality Data: Multiple mapping resources are available to identify water quality impairments within watersheds, including the HMW tool by EPA (https://mywaterway.epa.gov/) and the WQP developed by the National Water Quality Monitoring Council (https://www.waterqualitydata.us/portal/). These tools provide the ability to map waterways to identify sources of impairment as well as download more specific datasets.

Interpretation: Water quality impairments provide an indication of how human activities in the watershed may be adversely affecting aquatic organisms. Waters may be impaired for specific constituents, such as sediment, temperature or nutrients, or generally for aquatic life uses. Determining impairments can provide information on the types of stressors occurring in the watershed, and whether they could be overcome by mitigation activities proposed at a project site. For example, a watershed may be impaired for heavy metals from historic mining activities, which will limit aquatic life use within the project reach. Unless the project proposes to ameliorate the sources of these heavy metals, improvements to aquatic life may be limited. Alternatively, if there are temperature impairments, restoration, establishment, or enhancement of canopy and shade cover as part of a project may provide beneficial thermal refugia for aquatic organisms.

Hydrologic potential

Example of hydrology data: TWI data layer combines flow accumulation and direction from the NHD with digital elevation models to indicate areas likely to accumulate water on the landscape. This reflects not only potential wetlands, but stream channels as well. NHDPlus High Resolution Data has additional attributes for catchment areas and catchment characteristics.

Interpretation: The TWI provides a basis for understanding the propensity for an area to be wet. However, it does not represent groundwater presence, nor does it indicate duration of wetness. The TWI is based on an analysis of land elevations and cover, aerial images, and NWI to determine increasing probability of wetness (Wolock and Price, 1994). As TWI values increase, the probability of encountering wetness supporting wetland hydrology also increases giving the reviewer information about wetland site potential based on the probability that the site's topography contributes to the accumulation of water.

Example of aquatic resource data: The PWSL was created by NRCS to combine SSURGO data layers that indicate hydrologic and soil conditions indicative of wetlands. PWSL was developed to help identify sites that have hydric soils as a dominant or named component but are not mapped as NWI wetlands (Galbraith et al., 2011), and have the potential to be wetlands. Areas with dominant hydric soils might not be identified as wetlands for a number of reasons such as: a) the area was incorrectly mapped on the NWI maps, b) the area is missing wetland hydrology, c) the area is protected from flooding, and/or d) the area is not dominated by wetland vegetation.

Interpretation: Sites that are missing hydrology or vegetation might yet be suitable sites for mitigation based on the soil information in PWSL. This data also provides information about flooding and ponding frequency, which can help determine the HGM classification of wetlands as well as the site's potential to support wetlands.

Landscape Connectivity

Example of habitat connectivity: The NEF indicates landscapes with large accumulations of natural habitat either in hubs or corridors. The NEF defines ecological hubs as priority ecological areas consisting of at least 5000 acres of natural ecosystems, while corridors are derived from least-cost pathway (i.e., least human disturbance pathway) analyses among hubs. Auxiliary connections are manually derived adjustments for connected areas not captured in the computer-based least-cost modeling. The NEF was developed from the Southeastern Ecological Framework (Durbrow et al., 2001). The SECAS Blueprint is a living spatial plan that identifies important areas for conservation and restoration across the Southeast. The Blueprint stitches together smaller subregional plans into one consistent map incorporating the best available information about the current condition of key species and habitats, as well as future threats.

Interpretation: NEF provides an indicator of ecological connectivity and provides useful information about the larger landscape surrounding mitigation sites. The NEF and SECAS data indicate ecological connections between natural habitats, as well as indicating the extent of up-stream and down-stream riparian buffers. Connectivity of natural areas to a proposed mitigation site is an important aspect of maintaining wildlife habitat (Ainslie et al.,1999; Wigley and Lancia, 1998). Therefore, potential mitigation sites located in a hub or corridor, or that can be connected to a hub or corridor have the potential added benefit of contributing to wildlife habitat at the landscape scale. For streams, if a proposed reach is located within a hub or associated with upstream or downstream corridors, it has greater site potential than a reach that has no associated ecological connections, because it has riparian buffers that are either already established or, if not established, can potentially be connected to existing upstream and downstream riparian areas.

Example of longitudinal connectivity data: The NID is a congressionally authorized database documenting the current state of dams in the U.S. Specifically, dams included in the NID must have one of the following: a high- or significant-hazard potential classification, equal or exceed 25 feet in height and exceed 15 acre-feet in storage, or equal or exceed 50 acre-feet storage and exceed 6 feet in height. Last updated in 2016, it is maintained and published by USACE, and contains information, collected from state and federal regulatory agencies about a dam's location, size, purpose, type, last inspection, and regulatory facts. SARP barrier data includes the location of smaller dams and road-stream barriers, as well as parameters that identify the amount of habitat to be reconnected by barrier removal. SARP data can be found at https://connectivity.sarpdata.com/.

Interpretation: Dams can impact stream hydrology in many ways, such as: reduce peak flood flows, increase low flows due to dam releases, increase duration of moderate flows, and generally alter the stream's flow regime as compared to unimpaired pre-dam flows (Poff at al., 2006). The change in downstream hydrology from a dam can reduce the sediment supply to downstream reaches which may increase scouring in the channel. Reduced peak flows can affect riverine wetlands that depend on overbank flows as a hydrologic source, as well as a mechanism for the import and export of sediment, nutrients, and organic matter. Reviewers should identify dams in the proximity of a proposed site and have the longitudinal, lateral, vertical, and temporal effects on the site assessed.

Interpreting Watershed Baseline Assessments for Streams:

Like wetlands, stream functions are largely governed by the timing and delivery of water, sediments, and nutrients from the watershed. Stream functions are also influenced by vegetation and large wood that contribute organic material, as well as dissipating hydraulic energy on stream beds, banks and floodplains. Decades of research has demonstrated many of the threats posed to river and stream ecological integrity are a result of human actions occurring at the watershed scale (Allan, 2004). These effects tend to accumulate within watersheds, both over time and in the downstream direction, and it may take decades for the stream to recover, if ever (Harding et al., 1998; Pond et al., 2014).

Stream condition research has identified threshold values or ranges at which the percent cover of various land uses has strong correlations with various measures of stream condition (Allan, 2004). For example, both Paul and Meyer (2001) and the Center for Watershed Protection (2003) provide excellent reviews of the effects of urbanization (i.e., impervious surfaces) on the physical, chemical, and biological conditions of streams. Many research studies summarized in these reviews have clearly detected degradation of physical, chemical, and biological conditions in streams when the proportion of total impervious surfaces in watersheds reaches 10 to 20 percent. Similarly, Petty et al. (2010) found that ecological impairment to streams becomes almost ubiquitous in the central Appalachian region when the spatial coverage of coal mining in watersheds exceeds 18 to 20 percent. Further, Petty et al. (2010) and Bernhardt et al. (2012) both found that biological and water quality impairment of streams in this region can become apparent at mining intensities as low as 2 to 5 percent. Poff et al. (2006) found that increases in urbanization and agricultural landcover increased peak flows and flow variability, while decreasing low flows in the southeastern U.S.

Allan (2004) cites numerous studies documenting declines in water quality, habitat, and biological assemblages as the extent of agricultural land use increases in watersheds. However, the effect of agricultural land uses on streams is somewhat variable. Wang et al. (2011) found obvious declines in stream habitat conditions and biotic integrity (via fish Index of Biotic Integrity) that were apparent only when agricultural land use exceeded 50 percent in Wisconsin watersheds. However, Walser and Bart (1999) found significant increases in stream sedimentation and declines in fish diversity in Piedmont streams in the Chattahoochee River drainage basin (Georgia) when the percent agricultural land use in the watersheds exceeded 20 to 30 percent. Finally, Braccia and Voshell (2007) found that biological integrity, as measured by benthic macroinvertebrate metrics and community assemblage composition, was highly related to the density of cattle grazing adjacent to small streams in the Blue Ridge mountains of Virginia. Specifically, the number of sensitive taxa declined markedly when the density of cattle exceeded only one cow per hectare (Braccia and Voshell, 2007).

Activities affecting watershed-scale processes may be of such a nature that alterations to those processes cannot be undone (e.g., urban or mined watersheds), and that due to the condition of the watershed and the goals and objectives of a project, mitigation efforts focused only on a wetland or stream reach would be largely ineffectual. In these cases, the site potential for functional lift may be considered low or the project severely constrained. On the other hand, watersheds that have been impacted, but have best management practices (BMPs) or other remedies in place (e.g., watershed improvements, off-line stormwater management, and floodplain lowering), may be considered to have more potential for siting a compensatory mitigation project than those that do not because those BMPs may effectively ameliorate alterations to water, pollutant, nutrient, and sediment flows reaching the wetland or stream mitigation site. Therefore, assessment of land uses leading to stream impairment must take place at both the watershed and the reach scale.

In addition to assessing watershed stressors, it is important to evaluate mitigation site proximity to refugial habitats. Factors affecting the colonization of restored stream reaches by desired fish or benthic macroinvertebrates include water quality conditions (e.g., Kowalik and Ormerod, 2006) and the availability of a pool of organisms for colonization (Cornell and Lawton, 1992; Blakely et al., 2006; Hughes, 2007; Lake et al., 2007; Tonkin et al., 2014). For example, Sundermann et al. (2011) found that benthic macroinvertebrate assemblages improved in restored stream reaches only when there were source populations of the desired taxa within 5 km of the restored sites. Based on their evaluation of 21 stream restoration sites (ranging from 1 to 12 years old) and over 290 additional sites in the stream network within 10 km of the restored reaches, Tonkin et al. (2014) found that taxon pool occupancy rate (i.e., frequency and density of occurrence for a given taxa in near-vicinity stream reaches) was the most important factor affecting the likelihood of colonization of that taxa in the restored stream reach. The next most important factor cited by Tonkin et al. (2014) was distance to nearest source, with the first kilometer away from the restoration reach particularly important. Collectively these studies reinforce the importance of site selection and watershed conditions to biological success of stream restoration and enhancement efforts. Proximity of a proposed site to probable refugia should be considered by the mitigation provider and evaluated by the mitigation reviewer.

4.3 Use of Rapid Assessments in Evaluating Baseline Condition

Providers may include rapid aquatic resource (wetland and/or stream) assessments as part of the baseline assessment of a project site and/or USACE Districts may have prescribed methods to characterize current conditions. Rapid assessments can provide useful information by placing the baseline condition of a stream or wetland into context based either in terms of the project site's ecological condition (i.e., the relative ability of an aquatic resource to support and maintain a community of organisms having a species composition, diversity, and functional organization comparable to reference aquatic resources in the region (40 CFR §230.92)) or function (i.e., the physical, chemical, and biological processes that occur in ecosystems (40 CFR §230.92)). Many wetland and stream rapid assessment methods have been developed over the years (Fennessey et al., 2007; David et al., 2021; Dorney et al., 2018; Somerville, 2010). Aquatic resource assessments can be divided into two general types: condition or functional assessments. Generally, condition assessments represent point-in-time assessments, or snapshots, of a stream or wetland's condition, while functional assessments represent processes occurring over time and may provide more insight into what functions are impaired and the stressors contributing to the impairment. Either type of rapid assessment can be useful in a baseline assessment, particularly if calibrated to reference sites that occur across a range of disturbances. These can be helpful to compare the site to proposed target conditions, develop mitigation plans, and provide context to performance standards.

Condition assessments measure the extent to which a site departs from full ecological integrity using relatively simple field indicators to provide a measure describing the position of the site on a continuum ranging from full ecological integrity (least impacted or reference condition) to highly degraded (poor condition) (Fennessey at al., 2007). This relative score may be useful to give the reviewer an overall indication of the site's condition but may lack the specificity to determine the cause of impairments and/or information on ameliorating the impacts.

Functional assessments are considered better suited for application to compensatory mitigation projects. Functional assessment methods utilize field indicators to characterize chemical, physical, and biological functions and assess the functional capacity of wetlands or streams to perform these functions. Indicators are typically chosen to represent characteristics and processes of the wetland or stream that are responsive to impacts (e.g., vegetation changes, changes to flow regime, geomorphology, habitat and secondary effects) and stressors. These indicators could be used to detect change across typical post-construction mitigation monitoring timescales (e.g., 5–15 years) and spatial scales over which the assessment method is being applied.

An example of a wetland functional assessment method useful for determining baseline condition is the HGM approach. HGM explicitly links the characteristics and processes contributing to wetland functions with field indicators that are measured against reference and aggregated into functional capacity indices via basic logic multiple criteria assessment models. These assessment models are basic logic models representative of "the relationship between attributes of the wetland ecosystem and the surrounding landscape, and the functional capacity of the wetland," (Smith et al., 1995). The HGM assessment approach accompanies the wetland classification completed in Question 1 and is discussed below (Section 4.4.1).

The Stream Quantification Tool (SQT) is an increasingly used stream assessment approach in the stream mitigation program. The SQT is not a functional assessment, as it measures the point-in-time condition of structural variables rather than relying on measurements of functions themselves and does not link the variables via logic models to functions. As such, the SQT is considered a function-based assessment. What is novel about the SQT is that it aggregates multiple individual variables into a single tool to calculate the loss and lift of aquatic resource functions related to various impacts or restoration efforts. Therefore, the SQTs are more like a calculator than an ambient stream assessment protocol. Parameters included in SQTs are quantitative and can rely on rapid or more detailed data collection methods, and thus are more robust than qualitative rapid stream assessment approaches. The SQT assessment approach can be used to support baseline condition assessment and is discussed below (Section 4.5.1).

In instances when HGM, SQT or similar types of assessments are not available, other rapid assessment methods may be used in the collection of baseline information. Reviewers can gauge the effectiveness of a particular rapid assessment method by its ability to:

- Identify stressors acting on the site;
- Identify aquatic resource functions;
- Be applied to the variety of wetland and/or stream types in the region of use;
- Represent the functional capacity of a site calibrated against reference; and
- Provide field verification.

Regardless of the rapid assessment method used, most are limited in terms of resolution and quantitative data, and often lack the ability to capture all the parameters that are relevant for more-substantial projects (Somerville and Pruitt, 2004; David et al., 2021). In addition, rapid stream assessments, which are often based on visual estimates of parameter condition or value, have been shown to invite observer bias and suffer from poor objectivity and precision (i.e., repeatability) (Hannaford and Resh, 1995; Roper and Scarnecchia, 1995; Poole et al., 1997; Kaufmann et al., 1999; Somerville and Pruitt, 2004). Even field crew training does not consistently improve observer variability among crew members using the same rapid assessment protocol on the same group of streams (Hannaford et al., 1997). Stauffer and Goldstein (1997) also report that common rapid stream assessments include many highly correlated parameters and thus overemphasize some stream features and diminish the influence of others. Thus, assessing the baseline condition of a proposed site with rapid assessment methods alone will likely not provide sufficient information to ascertain watershed, riparian, and reach/site scale stressors or the current functional capacity of the pre-project site. More detailed site data, either calibrated with reference data or empirically derived, will likely be necessary (see Section 4.4.2 and 4.5.2).

4.4 Wetland Baseline Condition (Site-scale)

The following sections organize the discussion of wetland baseline condition into general wetland assessment considerations, as well as technical information for assessing vegetation, soils and hydrology. In addition to an evaluation of watershed stressors, reviewers will want to ensure a baseline assessment includes results from any approved rapid assessment approaches, and/or any necessary measurements to characterize the existing conditions on site, including site-scale vegetative, soil and hydrologic characteristics and any local site-scale stressors present (Box D). Remote data, such as information from hydrology and soils data layers (see Section 4.2), should be verified at the site scale. Local disturbances/stressors should also be verified, and any additional site-specific limitations should be inventoried and evaluated. These local, site-specific factors will affect baseline condition; and they represent the wrongs that may be righted through the implementation of the compensatory mitigation plan.

Box D. Recommended information to evaluate wetland baseline condition.

Information below is in addition to, and complementary of, the results of the watershed analysis:

- Is the site in the reference domain of an existing HGM regional guidebook?
- Is the wetland of similar class and subclass to that in the HGM guidebook? List the wetland functions of the site and how they have been impaired.
- If HGM guidebook is used, what are the results?
- Was a rapid assessment method used? If so, which one and what were the results?
- What stressors are present on the site (e.g., clear-cut, ditching, fill)?
- Has plot-level vegetation data been appropriately stratified and sampled at a sufficient intensity? If so, how was the information interpreted? What effect have stressors had on vegetation?
- Has site-specific soil mapping and soil verification been completed? What effect have stressors had on soils?
- Have soil profile descriptions, notation of hydric soil indicators, and impacts to soil integrity (e.g., tilling, plowing, bedding, land clearing, mining, and fill) been provided?
- Is there available hydrologic monitoring data, depending on HGM class and soils (e.g., surface water ponding, shallow groundwater/water table data)? For what duration?
    - Are there active stream stage recorders? For what period of record is data available?
    - Are there rain gauges in proximity to the site? For what period of record is data available?
    - Are there active ground water wells? How long have they been active and at what frequency/interval is the data available?
- Have results from hydrologic monitoring been graphically represented with rainfall data?
- What effect have the stressors had on ground and/or surface water hydrology?

4.4.1 Wetland Assessment

Reviewers should evaluate whether the mitigation provider's baseline assessment approach appropriately characterizes the wetland functions of the site. There is no expectation for reviewers to conduct wetland baseline assessments using HGM guidebooks, or any of the other rapid assessment protocols currently used. However, HGM or other rapid assessment approaches may be included in a baseline assessment and reviewers should become familiar not only with HGM classification but also with the rationale, structure, and basis for the functions, stressors, and indicators of any method used. Pertinent HGM guidebooks can provide not only general background information about the regional wetland subclass, but also functional capacity index curves which can be used as estimates of indicator response to disturbance.

Wetland classification (Section 3.2.) provides useful information about the current hydrogeographic context of a proposed mitigation site and a segue into assessing wetland baseline condition at the site. Wetland functions, defined by Smith et al. (1995) as "…the normal activities or actions that occur in wetland ecosystems, or simply, the things wetlands do," provide context and organize pertinent factors that must be addressed in a mitigation proposal. In general, HGM guidebooks and their associated reference datasets are a good starting point for gaining an understanding of the functions of different wetland types and can be used to frame baseline data assessment to ensure hydrology, soils, and vegetation data relate to wetland functions on site. All HGM regional guidebooks are available at: https://wetlands.el.erdc.dren.mil/hgmhp.html.

Current HGM regional guidebooks in the southeast address most of the classes typically identified (with the exception of lacustrine fringe) and describe many wetland subclasses over a large portion of the southeast (Figure 5). HGM regional guidebooks for a variety of HGM wetland subclasses in the southeastern U.S. are listed in Table 7. Major Land Resource Regions (MLRA) are designated by NRCS based on similarities in physiography, geology, climate, water, soils, biological resources, and land use and represent areas where HGM regional guidebooks could potentially be expanded or extrapolated.

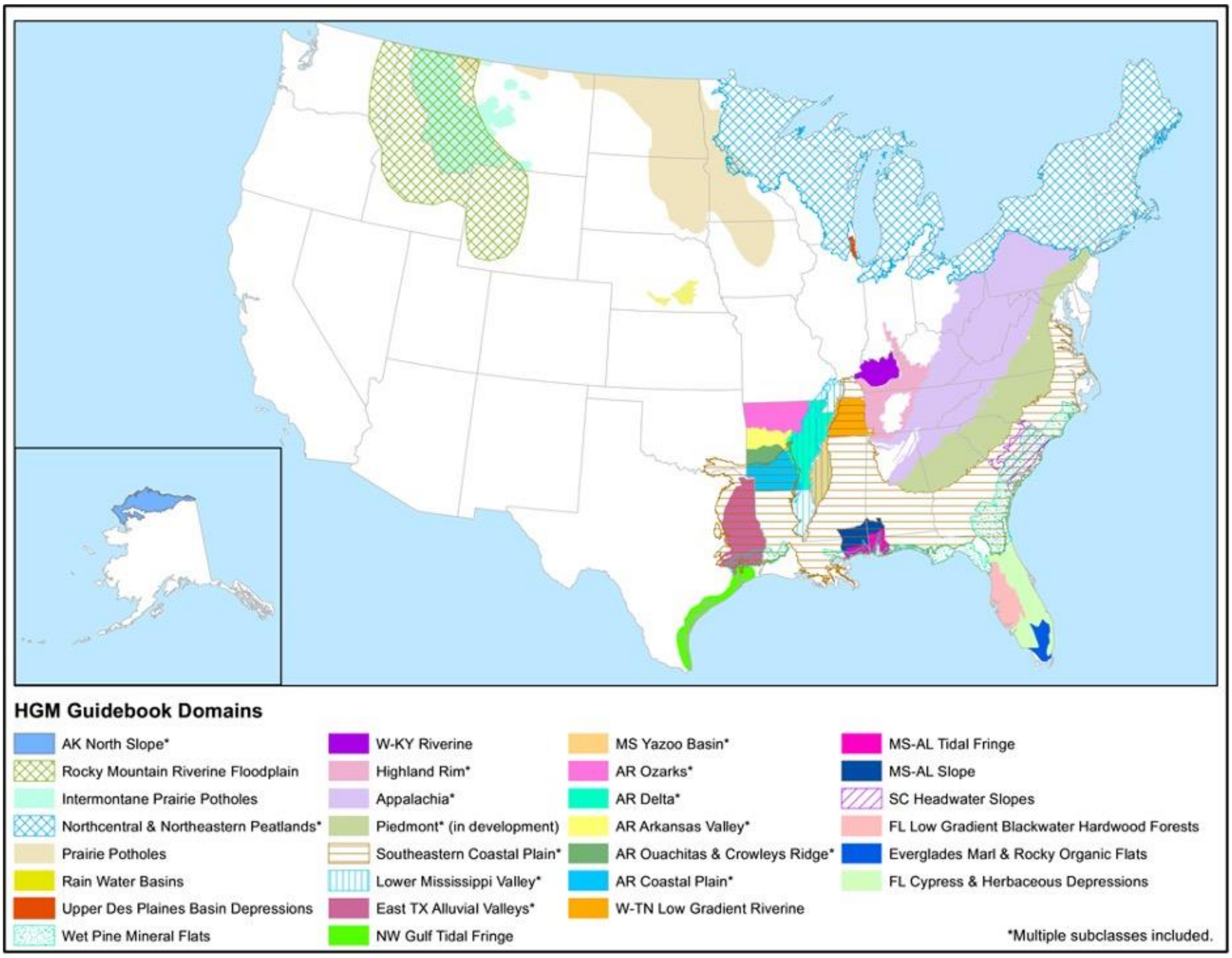

Figure 5. Reference domains of HGM regional guidebooks in the southeast and elsewhere in the United States (reproduced from ERDC HGM website).

A general list of functions organized by HGM wetland classes (Table 8) can be used to understand and describe hydrologic, biogeochemical, and plant and wildlife habitat functions of wetlands within these hydrogeomorphic classes. There are some functions which are not performed by certain wetland types due to their geomorphic position and/or water sources. For example, mineral and organic soil flats do not perform a sediment retention function since that requires a flowing water vector to carry the sediment into the wetland. Since flats are driven by precipitation, there is not the flowing water energy, or hydrodynamics, necessary to carry sediment into the flat. Even in situations where similar functions are performed by different wetland classes, they are not performed at the same rate or in the same way. In the instance of surface water storage, riverine wetlands store surface water delivered from overbank flooding; depressions store surface water delivered by overland flow, precipitation, and/or subsurface flow; and flats store rainwater that ponds on the wetland surface.

Table 7. HGM regional guidebooks developed in and applicable to assessing the functions of wetlands in the listed subclasses in the southeastern U.S.

HGM Regional Guidebook	State(s)	MLRA	HGM Subclass(es) Covered
Tidal Fringe Wetlands Along the Mississippi and Alabama Gulf Coast (Schafer et al., 2007)	AL, MS	S. Atlantic and Gulf Coast Lowland Forest and Truck Crop Region	Tidal Fringe Wetlands
Forested Wetlands in the Delta Region of Arkansas, Lower Mississippi River Alluvial Valley (Klimas et al., 2004)	AR	MS Delta Cotton and Feed Grains Region	Flat; Mid-gradient Riverine, Low-gradient Riverine Backwater, Low-gradient Riverine Overbank, Headwater Depression, Isolated Depression, and Connected Depression.
Flats Wetlands in the Everglades (Noble et al., 2002)	FL	Florida Subtropical Fruit, Truck Crop, and Range	Flats
Low-Gradient, Blackwater Riverine Wetlands in Peninsular Florida (Uranowski, et al. 2003)	FL	Florida Subtropical Fruit, Truck Crop, and Range	Low-gradient Riverine
Depressional Wetlands in Peninsular Florida (Noble et al., 2004)	FL	Florida Subtropical Fruit, Truck Crop, and Range	Cypress and Herbaceous Depressions
Forested Wetlands in the Mississippi Alluvial Valley (Murray and Klimas, 2013)	KY, TN, MO, AR, LA, MS	MS Delta Cotton and Feed Grains Region	Flat, Low-gradient Riverine Backwater, Low-gradient Riverine Overbank, Isolated Depression, and Connected Depression
Forested Wetlands in Alluvial Valleys of the Coastal Plain of the Southeastern United States (Wilder et al., 2013)	VA, NC, SC, GA, FL, AL, MS, TN, KY, LA, AR, TX	South Atlantic and Gulf Coast Lowland Forest and Truck Crop Region	Headwater Slope, Low-gradient Riverine, Mid-gradient Riverine, and Connected Depression.
Headwater Slope Wetlands on the Mississippi and Alabama Coastal Plains (Noble et al., 2007)	MS, AL	South Atlantic and Gulf Coast Lowland Forest and Truck Crop Region	Headwater Slope
Wet Pine Flats on Mineral Soils in the Atlantic and Gulf Coastal Plains (Rheinhardt et al., 2002)	NC, SC, GA, FL, AL, MS, LA, TX	South Atlantic and Gulf Coast Lowland Forest and Truck Crop Region	Mineral Soil Flats (Pine savanna)
Flat and Seasonally Inundated Depression Wetlands on the Highland Rim (Noble et al., 2013)	TN, KY, IN, AL	East and Central General Farming and Forest Region	Flats and Depressions
Low Gradient, Riverine Wetlands in Western Kentucky (Ainslie et al., 1999)	KY	East and Central General Farming and Forest Region	Low-gradient Riverine
Low-Gradient Riverine Wetlands in Western Tennessee (Wilder and Roberts, 2002)	TN	South Atlantic and Gulf Coast Lowland Forest and Truck Crop Region	Low-gradient Riverine
Selected Regional Wetland Subclasses, Yazoo Basin, Lower Mississippi River Alluvial Valley (Smith and Klimas, 2002)	MS	MS Delta Cotton and Feed Grains Region	Flats, Riverine Backwater, Riverine Overbank, Isolated Depression, Connected Depression

Table 8. Potential functions performed by HGM wetland classes in the southeast U.S. (R = Riverine; MF = Mineral Flat; OF = Organic Flat; S = Slope; D = Depression; LFr = Lacustrine Fringe; TFr = Tidal Fringe).

Processes	Functions	R	MF	OF	S	D	LFr	TFr	Description
Hydrologic	Store Surface Water	X	X	X		X	X	X	Capacity to temporarily store and convey surface water from overbank flows, precipitation, or runoff from adjacent uplands.
	Maintain Subsurface Water	X			X	X	X	X	Capacity to store and convey subsurface water from interflow and groundwater.
	Cycle Nutrients	X	X	X	X	X	X	X	Ability to convert nutrients from inorganic forms to organic forms and back through a variety of biogeochemical processes such as photosynthesis and microbial decomposition.
Biogeo-chemical	Remove/ Sequester Compounds	X		X	X	X	X	X	Ability to permanently remove or temporarily immobilize nutrients, metals, and other elements and compounds imported from sources outside the wetland.
	Sediment Retention	X				X			Capacity to physically remove and retain inorganic and organic particulates from the water column.
	Organic Carbon Export	X			X	X	X	X	Capacity of wetland to export dissolved and particulate organic carbon produced within the wetland.
Biological (Plants)	Maintain Plant Habitat	X	X	X	X	X	X	X	Capacity to provide the environment necessary for a characteristic plant community to develop and be maintained. This includes both existing plant community and the abiotic conditions required to maintain the characteristic community.
Biological (Wildlife)	Maintain Wildlife Habitat	X	X	X	X	X	X	X	Ability to support the wildlife species that utilize wetlands during some part of their life cycle.

Use of HGM Assessments: Relevant HGM assessment protocols can be used to perform a baseline site assessment. Results from these assessments transform and combine discrete field data into indices that relate a site's functional capacity to reference standard wetlands. Regional guidebooks not only identify and describe a suite of functions performed by each wetland class and associated subclasses, and characteristics and processes contributing to those functions, but also identify common disturbances that impair them (Table 9). The characteristics and processes associated with each function are represented by field measures or indicators, which are scaled against reference standard conditions, as well as across a disturbance gradient (see Section 5.3 for more discussion on reference). Having parameters scaled across a disturbance gradient incorporates the effects of disturbance into index scores. Consequently, HGM regional guidebooks can provide important insight on the types and effects of disturbance on particular wetland types, and they can be valuable as baseline assessment protocols for proposed wetland compensatory mitigation sites.

Note that the geographic coverage of all possible HGM wetland subclasses by guidebook reference domains is not complete in the southeast. Similar HGM models could be used; however, assumptions of applicability of particular assessment models would have to be made or demonstrated if a mitigation site were assessed outside of the stated reference domain. In these cases, additional reference data needs to be collected, compiled, and incorporated into existing reference data. The task of collecting appropriate additional data from reference sites would likely fall on the mitigation provider with input from the IRT.

Table 9. Typical impairments affecting wetland classes of the southeast U.S. (after Wilder et al., 2013). (R = Riverine; MF = Mineral Flat; OF = Organic Flat; S = Slope; D = Depression; LFr = Lacustrine Fringe; TFr = Tidal Fringe.)

Impairment	Affected HGM Classes							Effects
	R	*OF*	*MF*	*S*	*D*	*LFr*	*TFr*	
1. Ditching and draining	X	X	X	X	X	X	X	Eliminates wetland and wetland habitats, shunts pollution and sediment directly into downslope stream.
2. Filling to convert to cropland, silviculture, or impervious surface (e.g., roads)	X	X	X	X	X	X	X	Eliminates wetland and wetland habitats.
3a. Excavating, straightening, and/or stabilizing channels to move water downstream quickly (e.g., channelization, levees)	X			X			X	Reduces or eliminates hydrologic connection between channel and floodplain, lowers water table, reduces denitrification potential, eliminates sediment accumulation, and eventually changes species composition in channel and on floodplain.
3b. Timber removed or selectively cut from wetland; natural succession allowed	X	X	X	X	X			Removes biomass, changes species composition, decreases biodiversity, temporarily increases carbon detrital pool (from slash), and disrupts nutrient cycling and sequestration until forest regenerates.
4. Conversion to intensively managed industrial silviculture	X	X	X	X	X			Changes species composition, reduces biodiversity, and reduces detrital carbon pool.
5. Damming channel for flood control, recreation, waterfowl management, and/or power	X			X				Reduces sediment aggradation downstream; changes frequency, timing, and duration of overbank flow events; and changes species composition on floodplain.
6. Groundwater withdrawal from contributing aquifer (e.g., center pivot irrigation, pulp mills)	X	X	X		X		X	Reduces water table and duration of saturated conditions, perhaps changing species composition.
7. Deadfall removed from channel	X							Reduces instream habitat, decreases residence time of flooding, and reduces source of dissolved and particulate organic matter.
8. Stormwater runoff shunted directly to channel (e.g., often from impervious surfaces)	X				X			Increases flashiness of hydrologic regime, incises channels which decreases duration of overbank flow events, and increases pollution loading.
9. Excessive cover (>25%) of invasive species	X		X	X	X		X	Reduces biodiversity by reducing habitat heterogeneity for animals, reduces native plant species populations, and may alter nutrient cycling.
10. Fire exclusion			X	X				Affects plant community diversity and regeneration.
11. Damming by road	X	X	X		X			Disrupts wetland water budget and inundates upslope area causing longer than normal hydroperiod.

4.4.2 Wetland Site Sampling Considerations

The purpose of the baseline assessment is to capture the level and sources of degradation on the site. Applicable HGM regional guidebooks and other rapid assessments can provide useful information for assessing baseline condition but should not be used without additional site-scale vegetation, soils, and hydrology information. Rapid assessment methods are often not sufficient for use as a monitoring protocol alone to detect incremental changes in vegetative community succession, soil anaerobiosis or saturation, or increasing or decreasing hydroperiod that occur during the monitoring time frame of a typical mitigation project. As such, more detailed site hydrologic, soil, and vegetation baseline data will likely be needed, particularly where specific data and parameters will be used to inform performance standards and post-project monitoring. For instance, given the importance of hydrology to wetland functions, onsite hydrologic data is recommended to augment HGM and/or condition assessment results. If rapid assessments are not available, or not calibrated in a particular area, hydrology, vegetation, and soil sampling/characterization will need to be done as part of the baseline assessment. In addition, relevant stressors (e.g., ditches, levees, and fill material) should be identified. Reviewers should ensure parameters and protocols for baseline data collection are consistent with parameters and protocols for post-project monitoring (Section 7.3).

Elements of a Baseline Wetland Site Assessment

Vegetation sampling intensity within each habitat/cover type (area covered by plots) should be between 1-5% of the total area, although some have recommended covering as much as 20% of the sample area with plots (Stein, pers. comm. 2018). For example, if a proposed site's total acreage is 100 acres, then sampling 5% of that area would mean 2 acres of sample plots would be needed. If the sample design includes using 1/10-acre plots, then 20 plots would need to be sampled and the data analyzed and interpreted. Ideally, the number of plots required to adequately characterize an area should be determined using a species-area curve (Kent and Coker, 1992). Sampling is deemed sufficient when the species-area curve flattens out.

<u>Wetland Sampling Considerations</u>

- Detailed plot-level vegetation, site specific soil mapping and hydrologic data (e.g., shallow ground water/ water table data, stream stage, and surface water ponding) should be collected and reported.
- Sampling and analytical methods should be standard acceptable protocols that lead to the consistent and repeatable production of data.
- Parameters and methods should be consistent between the baseline assessment and post-project monitoring.

Vegetation data should, at a minimum, include (Stein et al., 2022):

- Vegetation cover
- Community composition and structure
- Physical disturbance of plant community
- Invasive plants present and total cover
- Age-stand distribution
- Evidence of recruitment (sapling species and abundance)
- Shoreline or littoral habitat for tidal fringe wetlands

Soil classification and mapping of the site should be required as part of baseline data collection and assessment with the production of a site-specific soil map. Location and areal coverage of each soil series, as well as disturbances (e.g., compaction, excavation, A-horizon removal, and contamination) should also be mapped during the soil characterization. Soil classification and series verification is, and should be, typically done by certified soils scientists. In addition to the soil series verification, information should be collected on microtopographic relief of the site, soil structure, organic matter accumulation, and bulk density, along with documentation of hydric soil indicators.

Assessment of the current **hydrologic** regime should rely on groundwater wells and/or staff gauges in concert with a rain gauge, installed onsite during the baseline condition assessment. Data from groundwater wells and stream gauges should be used with an analysis of rainfall data, which is compared to the standards for normal rainfall (Sprecher and Warne, 2000), to provide as much hydrologic information as possible prior to developing a detailed mitigation plan. Ideally, baseline data collection should include the information needed to quantify the wetland water budget in terms of inputs (i.e., precipitation, surface, and groundwater inflows), outputs (i.e., evapotranspiration, surface runoff, and groundwater outflows) and change in storage (see Section 7.4). Rain gauges are necessary to correlate the magnitude of rainfall events to water levels in the wetland. Ideally, a continuous recording rain gauge should be installed on the mitigation site, which can be correlated with either the stream stage and/or ground water changes. However, if a long-term, maintained rain gauge (NOAA, USGS, USACE, State, and university, etc.) is in close proximity to the site, it can be substituted for an onsite gauge.

HGM class and the associated soil survey information can provide insight into placement of wells and stage recorders. For instance, riverine wetlands typically experience overbank flooding, shallow groundwater near the surface from upslope sources, and even some ponding after flood events. Therefore, these wetlands will require hydrologic monitoring in the adjacent stream channel as well as groundwater wells in the floodplain. Mineral and organic soil flats are predominantly rainfall driven wetlands. No stage recorders would be needed in this wetland class, but the use of groundwater wells would be needed to verify saturation or ponding. The same is true of slope wetlands, which are predominated by groundwater flow downslope. No stage readings are required, but groundwater wells would need to be arrayed perpendicular to the direction of flow. Fringe wetlands may only require stage recorders to assess the level and extent of flooding, while depression wetlands may require either surface water and/or groundwater monitoring to determine water sources, frequencies, and durations (Noble, 2006).

Graphical depiction of water levels in relation to rainfall should be included in baseline assessment and subsequent monitoring reports. Graphing stage-discharge relationships in streams, in relation to overbank/flood elevations, and depths to shallow groundwater in relation to ground surface elevations can be critical to understanding the hydrologic regime of any given site. Any hydrologic monitoring devices (e.g., wells, crest gauges, and stage recorders) must be surveyed into common elevation benchmarks so that stage and groundwater elevations are consistent across the network. Reviewers should request and look for hydrologic monitoring early in the review process in order to compare before-project and after-project water levels.

The baseline data collected in the field on a proposed mitigation site must not only be sufficient to inform design, but it must also be technically accurate and thorough enough to provide a datum from which post-compensatory mitigation project development of the ecosystem may be compared. Areas considered to have high wetland restoration potential tend to be hydrologically and ecologically connected to other habitats upslope and downslope. They have soils indicating appropriate conditions for wetland re-establishment, and they provide habitat structure for suitable niches for a variety of wildlife and plant species. Finally, they also do not have land uses that might contribute to the site being contaminated with pollutants.

4.5 Stream Baseline Condition (Riparian and Site-scale)

The following sections organize the discussion of stream baseline condition into the same five categories of stream functions/processes (hydrologic, hydraulic, geomorphic, physicochemical and biological) as Harman et al. (2012) (Figure 6) and provide technical information for assessing relevant stream functions. Baseline assessments of streams should characterize functional capacity and how that capacity is affected by stressors. Rapid assessments can be used in the baseline assessment but should be able to link current stream condition and/or function to the stressors impacting those functions, and will likely need to be supplemented with specific watershed and reach-scale data characterizing hydrology, hydraulics, current and future channel form(s), water quality, and riparian and instream biology, particularly where these data and parameters will also be used to inform performance standards and post-project monitoring (Box E). Reviewers should identify connections between the stressors identified in the baseline assessment to the factors which are either addressed in the mitigation plan or treated as constraints on the project.

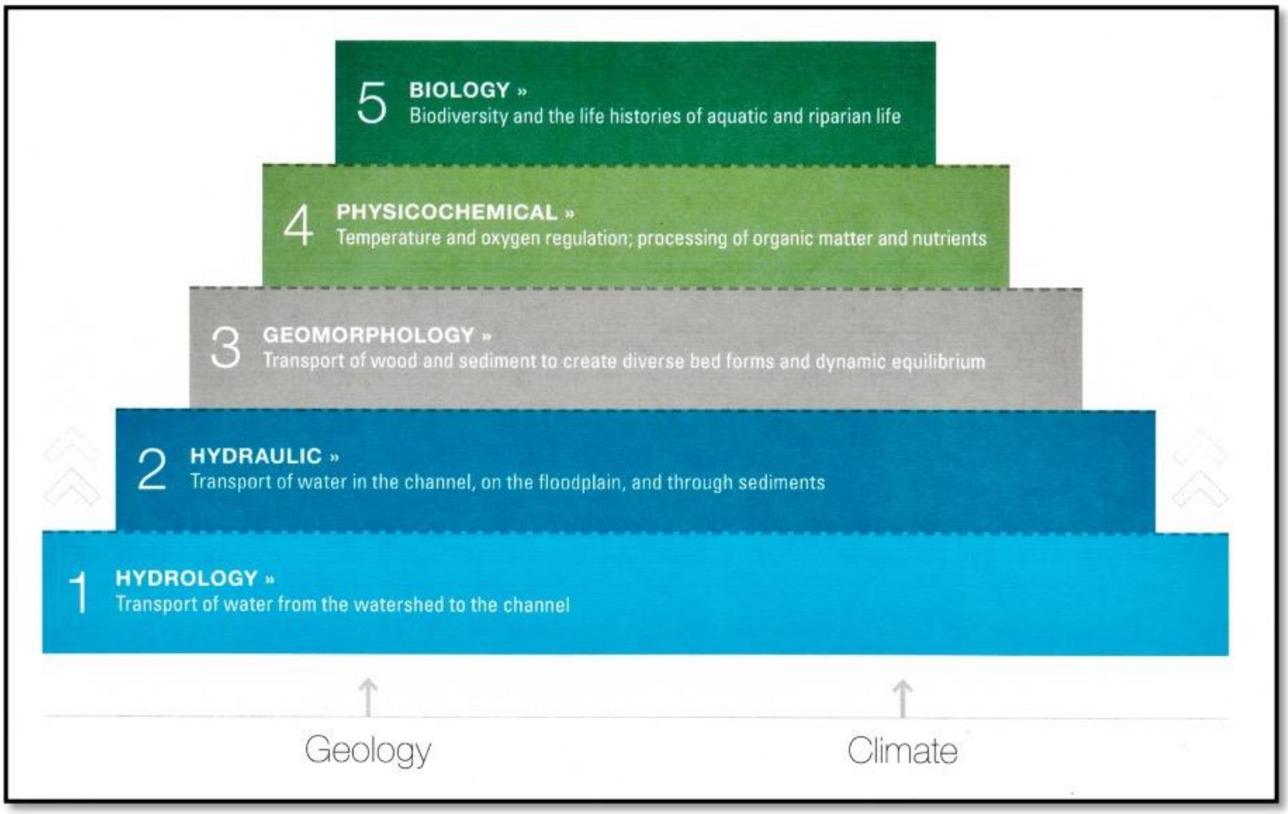

Figure 6. Stream Functions Pyramid overview (reproduced from Harman et al., 2012).

Box E. Recommended information to evaluate stream baseline condition.

Information below is in addition to, and complementary of, the results of the watershed analysis.

Hydrologic (Summary of hydrologic analyses conducted, data sources and period of record)
- How were flood flows, low flows, and bankfull flows calculated? Was a stream gauge used to evaluate the period of record for the site? If not, how were streamflow estimates made (e.g., Manning's equation, regional regression equations, StreamStats, hydraulic models, runoff and streamflow models)?
- Was floodplain groundwater elevation established? Is the groundwater flowing across the floodplain towards the channel? At what time of year?
- What watershed and site scale stressors affect the hydrology of the site?

Hydraulic
- Were hydraulic models used? If so which ones? Was the confidence in the model results explained?
- Were sediment transport models used? If so, which ones? Was the confidence in the model results explained?
- What watershed factors contribute to the sediment supply?
    - Severe bank erosion in the channel network? Mass wasting?
    - Channel incision upstream?
    - High availability of coarse sediment in bed or banks?
    - What flow and sediment retention areas exist in the upstream watershed? (e.g., reservoirs, ponds, low head dams)
- How will the evolution of the upstream channels effect sediment supply? What is the CEM / SEM stage above the reach? Below the reach?

Geomorphic
- Methods used to complete channel stability assessment? Results?
- What is the current planform; longitudinal profile; and dimension of the project reach?
- What are the causes of channel instability? How were they determined?
- How do channel impairments effect stream and floodplain habitat? Is the channel laterally constrained?
- Extent of channel alteration (e.g., enlargement, floodplain encroachment, or channelization) of the project reach?

Physicochemical
- Are state surface water quality standards being met? If not, how often and under what conditions are they out of compliance?
- What are the sources of nutrients and other pollutants in the watershed and are they effecting the site?
- Is this reach on the 303(d) list or other TMDL for any of the following impairments: sediment, nutrient, metals & toxics, temperature, or flow modification?
- Can the components of existing water quality that are limiting biological productivity be addressed at the mitigation site (e.g., mass wasting, flooding, streamflow, shade, vegetation, and soils)?

Biological
- Biological community parameters sampled? Protocol? Results?
- Are habitat features altered? Cause of those alterations?
- Are there high-quality sites upstream and downstream of the proposed site? Would this project connect the upstream and downstream sites?
- Are there sources of beneficial organisms that can migrate from the upstream or downstream portions of the watershed to repopulate the site? Proximity of those source areas to the mitigation site?
- Are there invasive species (animals, plants, and algae) that will migrate from the upstream or downstream portion of the site that would affect long term characteristics of the site communities?
- What is the percentage and average width of the intact riparian area contiguous to the site?

4.5.1 Stream Assessment

Reviewers should evaluate whether the mitigation provider's baseline assessment approach appropriately characterizes the stream functions of the site. There is no expectation for reviewers to conduct stream baseline assessments using SQTs or other rapid assessment protocols currently used (see Section 4.3). However, rapid assessment approaches may be included in a baseline assessment and reviewers should become familiar with the rationale, structure, and basis for the functions, stressors, and indicators of any method used. Applicable rapid assessments can provide useful information for assessing baseline condition but should not be used without additional site-scale baseline data for relevant stream functions, particularly where specific data and parameters will be used to inform performance standards and post-project monitoring.

Categorizing functions, or processes, provides context and organizes pertinent factors that must be addressed in a mitigation proposal (Roni and Beechie, 2013; Beechie et al., 2010; and others). Functions are defined as the physical, chemical and biological processes that occur in ecosystems (Harman et al., 2012). Fischenich (2003; 2006) proposed a list of fifteen primary stream functions and illustrated the relationships among them by showing which functions influence others (Table 10). From this work, Harman et al. (2012) organized categories similar to Fischenich's into a pyramid to illustrate the hierarchical nature of stream functions, with lower-level functions supporting higher-level functions (Figure 6).

Table 10. List of primary stream and riparian functions and their interrelationships (Fischenich, 2003; 2006). Reproduced from Somerville (2010).

		Functions Directly Affected	Functions Indirectly Affected
System Dynamics			
1.	Stream Evolution Processes	2, 3, 4, 5, 6, 7, 8, 9, 11, 13, 14, 15	10, 12
2.	Energy Management	1, 3, 4, 6, 7, 8, 9, 11	- -
3.	Riparian Succession	1, 2, 4, 6, 7, 11, 14, 15	10, 12
Hydrologic Balance			
4.	Surface Water Storage Processes	2, 5, 6, 7, 11, 13, 14, 15	1, 3, 8, 9, 10, 12
5.	Surface/Subsurface Water Exchange	3, 6, 11, 13	4, 10, 12, 15
6.	Hydrodynamic Character	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 13, 14, 15	12
Sediment Processes and Character			
7.	Sediment Continuity	2, 3, 4, 8, 9, 10, 11, 13	6, 12, 14
8.	Substrate and Structural Processes	1, 2, 5, 6, 7, 8, 11	3, 10, 12, 13
9.	Quality and Quantity of Sediments	1, 2, 3, 5, 7, 8, 11	6, 10, 12, 15
Biological Support			
10.	Biological Communities and Processes	3, 11, 12, 13, 14	5, 6, 8, 9, 14, 15
11.	Necessary Habitats for all Life Cycles	10, 12, 15	- -
12.	Trophic Structures and Processes	10, 13, 14	9
Chemical Processes and Pathways			
13.	Water and Soil Quality	9, 10, 12, 14	3
14.	Chemical Processes and Nutrient Cycles	9, 10, 12	2
15.	Landscape Pathways	10, 11, 12, 14	2

Hydrologic functions influence other processes which contribute to stream ecosystem integrity, and largely operate at a watershed scale. Thus, there is considerable overlap in assessing a project's watershed context and reach-scale hydrodynamics. Closely related to hydrology are stream hydraulic processes, which in this context are largely interpreted as the forces affecting sediment dynamics (e.g., sediment capacity, supply, and transport). Hydraulic processes also operate at a watershed scale with contributions of sediment being generated and transported from upstream to downstream. Geomorphic processes, supported by hydrologic and hydraulic processes, contribute to stream stability, channel complexity and form. Geomorphic processes operate largely at the reach scale, although watershed processes also clearly affect channel form and stability. Supported by these three categories are physicochemical (stream water quality) and biological (stream and riparian biota) functions. Stream water quality processes (e.g., nutrient and organic carbon cycling, pollutant transport, and temperature) also tend to operate at a watershed scale as, like sediment, the transport of materials occurs from upstream to downstream. Like water quality, stream biology is influenced by watershed-scale processes but is often evaluated directly via sampling at the reach scale.

There is considerable interaction and feedback between processes which ultimately stems from the inherent natural variability and diversity in stream systems. For example, hydraulic diversity (e.g., various water velocity regimes in the stream) is caused by variable water flows interacting with the physical structure of the stream bed (bedform diversity) and banks (riparian vegetation and coarse wood). This hydraulic diversity contributes to habitat for biota that utilize different areas of the stream at various times to fulfil life cycle requirements (e.g., resting, shelter, feeding, and reproduction), and also contributes to sediment flow and deposition within a reach. Ecological complexity is a result of the considerable interaction between stream processes and functions (Table 10).

Regardless of this complexity, a simplifying assumption is that functional capacity, or the degree to which a resource performs a specific function, will be influenced by stressors. In other words, a stream without site and/or watershed level stressors performs at full functional capacity, while a stream with stressors is more limited in its capacity to function. Thus, the identification of stressors and their resulting impact on functional capacity is an important component to baseline assessment. This, combined with the organizational framework from the functional pyramid, provides a simple and logical means to review baseline condition data and understand important aspects of a site's function and ecosystem integrity. Stressors identified in this step of the Approach should then be addressed in a project's goals and objectives, implementation, monitoring, performance, and long-term management.

The SQT is an assessment tool used to characterize the functional capacity within the functional categories outlined in the Stream Functions Pyramid (Harman et al., 2012). SQTs have been developed for numerous states, including Colorado (USACE, 2020), Georgia (Somerville et al., 2021), Michigan (MI EGLE, 2020), Minnesota (MNSQT SC, 2020), North Carolina (Harman and Jones, 2016), South Carolina (South Carolina Steering Committee, 2021), Tenessee (TDEC, 2018) and Wyoming (USACE, 2018). SQTs characterize these stream functional categories by evaluating a suite of indicators representing structural or compositional attributes of a stream using function-based parameters and measurement methods. The SQT approach integrates multiple function-based parameters and metrics across multiple assessment scales (i.e., watershed, riparian and reach) from these functional categories into a reach-based index score using index values per metric derived from reference curves compiled primarily from literature values and regional reference datasets. The function-based parameters, metrics and measurement methods used in SQTs are generally familiar to the stream mitigation community, including mitigation providers, practitioners and regulators.

Scale of assessment: There are essentially three scales at which stream baseline conditions should be assessed: 1) the contributing watershed (see Section 4.2), 2) the riparian zone and 3) the site or reach scale (Johnson et al., 2015). The riparian zone encompasses the area adjacent to the stream and for a distance upstream and downstream of the project limits. This scale encompasses riparian processes contributing to stream functions, as well as acknowledges the importance of conditions upstream and downstream of a project site in either contributing or controlling the flow of materials to, or within, the project reach (e.g., sediment inputs from upstream and/or aggradation or degradation downstream of the project area). The site or reach scale is the stream reach proposed for mitigation. While reviewing the baseline assessment of a stream mitigation plan, the scale at which hydrologic, hydraulic, geomorphic, physicochemical, and biological processes and functions operate is important to consider. Providers often focus on the reach to be restored and may not fully consider functional aspects that originate beyond the boundaries of the project site.

4.5.2.1 Hydrologic Condition Analysis

Hydrologic assessments determine if the current flow regime of the site has been altered by stressors, including land uses, barriers to flow, diversions, or flow augmentation. Changes in flow regime are typically reflected in changes to magnitude, frequency, timing, and/or duration of flood, low, and bankfull flows. Hydrologic analyses characterize the seasonal and interannual variation in the timing and volume of streamflow. The magnitude and duration of flow supplied to a stream is heavily influenced by the upstream watershed characteristics including the drainage area, topography, bedrock geology, surface soils, and the drainage network. Alterations to the contributing watershed will have a significant impact on flow and transported constituents to the site. As discussed in Section 4.2.2, as land uses within a stream's watershed change, so do the characteristics of the stream's hydrologic regime.

Elements of a Baseline Hydrologic Assessment

Important aspects of a baseline hydrologic assessment include characterization of a stream's flow regime, including the magnitude (i.e., how much), frequency (i.e., how often), duration (i.e., how long), and timing /seasonality (i.e., when) of important flows (e.g., extreme low flows, baseflow, bankfull, floodplain inundating flows). The following discussion is meant to provide the reviewer with basic background information on common approaches used to characterize flow regimes. The discussion also provides background information on important flow thresholds that a provider should consider when assessing the current hydrologic condition. Reviewers should evaluate whether appropriate methods have been used to characterize streamflow, and whether important flows have been accurately characterized. Note that the scale of analysis will be commensurate with the scope of a compensatory mitigation project, and thus, much of this information may not be needed for small projects.

Characterization of flow regime

It is important for the reviewer to understand the range of flows affecting a mitigation site, and how they may be currently or potentially influenced by stressors (Table 11). The level of the provider's analysis, and selected methods, will be influenced by the presence and intensity of these stressors. For example, many stream mitigation projects are located in watersheds with increasing impervious surface, often in urban areas. Flow variability due to imperviousness is often manifested as rapid short-term variations in streamflow during runoff events, referred to as flashiness (Bledsoe et al., 2017). Flashiness is strongly related to more frequent delivery of sediment to urban channels due to increased stormflow runoff velocities associated with the increases in impervious surfaces. If stressors linked to repeated, flashy flows are identified, bankfull and flood flows would be affected, and results of the hydrologic analyses should illustrate this relationship.

Table 11. Common stressors affecting stream hydrologic regime (after Johnson et al., 2015).

Common stressors		Examples	Explanation
Land	Forest thinning	Silviculture	Increased runoff rate causing higher peak discharge, increased flashiness.
		Development	
	Vegetation/ cover shift	Grazing	Increased runoff rate causing higher peak discharge, increased flashiness.
		Agriculture	
		Development	
	Impervious surface density	Roof density	Increased runoff rate causing higher peak discharge, increased flashiness, loss of groundwater recharge associated with roads and development
		Roads	
		Pavement	
		Compacted soils	
	Groundwater pumping	Ag wells	Aquifer depletion or water table depression that limits groundwater recharge or exacerbates loss
		Municipal wells	
Drainage	Dams, reservoirs	Large dams	Artificially managed hydrology, attenuated peak flows, evaporative losses
		Small dams	
	Diversions/ augmentation	Irrigation	Water extracted from the watershed or stream system via diversions and ditches
		Municipal	
		Intercept ditches	
		Off-channel	
	Widespread floodplain disconnect	Floodplain encroachment	Decreased aquifer recharge and diminished water storage in the contributing watershed due to lack of floodplain activation or loss of tributary wetlands
		Channelization	
		Incision	
	Widespread wetland loss	Various causes	

Methods used in estimating streamflows at any given project site can vary but may include measuring streamflow with stream gauge data; Manning's equation along with reach specific channel geometry measurements; regional regression equations; hydraulic models; and /or runoff and streamflow models (Cramer et al., 2012).

Gauge data- Ideally, the provider will be able to locate near-by long-term stream gauge data to assess hydrologic variability at the reach. The United States Geological Survey (USGS) has a number of sites with long-term stream gauge data which are typically available online (https://waterdata.usgs.gov/nwis/rt). Other federal or state agencies may also have long-term data from which a provider can obtain direct stream hydrologic measurements (e.g., USACE, U.S. Forest Service, and Florida Water Management Districts).

Ungauged sites- Many, if not most, sites proposed for stream mitigation will be ungauged, especially for lower order streams. Basic limitations in the current USGS streamflow gauging network will continue to require stream mitigation designers to rely on predictions in ungauged basins because, in many instances, continuous streamflow gauges are heavily biased toward relatively large streams and rivers: 95% of streams have less than 3% of the gauges and over 93% of stream length is represented with less than 1/3 of the gauges (Bledsoe et al., 2017). In ungauged situations, the provider will have to estimate streamflow using one or a combination of several methods. Some common methods for streamflow estimation are:

- **On-site hydrologic measurements:** To capture baseline and future stream hydrologic condition, it is recommended the provider install stream gauging equipment (e.g., staff gauge, crest gauge (Harrelson et al., 1994, USDA NRCS, 2020)), or a continuous recording device (e.g., water level logger and water level recorder) as early in the project planning/review process as possible. In addition, if groundwater is a potential source of low flows, then groundwater wells placed perpendicular to the direction of flow should also be established at the site. Collection and analysis of stream and groundwater hydrologic data will assist in establishing the range of flow conditions (e.g., low, bankfull, flood), flow durations and seasonality, as well as the lateral extent and depth of flooding on the floodplain. Commensurately, just as in the wetland hydrologic analysis (Section 4.4.2), analysis of rainfall records and establishment of normal rainfall should accompany any hydrologic evaluation. Unlike most wetlands, however, consultation of rainfall data collected by weather stations throughout the stream or river's watershed is important to help correlate observed stream discharge or stage with rainfall.

- **Manning's equation**, coupled with channel geometry measurements, is probably the most commonly used formula for basic hydraulic calculation in natural channels. In its most basic form, the equation relates flow velocity to hydraulic radius, hydraulic roughness, and channel slope. Manning's equation is often the basis for estimating bankfull discharge at ungauged sites. Despite the wide use of Manning's, the estimate for channel roughness (n) significantly influences the estimate of channel discharge and is difficult to estimate accurately, especially over the entire length of a reach.
- **Regional regression equations** relate discharge to channel dimensions and watershed characteristics. The equations vary by region and can be applied to ungauged basins within the same region to estimate flood magnitudes at recurrence intervals ranging from the 2-year to the 100-year events. Many of the regional regression equations estimating flood flows are available from the USGS in the form of StreamStats, a web-based GIS application which allows users to access, among other things, streamflow data. USGS regional regression equations are often accompanied by error estimates, and it is not uncommon to have 30-40% error associated with any given estimate.
- **Runoff and streamflow simulation models** can provide flood flow estimates where gauge and/or regional regression equations are unavailable, or in areas where the equations are not applicable, such as highly urbanized watersheds. These models predict streamflow based on simulated runoff from storm events and other inputs. Common models include HEC-1, developed by the USACE; and the NRCS TR-20 and TR-55. TR-20 provides an analysis of flood events, while TR-55 presents simplified procedures to calculate storm runoff volume, peak discharge, hydrographs, and storage volumes for floodwater reservoirs. Use of these flow estimates, survey data from the channels, and one and two-dimensional hydraulic models can provide sufficiently accurate data to assess channel and floodplain velocity and shear stress during storm events (Parola, pers. comm.).

Recognizing that any given model, or technique may have associated error is not intended to discourage the use of these models if the situation warrants. However, it is important to recognize how and why the error in these flow estimates is produced and discuss how this might affect results of a baseline assessment and potential stream design with the provider (i.e., all models are erroneous, some are useful). Hydrologic analyses should be accompanied by information on the models used to determine streamflow, the inputs and assumptions included with the model, associated error estimates, and an interpretation of the results in their project site assessments.

Important flows to be assessed:

Once methods for estimating flows have been determined, there are threshold flows that are important for the provider and the reviewer to evaluate. The provider should establish estimates of the timing, magnitude, frequency and duration of **low-flows**, **floodplain inundating flows**, and the **bankfull flow**. It is important to understand the range of flows, and/or potential flows delivered to the reach by the watershed and to the extent possible optimize the interactions of flood flows with the adjacent floodplain. The range of flows evaluated in the baseline condition assessment will be the range of flows used for the design.

Low Flow: Loss of channel flow and streambed drying are important ecological controls affecting stream organisms. Therefore, assessment of the low-flow characteristics (e.g., base flows and extreme low-flows) of the channel is critical, especially for headwater streams. Assessment of the channel low-flow characteristics follows the determination of flow permanence, or whether the channel is perennial, intermittent, or ephemeral. Transitions from each hydrologic regime should be identified and documented. Often the transitions occur where there are changes in surface topography, the thickness of alluvial or colluvial bedrock cover, or at locations of headcuts in channel bed.

Assessment of a channel's low-flow characteristics may include an assessment of the adjacent valley's groundwater system and its influence on stream low-flows. The groundwater system in the stream valley plays a significant role in determining how much of the water supplied by the watershed is valley groundwater and how much is low-flow surface water in the channel during seasonal dry periods and during droughts. In instances where valley groundwater may be a significant contributor to streamflow, reviewers should request an appropriate assessment of the valley groundwater system to identify any impairment (e.g., ditches, increased impervious surface, and groundwater pumping) to the low-flow regime and to provide a basis for how such an impairment might be addressed in the mitigation plan.

Bankfull Flows: Bankfull stage is the water level at which flows begin to overtop the banks and enter the floodplain. From a geomorphological standpoint, it is defined as the elevation of the stream channel that "corresponds to the discharge at which channel maintenance is most effective, that is, the discharge which moves sediment, forms or reforms bars, forms or changes bends and meanders, and generally does the work that results in the average morphologic characteristics of channels" (Castro and Jackson, 2001, cited in Saldi-Caromile et al., 2004). Generally, the bankfull discharge frequency for perennial rivers in humid environments is likely to fall in the range of one to two years using an annual maximum flood series (Soar and Thorne, 2001). As discussed in Section 3.3.4, it is important for the reviewer to understand how the provider verified bankfull flows and calculated bankfull discharge.

Flood Flows: The timing, frequency, and duration of floodplain inundation is critical for many morphological and ecological reasons. Generally, a higher level of ecological functionality results from more interaction of channel overflows with the floodplain (Cluer and Thorne, 2014; EPA, 2015). Flows that reach the floodplain typically dissipate shear stresses and stream power and, along with increased roughness from riparian vegetation, often cause sediments carried by flood waters to drop on the floodplain. In addition, organic debris is often moved into and out of floodplains during flood events to support downstream organisms. Water quality enhancements can occur, as well, if flood durations are sufficient to allow removal and sequestration of elements and compounds.

If not provided in the draft mitigation plan materials, reviewers should request the provider characterize the magnitude, frequency, duration, and timing of current flow(s) that inundates the floodplain of the mitigation project site, along with the shear stress on the channel bed and banks that correspond to that flow. The results of this analysis can then be used to compare the range of flows designed to inundate the floodplain after the project is implemented. It is important that the current range of flows be discussed to allow the reviewer to compare the degree of the impairment to the intent of the mitigation.

4.5.2.2 Hydraulic Condition Analysis

Hydraulics can be defined as the movement of water within a channel and the forces generated by this movement. Hydraulic effects result in movement and deposition of sediment, erosion of channel banks, and scour of the channel bed (Copeland et al., 2001; Saldi-Caromile et al., 2004; Gordon et al., 2004). Diverse hydraulic conditions (e.g., varying patterns of depth, velocity, and substrate in space and time) are created by the interaction between the inflowing water (i.e., hydrology), sediment regime, boundary materials, and the channel form (i.e., geomorphology). Channel hydraulic conditions contribute to maintenance of stream energy and evolution processes (Fischenich, 2006) as well as a range of channel morphologic conditions which contribute to a diversity of fauna (Cramer et al., 2012; Cluer and Thorne, 2014).

Elements of a Baseline Hydraulic Assessment

Important aspects of a baseline hydraulic assessment include hydraulic parameters that relate channel conditions to flow and a characterization of stressors affecting sediment dynamics and evolutionary stage. The following discussion includes basic background information on the types of information that may be needed to assess the current hydraulic condition. Reviewers should look for information on the hydraulic and sediment parameters described below.

Hydraulic parameters

Hydraulic conditions are typically evaluated using parameters that relate channel conditions (e.g., cross-sectional area, wetted perimeter, and hydraulic radius) to water flows in the channel (e.g., water surface elevation, energy gradient, water velocity, and shear stress). These parameters represent the basic components of hydraulic calculations that will likely be performed during the assessment and design of a stream mitigation project. Perhaps the most used hydraulic equation is Manning's (see Section 4.5.2.1) which relates the flow of water to the slope, size, and roughness of the channel. Slope, roughness, cross-sectional area, wetted perimeter, and hydraulic radius are channel parameters that are typically manipulated in a stream restoration to accommodate various water surface elevations, velocities, and associated shear stresses on the bed and banks. Although the interactions of water flow and channel conditions are complex, these basic parameters should be kept in mind when interpreting a provider's hydraulic assessment.

Hydraulic assessments can also be done using more complex 1-D, 2-D, or 3-D models (described in Section 6.3.2) that include sediment transport. In-depth understanding of channel hydraulic conditions (velocity distributions) is very complex, three dimensional, and influenced not only by channel morphology and boundary conditions in the project reach, but also by conditions in the reaches immediately up and downstream. This complexity makes detailed assessment of hydraulic conditions challenging. A simple assessment might suffice for a provider, or reviewer, to use to verify bed, bank, and floodplain conditions during the baseline assessment. However, more complex analyses may need to be completed by the provider during the design phase of a proposed project, particularly if project objectives relate to improved hydraulic conditions or changes in hydraulic forces or sediment supplies. Likely, the provider will need to have engineering and/or hydraulics expertise on the design team to adequately address stream hydraulics.

An assessment of baseline channel and floodplain (i.e., overbank flows up to the 100-year flood) hydraulics is normally completed to provide information on the current channel and floodplain elevations that would be used to compare with mitigation design flood elevations. This baseline condition analysis is useful for assessing hydraulic parameters of the current channel such as bed and bank shear stress, and channel flow velocity and depth. Survey data to inform a hydraulic assessment, such as cross-sections and a longitudinal profile, are also used to inform a geomorphic assessment (see Section 4.5.2.3).

Sediment

Assessment of stream sediment dynamics is a complex, cost and time intensive undertaking and often is not evaluated directly. However, it is important for the reviewer to understand the sediment dynamics affecting a mitigation site, and how sediment may be currently or potentially influenced by stressors (Table 12). A baseline assessment should indicate the potential hydraulic and sediment transport problems needing to be addressed, and should provide basic information on sediment sources, stressors affecting sediment transport, and the potential for a project reach to experience changes in sediment supply or transport. The following provides background information to help the reviewer interpret landscape and site scale indicators, either included in the baseline assessment or observed during site visits, for potential sediment problems. Potential problems noted as a result of the baseline assessment should be addressed in the provider's mitigation design, performance and monitoring plans.

Table 12. Common anthropogenic stressors contributing to total sediment regime in streams (after Johnson et al., 2015).

Common Stressors		Examples	Explanation
Land	Forest thinning	Silviculture	Increased susceptibility to surface erosion and rill formation; consolidation of runoff flows; increased risk of bank and mass erosion when occurring on steep unstable drainages
		Development	
	Vegetation/ cover shift	Grazing (including hoof sheer)	
		Agriculture	
		Development	
	Roads	Road surfaces	Surface erosion on unimproved roads, flow consolidation in drainage/borrow ditches, mass erosion risk with cuts at the toe of steep slopes, sediment transport barriers at undersized crossings
		Drainage ditches	
		Road cuts, Crossings	
	Point sources	Stormflow effluent	Direct sediment input
Channel	Dams/reservoirs	Large dams	These are major stressors that can overwhelm all other impacts. Large in-line dams and reservoirs typically trap all incoming sediment. Small dams may pass some suspended sediment, but still often interrupt all bedload transport.
		Small dams	
		Weirs	
	Direct stability impacts	Instream mining	Direct manipulation of channel leading to excess erosion from lateral instability or incision and gully formation; possible barriers to sediment transport
		Channelization	
		Reconstruction	
		Hardening	
		Straightening	
		Culverts/Crossings	
	Indirect stability impacts	Many causes of riparian vegetation shifts	Indirect impacts that lead to channel instability and excess erosion.

A common goal of stream mitigation projects is to attain a sediment flux sufficient to maintain channel habitat and connection of flood flows to the floodplain. In an unconfined alluvial channel, providers will try to balance a stream's sediment capacity (i.e., stream power sufficient to move incoming sediment) with the sediment supply (i.e., the type and amount of sediment entering the reach) in an effort to make them equivalent. Equilibrium conditions exist when the amount and type of sediment moving into a reach can be efficiently transported out of the reach, thus resulting in little, or no accumulation or excess transport of sediment in that reach.

Sediment is produced in the contributing watershed via land erosion (surface erosion, mass erosion, and point source discharges) and channel erosion on reaches upstream and tributary to the assessment reach (Table 12). Some sediment enters the reach directly from valley side slopes, but most is discharged to the reach from the contributing watershed as bedload and suspended sediment in the stream. Watershed impacts affect sediment production, and major drainage impacts such as dams affect the transport of that sediment to the reach (Johnson et al., 2015). Presence of these stressors indicate the need to consider sediment capacity and supply in the project documentation, particularly in the design phase.

Land erosion considers the amount of sediment produced in the watershed via surface and mass erosion (Table 12). Surface erosion includes land uses that affect ground cover over significant portions of the watershed area, particularly those that result in exposed or bare soil. Mass erosion includes sediment supply impacts from natural disturbances such as forest fires, blow-downs, insect infestations, or other natural processes.

Channel erosion considers the rate of sediment produced by channel erosion in the contributing watershed (Table 12). Erosion is a natural process on all streams and tributaries, but the rate of erosion can be severely altered by human impacts, particularly when alluvial streams become incised to form gullies. In most watersheds, channel erosion is a much greater source of sediment to streams than land erosion.

Some degree of sediment mobility is critical for the ecological health of a stream system. Physical habitat is created and sustained through processes such as the maintenance of pools and riffles, the formation of transient bars, side channels, and backwater areas, the deposition of spawning gravels, and the flushing of fines from bed substrate. Sediment sorting through selective transport creates spawning habitat and quality habitat for benthic organisms. The maintenance of pool-riffle sequence morphologies and the effective sorting of bed materials exemplifies balanced conditions of sediment caliber, hydraulic complexity, and transport energy that serve to generate and maintain quality aquatic habitat.

In addition to the land and channel sources of sediment production, another aspect of sediment dynamics is sediment transport. Within the contributing watershed, sediment transport is concerned with the transport of sediment to and through the project reach. In-line dams and reservoirs are the greatest stressor to sediment transport by trapping sediment and limiting its distribution in the downstream system. However, dams and reservoirs may largely attenuate any impacts from unnatural sediment production. Even in watersheds with greatly accelerated sediment production, the reaches downstream from dams may be in a sediment-starved condition because reservoirs are such efficient sediment traps. If dams are present upstream of a proposed project, their effects on sediment transport must be considered in the project documentation, particularly in the design phase.

In an unconfined alluvial channel at equilibrium, the balance of sediment capacity to sediment supply is equivalent. Simply put, equilibrium conditions exist when the amount and type of sediment moving into a reach can be efficiently transported out of the reach, thus resulting in little, or no accumulation or excess transport of sediment in that reach. Note however that altering the sediment capacity of a stream reach without also considering its sediment supply or the sediment capacity of downstream reaches may have unintended consequences in both the mitigation reach and downstream.

Reviewers can use the providers' assessment of CEM/SEM stage (Section 3.3.4) as an indicator of sediment dynamics that may have to be addressed in the mitigation plan (Section 6.3). Reviewers can interpret the baseline assessment of CEM/SEM stage as context to more complex modelling of sediment dynamics that likely will need to be completed during the mitigation planning and design phase. Basically, as channels progress through the stages of channel evolution, the balance of sediment supply (represented by stream bank failure) and sediment capacity (represented by channel slope) provide information about trends in sediment dynamics of the channel (see Table 6). Bank failure via mass wasting can be a significant sediment source to reaches downstream of the failing banks. Therefore, the height of banks compared to the critical height is an indicator of potential sediment supply (Watson et al., 2002). As the channel degrades, either through channelization or incision, sediment coming into the reach is less than sediment moving out, indicating an increase in the capacity of the reach to transport sediment, or a reduction in supply, and inducing incision. Typically, when streams reach the stages of degradation and widening (Table 6), the bank heights exceed the critical bank heights and banks begin to fail (i.e., sloughing into the channel) and contribute sediment to the onsite reach as well as those downstream. Following this, the channel begins to aggrade and widen, indicating a situation where the sediment supply is greater than the capacity to move the sediment through the reach. Hydraulically, as streams begin to aggrade, channel slopes are reduced contributing to the stream not having the stream power to move the amount of sediment coming into the reach. Eventually, the sediment contributed from bank failure, reinforces the toe of the bank, and the banks cease failing and contributing to the sediment supply.

CEM/SEM stage should be assessed both upstream and downstream of the proposed project reach to place the project reach in context with conditions outside the project area. For instance, upstream reaches going through degradation and widening, may be contributors of sediment to the project reach. Providers should be aware of the potential for sediment inputs from upstream in order to accommodate those inputs in the design, implementation, and post-construction phases. At the downstream end of the reach, providers should be aware of potential headcuts moving up the valley that may impact the project by causing incision, changing channel slope (due to incision), increasing stream power, and transporting more sediment out of the reach than is being supplied from upstream. On the other hand, where downstream reaches have aggraded, these reaches could serve as grade control and diminish the stream power available to transport sediment, leading to aggradation in the project reach.

4.5.2.3 Geomorphic Condition Analyses

Inflowing regimes of water and sediment are the drivers of geomorphic conditions within, and beyond, a project reach. In the two previous sections, Hydrology (Section 4.5.1.1) and Hydraulics (Section 4.5.1.2), assessing the baseline condition of water and sediment flows, respectively, were discussed. While hydrologic and hydraulic processes contribute to and affect the geomorphic condition of the channel, this section focuses on information to evaluate the range of channel features, aggradation or degradational status, and whether the channel has stable boundary conditions. Some information needed to assess the baseline condition of the project reach may also have been compiled as a result of the classification of the channel (e.g., stream width/depth ratio, entrenchment ratio, sinuosity, and slope, SEM/CEM) (Section 3.3.4).

Some key indicators of geomorphic instability include evidence of incision, aggradation, rapid lateral migration, or planform metamorphosis. These processes can occur naturally, however, excessive rates of change caused by historic and contemporary land use practices or by the effects of past channel manipulation (e.g., enlargement, floodplain encroachment, and channelization) constitutes a stream problem. Reviewers, as well as providers, must be mindful of the information collected during the assessment of watershed conditions, especially the potential influences of land use effects on water and sediment flows when assessing the baseline geomorphic condition.

Elements of a Baseline Geomorphic Assessment

Important aspects of a baseline geomorphic assessment include morphology, departure from expected stable conditions for the given stream type, determination of causes of channel change, floodplain connection and presence of large wood. The following discussion is meant to provide the reviewer with basic background information to determine if the provider has adequately assessed the current geomorphic condition. Reviewers should look for information on the geomorphic parameters described below. Descriptions of these common geomorphic parameters is largely taken from Saldi-Caromile et al. (2004).

Morphologic conditions:

- **Channel longitudinal profile** – Channel profiles (elevation vs. distance plots) depict slope trends on a stream system, as well as the shape and pattern of the channel bed (e.g., pools and riffles). Channel slope is defined as the vertical fall of a stream over a given distance. It is typically reported as a percentage (ft/ft) or as feet of drop per mile (ft/mile). Slope is typically determined by surveying the channel thalweg, water surface, and elevation of bankfull indicators. The longer the survey length, the more accurate the reach slope calculation will be.
- **Channel planform** – Channel planform is the form a stream takes as seen on a map (i.e., aerial view). Other parameters that describe channel planform are the sinuosity, belt width, wavelength, amplitude, and radius of curvature of an individual meander bend. Collectively, these planform characteristics can be compared to historical conditions in order to assess channel behavior over time, and to expected ranges of values for channels of the same type in the same physiographic province. Radius of curvature is particularly important, as overly sharp radii (i.e., tight bends) greatly increase the near-bank shear stress and erodibility and can lead to channel instability.
- **Channel cross-section** - Channel cross-section reflects the two-dimensional view across the channel, typically viewed in the downstream direction. A set of surveyed cross-section points typically include terrace elevation, floodplain elevation, top of bank, bank toe, lower limit of vegetation, and thalweg with enough intervening points to define the shape of the channel. The ends of the cross-section should extend into the floodplain to define at least some of the important peak flows (e.g., including the extent of the 100-year floodplain).
- **Pools and riffles** - Pools and riffles generally occur at relatively constant spacing in alluvial streams. A pool-riffle sequence is a dynamic response of the channel to large-scale, non-uniform distribution of three parameters: stream velocity, boundary shear stress, and sediment. Generally, riffle spacings are on the order of five to seven times the channel width.

Channel stability: Channel stability is assessed by measuring excessive bank erosion, excessive streambed erosion or scour, or excessive deposition. Here, excessive means outside the expected range of variability for the given stream type and setting. If excessive erosion or deposition is occurring, the channel is in a state of transition from one type to another, i.e., it is changing its basic shape, pattern and/or longitudinal profile. Vertical instability (incision or aggradation) is often coupled with lateral instability (excessive bank erosion and accelerated channel migration or avulsion rates). Common indicators of channel incision and aggradation are listed in Table 13.

Table 13. Field indicators of channel incision, aggradation, and bank erosion (after Phillips, 2013) that can help identify SEM/CEM stage.

Channel degradation/ incision:	Channel aggradation	Mass wasting
Exposure or undercutting of bridge pilings, boat ramps, docks, pilings, pipe crossings, perched culverts, etc.	Burial or partial burial of channel and lower bank vegetation, large woody debris, and/or culvert outfalls	Concave bank profile or lower profile
Failed revetements due to undercutting	Reduced bridge clearance	Absence of vegetative cover
Exposure of bedrock or material known to be from a previous regime in bed	Island formation; relatively young islands as indicated by vegetation and soil characteristics	Isolation in channel of formerly bank-attached features (e.g., bulkheads, docks, and signs)
Headcuts and knickpoints	Sand sheets	Exposed roots
Channel ledges or paleobanks	Crevasses and avulsions (local levee damage or flow diversion)	Toppled trees (toward channel)
Obligate hydrophytes well above normal water levels (perched ground water)	Evidence of increased frequency of overbank flow (e.g., increased floodplain sedimentation, soil redox features, vegetation changes, floodplain flow and hydrologic indicators, erosional floodplain stripping and increased discharge)	Encroachment on or toppling of buildings, boat ramps, utility poles, etc.
Riparian trees tilted back away from river (wind throw)	Tributary aggradation	Scarps and failure surfaces
Evidence of reduced overbank flow (e.g., reduced sedimentation, soil formation, soil redox features, and vegetation changes)	Increased tributary back-flooding, indicators of floodplain or channel aggradation along lower tributary reaches, organic deposits near tributary mouths	
Channel narrowing without evidence of significant changes in discharge, stream power or sediment supply		
Tributary downcutting		
Perched tributaries		

Streams with vertical instability, or channel incision and/or aggradation, leading to Stages 2, 3, or 4 of Schumm's channel evolution model are likely to be considered unstable. Channel incision causes reduced interaction between the stream and its floodplain, reduced spatial habitat heterogeneity, greater temporal instability, reduced hydraulic retention, degradation of water quality, stream channel enlargement, and shifts in the fish community structure (Doll et al., 2016). Vertical instability may be initiated or exacerbated by a lowering in the base level of streams downstream of the mitigation site, loss of grade control downstream due to the removal of structures (e.g., culverts, roads, dams), or channel narrowing due to human encroachment and channelization. Vertical instability can be assessed with indicators such as bank-height ratio (BHR) and entrenchment ratio (ER) calculated from channel cross-section data.

Lateral migration, or bank erosion, may be initiated or exacerbated by hardening, or stabilizing, channel banks upstream or along the opposite bank, which may reduce the channel's capacity to adjust locally, and may transfer the excess energy to an un-hardened area. Channel aggradation, channel incision, removal of riparian and channel bank vegetation, excessive saturation of banks during low flow periods due to irrigation, and rapid drawdown and saturation failures related to dam releases can also contribute to bank erosion. Excessive lateral migration, or lateral instability, can be assessed using indices that quantify near-bank shear stress and bank erosion potential, such as the Bank Erosion Hazard Index (BEHI) (Rosgen, 2001), width to depth ratios calculated from channel cross-section data, and measured bank erosion rates from surveys (bank pins, toe pins, or cross-sections) or aerial photos.

A field inspection, along with georeferenced photos of channel conditions of the site, is always recommended to look for indicators of channel incision, aggradation, bank erosion through mass wasting, and/or accretion as well as artificial constraints to alluvial processes like bank protection, weirs, or grade control structures. The reviewer should be looking for signs that may indicate instability of the channel and the local or watershed-level causes of the instability and discuss these with the provider. Indicators used to estimate SEM or CEM stage in Section 3.3.4 (Table 6), as well as those in Table 13, may also be useful in assessing channel instability as well as upstream and downstream of the project reach.

Changes in stream geomorphology and channel stability will likely be the focus of design elements in the mitigation plan. However, instability manifested at the reach scale could have causes at the watershed, riparian and/or reach scale (as previously discussed). Stressors to the stream's energy (i.e., hydrologic and hydraulic) regime, sediment supply, and boundary conditions could all contribute to channel instability. Some common examples of these stressors and an explanation of how they affect the channel are listed in Table 14. To the extent possible, a provider and/or the reviewer should strive to identify the stressors acting on the channel to cause its instability, and determine which stressors can be rectified (at the reach scale) and included in the mitigation plan versus stressors that cannot and hence may become constraints (at the riparian/watershed scale).

Table 14. Common stressors affecting stream stability (after Johnson et al., 2015).

Common Stressors		Examples	Explanation
Energy	Unnatural hydrology	Water volume	Impacts to hydrology, particularly bankfull discharge and peak flows directly alters energy.
		Peak flows/floods	
		Bankfull discharge	
	Channel evolution	Channel change	Altered stream morphology changes hydraulics including shear stress, stream power and work. Sediment transport capacity and competence depend directly on hydraulic characteristics of the channel.
	Planform impacts	Branching	
		Sinuosity	
	Dimension impacts	Entrenchment	
		Cross-sectional area	
		W/D ratio	
	Profile impacts	Bankfull slope	
		Localized gradient	
Boundaries	Floodplain disconnection	Floodplain access	Floodplains function as safety valves that limit stream power by distributing large discharge over wide area and provide wide area for channel to move and adjust.
		Floodplain extent	
		Saturation duration	
	Riparian vegetation removal	Streamside vegetation	Riparian vegetation provides roughness, bank protection, and soil-binding root mass. Mechanism for rapid recovery following disturbance.
		Riparian vegetation	
	Changes to biotic drivers	Beavers, large woody debris	Biotic drivers such as beavers and large woody debris provide stabilization functions and a mechanism for rapid recovery following disturbance.
	Direct channel impacts	Channel hardening	Hardened bed or banks or solid structures affects stability and decreases ability to move or adjust.
		Bridges, crossings	
Sediment	Changes to watershed supply	Land erosion	Changes to the amount, size, timing of sediment delivery from the watershed is a direct impact to the sediment side of Lane's balance, altering dynamic equilibrium.
		Channel erosion	
		Delivery	
	Changes to reach supply	Degradation	Positive feedback; instability may be increased by rapid sediment production on an unstable eroding reach.
		Bank erosion	

Floodplain Connection: Another important aspect of geomorphic assessment is the connection of the channel to its floodplain. The floodplain becomes part of the channel during flood flows. Therefore, the ability of flood flows to access the floodplain during storm events and the extent and condition of the floodplain to store and slow flood waters are important geomorphic and ecologic factors (Cluer and Thorne, 2014; EPA, 2015). If a channel is too incised, flood flows may be contained within the stream channel. This will lead to increased shear stress on the channel bed and further exacerbate incision. Floodplain encroachment by agricultural, urban, and/or residential land uses, decreases the area available to store flood waters and alters the frictional resistance, or roughness, provided by native vegetation on floodplains. The frequency and extent of the floodplain connectivity, and the degree of anthropogenic encroachment on the floodplain should be documented during the baseline assessment.

Large woody debris: Woody debris and several forms of coarse and fine particulate carbon play an important role in channel morphology and ecology (EPA, 2015). Woody debris has important effects on controlling bed grade and creating pools and riffles, as well as providing stable epifaunal habitat at low flows. Large wood in streams represent large roughness elements that divert flowing water and influence the scour and deposition of sediment in forested streams. Large wood in stream channels results from trees that fall from banks or hill slopes. The quantity of woody debris in the channel and on the floodplain should be measured to determine if conditions are adequate for supply and retention of this habitat feature.

4.5.2.4 Physicochemical (Water Quality) Condition Analysis

The physicochemical condition of a stream is a major determinant of the quality of habitat for instream aquatic organisms. Some solutes may be beneficial or necessary to support life within a certain range of concentrations (e.g., dissolved oxygen and nutrients) while others have only detrimental impacts above a certain threshold concentration. Where water quality is impaired, restoration, establishment, or enhancement of physical habitat in the absence of water quality improvement measures may provide minimal benefit, if any, to the instream aquatic biological community (e.g., fish and macroinvertebrates). Water quality impacts may also affect the riparian biological community, providing limited benefits for more mobile biota like birds and mammals. Many of the factors affecting water quality in a particular reach emanate from the upstream contributing watershed. Typically, the water quality parameters of concern include temperature; pH; dissolved oxygen (DO); specific conductance; nutrients (phosphorus and nitrogen); sediment; and sometimes metals (e.g., selenium), pesticides, herbicides, or fungicides. Sediment is a natural constituent of stream ecosystems, as are nitrogen and phosphorus, however, abnormally high levels of any of these constituents can result from anthropogenic disturbances and should be recognized and, if possible, addressed in the mitigation plan.

Reviewers should ensure that any adverse water quality conditions that limit the biological condition of the stream are identified by the mitigation provider early in mitigation project planning and are characterized in the baseline assessment. If water quality is limiting the biological diversity and abundance of the site, the mitigation plan should identify whether site-scale management will ameliorate the water quality problems. In some cases, these adverse water quality conditions may be caused by discreet point sources or spatially contained non-point sources that the project itself may be able to address (e.g., stormwater and/or sediment detention). In other cases, degraded water quality may be the result of widespread non-point sources over which the project proponent or sponsor has little control or recourse (e.g., urbanization, agricultural, and mining land uses). The latter situation may limit the ability of the proposed stream mitigation site to develop and sustain a productive and diverse aquatic biological community, which may in turn limit its ecological suitability as a mitigation site.

Elements of a Baseline Physicochemical Assessment

Important aspects of a baseline physicochemical assessment include collection of temperature, pH, DO, specific conductance, nutrients, and sediment data at the upstream end of the project as well as at the downstream end. If there are known or suspected sources of metals or pesticides, herbicides, etc., in the contributing watershed, these should be evaluated as well. Water quality parameters should be collected using the sampling protocols and standards established by the state in which the mitigation project is occurring, as this allows results to be compared with state datasets and water quality standards. Each state has numeric or narrative water quality standards which can be used to compare the water quality of these parameters to standards. Comparison of water quality at the project reach to water quality standards will form the basis of discussions about the provider being able to ameliorate water quality concerns with their project. The water quality status of any stream in the U.S. can be checked by going to: https://www.epa.gov/waterdata/hows-my-waterway.

4.5.2.5 Biological Condition Analysis

Given the overall objective of the CWA to restore, maintain and enhance the chemical, physical, and biological integrity of the nation's waters, biological condition should be characterized as part of a baseline assessment of any proposed stream restoration, establishment or enhancement site, particularly when the objectives of a project relate to improving biological functions. As the top level of the functional pyramid, a stream's biological community is largely influenced by the hydrologic, hydraulic, geomorphic, and physiochemical conditions which operate at watershed, riparian, and reach scales. In turn, biota, particularly riparian plant communities, contribute to the geomorphic stability of, and the organic carbon/detrital inputs to, the channel. Stream biota utilize the organic carbon inputs and contribute to the overall biochemical cycling within the stream ecosystem. The complex interactions of these ecosystem components contribute to the faunal diversity found in natural streams.

Elements of a Baseline Biological Assessment

Important aspects of a baseline biological assessment include characterization of the condition of and stressors affecting riparian and floodplain vegetative communities and the instream faunal communities (e.g., fish and/or benthic macroinvertebrates). The following discussion is meant to provide the reviewer with basic background information to determine if the provider has adequately assessed the current biological condition. Reviewers should look for information on the following parameters.

Riparian Vegetation: The riparian vegetation community is a complex assemblage of plant species that interact with each other and with abiotic factors to produce critical structural and functional aspects of the stream ecosystem. Riparian vegetation provides the root structure and roughness that stabilizes banks, channels, and floodplains while also providing a buffer to the stream from nearby stressors. Riparian vegetation is the source of large woody debris that supports channel complexity, stability, and structure, as well as the detritus that forms the basis of aquatic food webs. It also provides cover, shading, and habitat for species with terrestrial life stages. Important aspects of the riparian community to document in a baseline assessment are:

- **Vegetation structure** (physiognomy) of canopy, shrub, and herbaceous layers (e.g., percent cover, age-stand distribution, density, and canopy height);
- **Species diversity, distribution and abundance, and recruitment** (e.g., floristic quality index);
- Percent **non-native species**; and
- **Riparian extent** (e.g., buffer width, area).

Identifiable stressors affecting the riparian community which should be noted are:

- **Tree and shrub removal** - Direct manipulation of tree or shrub strata, altered light regime for herbaceous stratum;
- **Grazing** - Species composition shift (grasses and grazing tolerant species), cover depletion, bare ground, introduction of weedy species, biomass and nutrient export;
- **Cultivation** - Suppression of non-grass species, biomass and nutrient export;
- **Hydrologic Impacts** - Unnatural hydrology (e.g., wetting or drying from ditching, upstream dams, levees, irrigation; see Section 4.5.2.1) which may favor some species over others. For instance, causing native hydrophytes to drop out due to drying; and
- **Invasive species** - Introduced or escaped species which alter vegetation structure.

Instream Biota: Aquatic life represents the biological component of the natural infrastructure of a stream, and is the main subject of stream ecology. Stream biota include microbes, macrophytes, macroinvertebrates, fish, terrestrial mammals, and amphibians. These biota carry out biochemical processing through a characteristic trophic structure which is assumed to take place in the absence of stressors. A stream's biota is a core feature of reach condition and an important element to characterize in a baseline assessment. A baseline assessment should consider the stressors that may affect biological functions and should include site-specific data to characterize biota (e.g., fish and/or macroinvertebrate surveys, biomass estimates, indices of biotic integrity).

Ecologically, diversity in channel dimensions and geometry, channel features (e.g., bars, bedforms, islands, banks, riparian margins, and confluences), and substrate all contribute to habitat diversity under a variety of flow conditions. As stream channel conditions decline, habitat diversity may diminish. As such, reviewers should consider the results of the hydrologic, hydraulic and geomorphic baseline assessments (e.g., channel cross-sectional dimensions, channel planform patterns and attributes, longitudinal in-channel features (e.g., bedforms and spacing thereof), characterization of channel substrate and floodplain elevations relative to the channel bed) when reviewing the results of the baseline biological assessment to ensure that reported biological condition aligns with baseline habitat conditions.

Stressors affecting instream biota include alterations of characteristic habitat, including any physical, chemical, or biological features that affect the habitability of the reach by organisms (Table 15; Johnson et al., 2015). Energy or food limitations may disrupt food webs, causing shifts in characteristic biota. A common and easily identifiable biotic stressor is the presence of migration barriers that limit access of specific organisms, primarily fish, to and from the reach. The presence of exotic or non-native species affects the normal distribution of plants and animals, as well as the balance of competition, predator-prey interaction, and symbiotic relationships among organisms and populations leading to community-level changes. The loss of native species by extinction or extirpation is similarly both a direct and indirect stressor on community assemblage and biotic structure. Direct management of certain biotic components, especially game fish and pest management are also common human impacts.

Table 15. Common stressors affecting stream biota (after Johnson et al., 2015).

Common stressors	Examples	Explanation
Chemical habitat	Temperature regime	Temperature or water quality limitations, tolerance or preferred range exceedance
	Water quality	
Structural habitat	Stream morphology	Physical habitat structural limitations
	Coarse scale (e.g., bed and bank structure, LWD, jams and dams, and rock)	
	Fine scale (e.g., bed material size distribution, fine sediment deposition and scour, embeddedness, compaction, and macrophyte cover)	
	Riparian tree and shrub removal	
Energy/ food limitations	Nutrient sources	Lack of available energy from lower trophic level biomass
	Organic matter (dissolved, coarse, and fine particulate)	
	Trophic level impacts	
Direct management	Stocking	Direct manipulation of biota
	Culling / Control	
	Grazing	
	Cultivation	
Migration Barriers	Crossings (e.g., culverts, bridges)	Barriers that limit organism access to and/or from the reach. Note that these barriers may be a long distance up-or downstream from the reach.
	Dams/reservoirs	
	Temperature/chemical barriers	
Non-native species	Introduced microbes	Non-native species (introduced and invasive) that come to occupy natural and novel niches. Aggressive invasives can overwhelm entire functional guilds and have far-reaching effects.
	Other invasives	
	Game species	
Extirpation/ extinction	Native fish	Regional or global loss of characteristic species
	Amphibians	
	Macroinvertebrates	
	Beavers	

Site-specific data can be obtained by a variety of field methods including population sampling to quantify number or biomass of specific organisms by species, age class, size class, functional guild, or other specific grouping. Biological data collection is typically an intensive effort, and may involve multiple sampling dates, paired sampling with a control reach and post-field sample processing. Biological condition should be monitored using sampling protocols and standards established by the state in which the mitigation project is occurring or by the agency(ies) responsible for administering the mitigation program, as this allows results to be compared with regionally applicable biological datasets and, sometimes water quality standards. When reviewing baseline data, ensure data were collected within appropriate index periods and using approved methods.

Data are often used to calculate specific indices that quantify biotic community-level characteristics such as diversity and richness; and specific parameters are available for quantifying functional characteristics at the community level, such as indices of biotic integrity (IBI) and parameters of condition based on macroinvertebrate diversity. For larger taxa, indirect measures of populations are often measured instead of direct samples of organisms such as redd counts, scat counts, creel samples, etc. (Johnson et al., 2015). As discussed in Section 4.2, it is important to document, the location of, and the distance to, proximate intact biological communities that serve as recruitment sources for the restored stream reach. These refugial aquatic habitats and their existing water quality and aquatic organism population levels should be documented in the baseline assessment.

5.0 What is the target condition?

The intent of this question is to understand the target condition of the site, given the site's aquatic resource class(es), watershed and site-scale stressors and baseline condition. Stating this target condition is important because it establishes the functional expectations for the site (goals), the specific actions (objectives) which will be implemented and tracked to assess progress towards achieving the target condition and identifies the reference(s) used to inform the target condition. A realistic target condition serves as the basis for developing workplans, performance standards, monitoring, adaptive management, and long-term management plans.

Key points for establishing target condition:

- Establishing goals (statement of functional expectations)
- Objectives: SMART
    - Specific
    - Measurable
    - Attainable
    - Relevant
    - Time bound
- Establishing reference

At the prospectus or pre-application stage, goals and objectives should be outlined in enough detail to inform conceptual mitigation workplan elements (e.g., what stressors should be addressed, whether areas are being established, restored, enhanced, or preserved). The statement of goals and objectives should describe the target condition, with appropriate references proposed for comparison. When reviewing and commenting on early stages of mitigation proposals, reviewers should consider whether the target conditions and project-specific goals and objectives are logical and achievable given the aquatic resource class(es) and existing baseline condition of the site (including the presence of watershed and site-specific stressors). It would be advantageous for the reviewer to inquire about the selection of reference sites early in the process to ensure that reference data and/or sites are being considered by the provider and that the reference sites are applicable (e.g., of the same class, comparable watershed size). If reference data collection is required, early consideration of reference sites will better accommodate the time required to collect, analyze and digest the data early in the planning process. Reviewers should also consider requesting a field visit to available reference sites to provide additional perspective on the target condition.

During review of complete draft mitigation plans, reviewers will want to ensure target conditions are consistent with the actions proposed in the mitigation workplan, that they are informed by appropriate reference datasets or analog sites, that they relate to identified performance standards, and that appropriate methods and measurements are included in the baseline and monitoring assessments to determine whether target condition has been achieved at project closeout. The main opportunity to provide these comments may be during pre-application or draft prospectus stages or the Public Notice comment period for individual permits, or during review of the draft mitigation bank instrument or ILF project addendums.

Important elements in this step include clear, function-based expectations for the outcome of the project (goals) given aquatic resource class(es) and the level of disturbance and stressors acting upon the site, quantifiable actions (objectives) needed to ameliorate the stressors and achieve target condition, and relevant reference comparisons (Box F). Establishing target condition is highly dependent on identifying the watershed or site-scale problems that may be affecting functional capacity. For example, in streams, stressors will affect the status of watershed controls, including hydrology and sediment, resulting in changes in the watershed and stream corridor that may explain changes in condition; and this information needs to be reflected in the goals and objectives that inform an appropriate design (Roni and Beechie, 2013). This section provides the reviewer with background information on developing goals and objectives, as well as technical information on identifying reference comparisons in both wetlands and streams.

It is important to be clear about the time frame in which the stated target condition is expected to be reached and the basis of this expectation. Often, regulatory time frames may expire before the stated target condition is attained. For instance, a target condition of full wetland functional replacement for a forested, riverine wetland may take several decades. Likewise, full functional replacement and reaching equilibrium conditions in stream ecosystems may take time as the channel and floodplain adjust after the project. Therefore, the time expected to reach any stated target condition should be clearly stated. The rationale for estimating the trajectory of the site should be explained. Target conditions at various points in time can be estimated by substituting space-for-time using appropriate reference sites that represent different ages of development.

Box F. Recommended information to identify appropriate target condition.

- What are the goal statements outlining the expectations for the project considering the aquatic resource class(es), baseline conditions and the identified stressors and impairments affecting the site?
- Given the conditions in and around the site (from baseline assessment), will the proposed site support the target functions/condition(s)?
- Are goals and objectives tied to specific functions?
  - For wetlands, consider hydrologic, biogeochemical and habitat functions
  - For streams, consider hydrologic, hydraulic, geomorphic, physicochemical and biological functions
- Are the objectives:
  - Specific to the aquatic resource class(es) on site?
  - Measurable (as indicators of functions outlined above)?
  - Achievable given current and projected site-specific and watershed stressors?
  - Relevant and supportive of the goals of the project?
  - Time bound to the monitoring and performance period of the project?
- What reference approach(es) was (were) used to establish target condition(s)? Are there reference aquatic resources, including reference standard sites or regional references (e.g., HGM regional guidebooks), to which the target condition can be compared?
- Is (are) the reference site(s) the same class and representing the least-altered condition to which the biology can be compared?

5.1 Regulatory Context

The Mitigation Rule indicates that mitigation project objectives must include a description of the resource type(s) and amount(s) that will be provided, the method of compensation (i.e., restoration, establishment, enhancement, and/or preservation), and the manner in which the resource functions of the compensatory mitigation project will address the needs of the watershed, ecoregion, physiographic province, or other geographic area of interest. These project objectives, as informed by the classification and baseline condition considerations, outlined in Sections 3.0 and 4.0, provide the basis for this step of the Approach (Figure 1). Objectives are foundational to subsequent required rule elements, including developing ecological performance standards, which relate directly to achieving project objectives.

Reference data are used to help establish realistic objectives for mitigation projects. The Mitigation Rule defines reference aquatic resources as “a set of aquatic resources that represent the full range of variability exhibited by a regional class of aquatic resources as a result of natural processes and anthropogenic disturbances." The preamble provides further clarification on how reference aquatic resources relate to concepts of reference condition in the ecological literature, noting that "the term 'reference standard' is used for the subset of reference aquatic resources that are the least disturbed and exhibit the highest levels of functions."

5.2 Goals and Objectives

Mitigation providers sometimes characterize project objectives in terms of providing credits. However, the Mitigation Rule describes mitigation objectives in terms of identifying the functions that the proposed mitigation project will provide and the manner in which they will be provided. The Approach adds goal statements as the place to identify which functions are expected to be replaced, with objectives identifying the manner in which they are replaced. Therefore, clearly enunciating project objectives tied to aquatic resource class and the re-establishment of functions typical of that class is critical for tracking the mitigation project and its performance. After assessing the stressors acting on the project site, the goals and objectives should address the problem cause and context (Roni and Beechie, 2013).

Goals are broad statements of the intended outcome, or expectations of the mitigation project, including the functions provided by the mitigation site. Function-based design goals are statements about why the project is needed at the specific project site (ELI et al., 2016). Goals should efficiently express the intent of a project and serve as a fixed point for evaluating project elements (Skidmore et al., 2011; Roni and Beechie, 2013). For example, a project goal may be "restoration of a forested low-gradient riverine wetland to provide hydrologic, biogeochemical and plant and animal habitat functions similar to reference standard wetlands of this wetland type." This statement provides an expectation of the type of wetland and functions to be restored which can be used to guide the project. An equivalent stream goal might be "to restore channel processes needed for resilient and sustainable riparian and biotic habitat." This statement provides an expectation that to restore sustainable riparian and biotic habitat, hydrologic and hydraulic reconnection of the floodplain, as well as repair of instream channel functions, might be needed.

> Goals and objectives should reflect the possibilities and constraints of the site by setting realistic expectations.
>
> Both the provider and the IRT should understand limitations imposed by watershed conditions and consider project goals and objectives accordingly to address the anticipated outcomes of the project.

Objectives, by comparison, are designed to describe the actions needed to achieve the goal. They are typically specific, measurable targets critical to the establishment of the functions that describe the time necessary to reach the target. It is likely each goal may have multiple objectives. Well-defined objectives form the basis for specific performance standards (see Section 7.0) that allow for evaluation of the success or failure of the mitigation project. The objectives tie the actions planned to the performance measures (i.e., specific level of measure attained) needed to evaluate if the goals have been achieved.

SMART objectives are recommended because they can be efficiently tracked through the mitigation project (Skidmore et al., 2011; Galatowitsch and Zedler, 2014; Roni and Beechie, 2013). Some USACE Districts in the southeastern U.S. (e.g., Savannah and Wilmington) have adopted a similar SMART approach for identifying objectives. For this Approach, SMART objectives are:

- **Specific** to the aquatic resource type and location (classification and watershed position);

- **Measurable** using parameters that can be monitored before and after project implementation;
- **Achievable** given the current and projected site and watershed stressors;
- **Relevant** (clearly related) to the identified problem and supportive of the project goal; and
- **Time-bound** to the monitoring and performance period of the project.

It is important to recognize that it may not be possible to fully restore a wetland and/or stream ecosystem to its pre-disturbance condition. Past and current land use, existing infrastructure, invasive species, limited native species abundance and extinction, among other perturbations, may prevent full ecosystem recovery from being achieved. In such systems, returning the system, or a portion of the system, to an improved state of ecological functioning but not necessarily its pre-disturbance condition may be the only achievable goal. Goals and objectives should reflect the possibilities and constraints of the site, or its restoration potential, by setting realistic target expectations. In the instance of a degraded wetland or stream that may never reach a pre-disturbance condition, a goal should be to establish a self-sustaining ecosystem that is resilient in its recovery response to its disturbance regime, and not one that will require repeat intervention by humans (Saldi-Caromile et al., 2004; ELI et al., 2016).

The goals and objectives become the statements of target condition and are the elements needed to inform workplans and mitigation activities. Reviewers and providers will likely have to work together to produce effective goals and objectives that provide realistic target conditions for a site. Classification, as well as the baseline condition of the site, need to be considered in formulating the goals and objectives. Reference sites (discussed below) can also be useful in visualizing the target condition. Differences between developing target conditions for wetlands and streams is discussed below in Sections 5.2.1 and 5.2.2

5.2.1 Wetland Goals and Objectives

In general, the target condition of wetland compensatory mitigation will be the restoration or enhancement of a sustainable and resilient level of the functions performed by the appropriate HGM class at the proposed site. HGM classification and consultation of applicable regional guidebooks facilitate description of project goals by laying out the functions expected to be performed by a particular wetland class or subclass. Understanding these functions, the level of on-site and surrounding watershed impairment and the restoration potential of the site should lead to development of appropriate, realistic wetland goals and objectives. Watershed and site-scale stressors should also be considered in the scoping of goals and objectives. Importantly, wetland goals and objectives should be framed in the context of reference standard conditions, not jurisdictional criteria.

> Goals and objectives for wetland mitigation projects should be expressed with a clear understanding of where the site sits along the disturbance gradient represented by similar reference wetlands, and whether and how the site can be returned to a reference standard condition.

Goals should be realistic and not set expectations of full functional replacement if the landscape level factors affecting the wetland do not support some functions. For instance, a goal of “full functional replacement of low gradient riverine wetland wildlife habitat functions” would likely be unattainable if the riverine wetland was disconnected from habitat types up- and downstream of the site and land uses prohibited reconnection. Understanding that habitat replacement, including connection to a naturally vegetated corridor, may be unattainable for this particular wetland class in the specific landscape setting is important for determining appropriate goals. A more appropriate goal would be "to restore onsite wildlife habitat characteristics that will provide usage by species whose requirements can be met onsite."

Objectives need to reflect the characteristics and functions of specific wetland classes and the stressors intended to be repaired. For instance, restoring overbank flooding to a mineral soil flat wetland would not make sense, as mineral soil flats are not associated with streams and do not rely on overbank flooding as a water source. Therefore, an appropriate goal for mineral soil flats would be to re-establish the hydrologic regime typical of reference standard mineral soil flats (i.e., saturation and/or ponding). If the mineral soil flat site was impounded by a road, leading to prolonged ponding of the site, an objective would be to decrease the ponding on the site to reference levels of timing and duration. This objective supports the goal of re-establishing hydrologic function to the wetland and is quantifiable (i.e., timing and duration can be measured). A commensurate hydrologic goal for riverine wetlands would be to re-establish surface and subsurface water storage functions typical of reference standard wetlands. The objective(s) could then be to re-establish overbank flooding, and shallow groundwater, magnitude, frequency, timing and duration typical of the reference standard wetland.

5.2.2 Stream Goals and Objectives

Setting target conditions for streams means recognizing stream classification characteristics (i.e., watershed and landscape context, flow permanence, and geomorphic context) in the context of baseline conditions and relevant stressors at the project site. Target conditions will be informed by the condition of the stream at the reach, riparian, and watershed scales. It is possible that target conditions may only be projected to improve or restore certain categories of functions (e.g., hydrology, hydraulics, and geomorphology).

Goals should include the intention to improve processes that sustain and support natural ecosystem functions and conditions, and emphasize resilience (i.e., capacity to recover from natural disturbance) (Roni and Beechie, 2013; Palmer et al., 2007). More succinctly, goals should be function-based (ELI et al., 2016). Ideally, goal statements will describe intended outcomes without being too prescriptive about the means to those outcomes (Skidmore, 2011). For instance, goal statements which might be considered too prescriptive include restoring historic planform alignment, stabilizing stream banks or streambed, returning channel bed elevation to historic elevation and grade, or restoring channel dimension, pattern, and profile. Each of these examples drive the planning toward stabilization, reconstruction, or reconfiguration and may constrain the options for achieving improved ecological conditions. Examples of more appropriate goal statements might include:

- Increase recruitment of target species;
- Remedy direct or indirect human actions contributing to channel instability to address sources of excess sediment and associated habitat and water quality degradation; or
- Restore and maintain dynamic channel processes to foster sustainable riparian and fish communities.

Goals associated with the restoration of aquatic biota should be reasonable given site and watershed constraints and the importance of site selection and watershed conditions to biological success of stream restoration and enhancement efforts, particularly where water quality, proximity to colonizing populations and probable refugia may be limited (Section 4.2). Where there are constraints to restoring biota, reviewers should also consider the appropriateness of habitat-related goals or objectives.

Objectives may be either structural or functional, and in either case, should include an action, a measurable, quantifiable target and the time frame required to reach the target (Roni and Beechie, 2013; Skidmore et al., 2011). A **structural objective** focuses on the distribution, abundance, and physical condition of some element of the ecosystem and is measured as a point-in-time value. Examples of structural objectives include “to restore native riparian vegetation to include at least four native woody species within three years” or “to create a minimum of two acres per stream mile of rearing fish habitat in the first year of restoration.” A **functional objective** focuses on processes that sustain an organism or environmental components and is measured as a change, or a rate over time. Examples of these include “to establish fish passage to at least one mile of stream within two years” or “to restore overbank flow to an average duration of five percent of the growing season in three out of five years within ten years.” Stream functions outlined by Fischenich (2003; 2006) or Harman et al. (2012) can provide a general framework for identification of applicable stream functions and potential goals, objectives and parameters that can be designed for and monitored.

5.3 Reference

> Selecting reference sites for comparison to mitigation sites must emphasize the similarity that defines the physical, chemical and biological composition of the particular stream or wetland resource.

Assessing baseline condition, setting appropriate target conditions, designing the project, and evaluating compensatory mitigation performance all require a basis of comparison, a benchmark, or a reference. At its most inclusive, an ecosystem reference represents some target, benchmark, standard, model, or template from which, or to which, ecosystem structure, function, condition, biological integrity, or relative health are compared (Smith et al., 1995; Brinson and Rheinhardt, 1996; Miller et al., 2012). Ecosystem impacts are typically assessed by comparing what is seen on the ground (current condition) to some standard (real or virtual) representing a non-altered condition (reference). The Society for Ecological Restoration recognizes the importance of reference sites in representing the target condition upon which restoration designs are based and against which the progress of a site is evaluated (McDonald et al. 2016). Reference conditions used in targeting, and subsequent design, monitoring and assessing performance, can be derived from reference site data, historical information about the site to be restored, existing or historical sites with similar structural characteristics, and/or predicted conditions based on computer models (Merkey, 2005; Hawkins et al., 2010). Selecting reference sites for comparison to mitigation sites must emphasize the similarities with the landscape-scale attributes (e.g., landscape position), as well as the representativeness of the target physical, chemical, and biological composition of the particular wetland or stream resource. For instance, it would be inappropriate to choose a reference condition similar to the pre-mitigation degraded biological or stream geomorphic conditions. This is one reason why classifying the aquatic resource is critical. Without similar structural characteristics (e.g., landscape position, hydrodynamics, geomorphology, slope, sediment grain size, hydroperiod, and salinity) between mitigation and reference sites, comparison of functional characteristics, such as presence and abundance of specific groups of organisms or nutrient cycling dynamics, is inappropriate (Brinson and Rheinhardt, 1996; Merkey, 2005).

Setting wetland target conditions conceptually is more straightforward than setting those for streams, since the HGM guidebooks have already scaled reference data collected across a disturbance gradient (i.e., regional index) that can be used to narrow natural variability and better define a given wetland target condition. Streams, being more dynamic, exhibit more variability and are more difficult to capture in a system where key landscape, physical, hydrologic, and biological processes allow ecological classification based on functional similarities. Thus, setting stream target conditions with appropriate reference streams involves understanding terminology and use of different approaches. Reviewers should be aware of differences in reference terminology between wetlands and streams, and the limitations in reference data approaches, including how such limitations may affect not only the target condition of the project but also its design, performance, and adaptive management.

Discussion of the use of existing reference data and/or collecting reference data for application to a particular project with a provider and/or other IRT agencies, is facilitated by understanding some concepts and terminology associated with ecosystem reference (Smith et al., 1995; Brinson, 1993; Stoddard et al., 2006; Miller et al., 2012).

- A **reference standard ecosystem** is one or more existing, former or hypothetical ecosystems that serve as a guiding image, or target ecosystem, for a mitigation project. Aquatic ecosystems that represent the full range of variability are referred to as reference aquatic resources in the Mitigation Rule, with **reference standard sites** representing the subset of reference aquatic resources that are the least disturbed and exhibit the highest levels of functions. Typically, the reference standard ecosystem is considered the best representation of a particular class. A **reference** site can represent one whose functional capacity is very degraded, or one within the range of natural variability, across a range of conditions exhibited by a particular aquatic resource class.

  For example, in wetlands, a **reference standard** wetland can be one of a group of wetlands in minimally disturbed or least disturbed condition on the landscape that represent the natural range of variability exhibited by that wetland subclass. Reference standard wetlands also represent the highest level of functions across the suite of functions performed by the particular wetland class. However, **reference** wetlands are wetlands of the same HGM class that represent wetland conditions under an anthropogenic disturbance regime (e.g., vegetation removed, hydrology altered, and soils disturbed). In other words, reference wetlands represent examples of a particular wetland class along a disturbance gradient. For example, for riverine forested wetlands, a reference standard would be one with mature timber, well stratified forest layers, intact hydrology and soils, and being part of a well-connected corridor. A wetland that is of the same type but disturbed (e.g., clear-cut, ditched, and/or soils disturbed) would be included as a reference wetland that exhibits conditions along a disturbance gradient.

  Within the stream assessment and restoration arena, the concept of reference standard, or least-disturbed condition, is typically discussed using related but different terms depending on the stream function being assessed.

- **Reference condition**, typically used in stream biological assessment, is the set of quantifiable characteristics of the reference ecosystem that characterize the range of natural variability under undisturbed conditions. In this manner, the term reference condition is similar in concept to reference standard in representing undisturbed or least disturbed biological condition. They can be developed using current or historical information, conceptual, empirical, or quantitative models (Nestler et al., 2010), or well-documented professional judgment (Miller et al., 2012).

Reference condition categories (i.e., historical condition; minimally disturbed condition; and least disturbed condition (Stoddard et al., 2006)) pertain not only to the site characteristics of particular reference sites, but also to the landscape conditions in which these reference sites are found. In the southeast U.S., it is highly unlikely to have a stream or wetland site that would be considered pristine or completely unaltered by anthropogenic impacts. The most likely reference condition will fall into either the category of minimally disturbed (i.e., really close to pristine conditions) or least disturbed (i.e., this is the best we could find) (Miller, 2012). In other words, even within the same aquatic resource class, the reference condition, or reference standard, could vary depending on the level of disturbance in and around the sites used to define undisturbed conditions. The state of the contributing watershed or ecoregion will indicate the type of reference conditions available for comparison to the mitigation project which will affect setting mitigation targets, assessing baseline condition and performance.

- **Reference/reference reach**, typically used in stream geomorphic assessments, is the portion of stream segment that represents a stable channel within a particular valley type (Rosgen 1998). Reference reaches are typically used as templates for stream designs (see Section 6.3) and in the context of stream mitigation, typically represent only the geomorphic function(s). The term reference and/or reference reach are often used by providers when discussing Natural Channel Design (NCD) plans, and reflect the portion of stream from which measurements for optimal channel dimensions were collected.
- A **reference approach** is a set of assumptions and techniques for characterizing and applying reference ecosystem and reference condition data to practices associated with compensatory mitigation. Reference approaches (discussed below) vary and may rely on one, or more, of the reference condition categories described above.

The availability of regional reference data is not ubiquitous. In many cases, mitigation providers are asked to supply project-specific reference data early in the mitigation planning process to compare to baseline conditions, help to establish target conditions, assist in design and to guide setting performance standards. In a mitigation proposal, reference sites and reference site data (from regional datasets) should correspond to the appropriate wetland class and/or the appropriate contributing watershed and stream setting to ensure an apples-to-apples comparison. Reviewers should be clear on the use of reference terminology to understand the context and type of reference data being used in the project. It is primarily through comparison of the mitigation site to reference sites that providers and IRTs can document changes resulting from mitigation activities versus those caused by natural variability.

Reference ecosystem information can be gathered using essentially four approaches: analog, empirical, analytical, or using regional indices and condition gradients. The specific reference approach selected for a mitigation project will depend upon the ecosystem type, the application of the reference data (baseline assessment, target condition, design, and monitoring, etc.), and especially the availability of information from which a reference standard can be specified. These four approaches are not mutually exclusive and combinations of these can be, and often are, used together. In fact, a hybrid approach, where different approaches are used for different components of a design or as corroborative evidence, is commonplace in contemporary channel design practice (Bledsoe, pers comm.). Therefore, reviewers should be aware of shortcomings of the various reference approaches and the data they produce and look for use of several reference approaches to apply to the project. The reference approach(es) used, and the information gathered, should be reviewed and agreed upon by the IRT.

5.3.1 Reference Approaches Useful in Compensatory Mitigation

Analog Approach

An analog approach to collecting reference information simply refers to sampling current, on-the-ground sites of equivalent aquatic resource class, where data collected represents the structural and functional characteristics associated with a healthy ecosystem. These analogs can be located either on- or off-site of the mitigation area. On-site analogs can be wetland patches or stream reaches, in close proximity to the mitigation area, that represent a set of characteristics that represent one or more project features (Miller, 2012; Stein et al., 2022). For instance, forested wetland patches with mature timber may be sampled as analogs for vegetation structure and species composition, but because that patch is surrounded by agriculture, the site may not represent the connectedness needed for good wildlife habitat. For streams, an analog reach may be sampled for its geomorphic form but may not be appropriate for biologic reference due to sustained water quality impacts upstream.

Looking for appropriate analog sites within or beyond a compensatory mitigation site's watershed requires adherence to stream or wetland classification but offers flexibility to identify a more ecologically representative reference for the system of interest (Miller et al., 2012). This might involve, for example, identifying a stream reach of a similar type in a nearby watershed and similar geomorphic setting that is fully functional and otherwise healthy. Data gathered from this reference system can be used to evaluate conditions at the project site and serve as a guide for project formulation and design.

For wetlands: Identified reference wetlands should be of similar HGM class and subclass to warrant appropriate comparison with a proposed site (Bruland and Richardson, 2005b; 2005c). If sites fall within the reference domain covered by an HGM regional guidebook, these guidebooks may be used to describe prevalent functions, characteristics, and processes expected on the project site (see regional index approach below). If sites do not fall within such reference domains, they will require collection of additional reference data to provide a basis of comparison. Providers can use aspects of the SSURGO database to determine the likelihood of particular sites being of similar HGM class to the mitigation site, as discussed in Section 3.2.3. In addition, landscape information from Section 4.2 and any other available watershed information can be used to select reference sites with similar landscape settings to determine if a reference site represents a reference standard or a more degraded condition along the disturbance gradient.

For streams: Typically, reference standard conditions for geomorphic channel designs in the compensatory mitigation program have been obtained from reference reaches (analog approach) in combination with empirical relationships (regional curves) and analytical methods using computer models like HEC-RAS, River-2D, or FESWM (FHWA) (Hey, 2006; Bledsoe et al., 2016; Yochum, 2016; Jennings, pers comm, 2018). The challenge in designing a geomorphically stable channel is to identify a reference standard condition which is appropriate for the project site's channel boundary materials and setting, as well as being able to accommodate current flow and sediment regimes. Analog reference standard sites may also be used to provide biological data, including vegetative communities, that represent the communities that occur in minimally or least disturbed conditions.

Finding appropriate analog reaches involves ensuring that key criteria including the valley setting, boundary conditions, and inflowing loads of water and sediment are equivalent between the analog and project reaches. The following criteria assess the appropriateness of an analog reach chosen by a provider for use in stream design (Bledsoe et al., 2017). For an analog reach to be deemed appropriate for channel design purposes it must have:

- **Similar drainage area** as the proposed restored reach (e.g., within 20%);
- **Location** - If on the same river, the analog reach is located upstream from the project reach;
- **Same hydrophysiographic region** (type, amount, timing and magnitude of precipitation events) is the same as the restored reach;
- **Similar channel type** to the target project, given (1) prevailing historical channel type that was previously stable (diagnose why departure occurred) in that location under current land use; or (2) channel type is stable under same current land use, flow, and sediment supply in analog reach;
- **Stable channel** - (i.e., CEM stage I or V per Schumm et al. (1984); Table 6) banks stable, no evidence of trends in aggradation/degradation, planform change, etc. over approximately 50-year time-frame;
- **Similar land use** - The extent and nature of land use (e.g., curve number) is similar between the two watersheds (within 20%);
- **No flow/sediment regime alterations** - Analog reach has no noteworthy tributaries, dams, or intervening flow augmentations or extractions initiating changes in the flow and sediment regimes.

Many of these same considerations are also important in the selection of biological analog reference streams from which, for example, macroinvertebrates, fish, and/or riparian vegetation data may be collected to inform target conditions or performance standards. In addition to the above factors, historical watershed land use, water quality analysis and biological community sampling should be completed at potential analog sites prior to selection. Contemporary watershed land use may be a poor indicator of instream biological communities (Harding et al., 1998), and thus historical land use should also be considered. Further, it can be difficult to ascertain if a high quality biological reference has been selected without completing field sampling and analyzing the water quality and biological community data from that stream. Water quality plays a critical role for instream biological communities. Some adverse water quality conditions significantly affect in-stream biota quality and may not be readily observable without measuring or analyzing water quality (e.g., elevated specific conductance; see Boehme et al., 2016; Cormier et al., 2013). In-situ measurement of water quality using appropriate techniques (e.g., properly calibrated multiparameter sonde) should be included to investigate whether water quality could be a biologically limiting stressor prior to full biological sampling in the field.

Regional Curve/ Empirical Approach

Empirical equations generally relate attributes of channel form (e.g., width, depth, flow velocity, slope, meander wavelength, and amplitude) to independent parameters defining the channel-forming flow (usually bankfull discharge), sediment regime, and the boundary conditions (bed material size, valley slope, bank characteristics, and bank vegetation). In an empirical approach, the functions, constants, and exponents are derived from local, regional, or global sets of experimental or observed data. The approach is similar to the analog approach, with the difference being that the dataset used for the method relies on a population of analogs to derive average values and predictive formulas rather than an individual analog or reference reach. This is a logical extension of the analog approach, because it adopts the intuitive approach of replicating equilibrium conditions observed in nature, but the values derived are more defensible since they are based on a larger data set (e.g., regional curves) (Skidmore et al., 2011).

Regional curves are empirically derived, and typically plot the cross-sectional geometry of a subset of stable streams in a region against their respective drainage areas. These regional relationships between bankfull geometry and flow can be used to approximate bankfull channel geometry in unstable channels where indicators are difficult to find or do not exist. These regional curves can also be used to corroborate the reasonableness of bankfull channel geometry obtained for a specific site. Verification of bankfull indicators with estimates of bankfull flow is typically accomplished using regional curves (see McCandless and Everett (2002) for information on curve construction).

Regional curves have been developed for many regions of the country (Somerville, 2010) and reviewers should verify the source of any regional curves used as a reference in stream design. There are a number of southeastern-specific regional curves developed in Alabama, Tennessee, Georgia, North Carolina, South Carolina, and Florida. The USDA National Water Management Center is also working with other federal, state, and local agencies to develop Regional Hydraulic Geometry Curves throughout the country (see USDA Regional Hydraulic Geometry Curves): https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/water/?cid=nrcs143_015052.

Limitations of a regional curve/empirical approach are similar to those on the analog approach; that is, the reference comparison(s) must be in equilibrium, and conditions in the project reach must match those in the streams from which the hydraulic geometry equations were derived. The empirical approach is appropriate where the causes and adverse impacts being addressed in the project are localized (for example, being due to a poorly designed culvert, local channelization, or unmanaged bank grazing and trampling), and where sediment and flow regimes are relatively undisturbed. Even using appropriately derived empirical equations, the confidence in the precision of these can be quite variable (Bledsoe et al., 2017). Therefore, it is important to have the provider address how situations within the range of variation might be addressed after construction (e.g., within the adaptive management plan).

Analytical Approach

Analytical approaches differ fundamentally from analog and empirical relations in that they are theoretical and require the quantification of the independent parameters governing alluvial channel form (e.g., water and sediment flow and boundary resistance) (Skidmore et al., 2011). Further, analytical approaches are capable of simulating dynamic process-response mechanisms in unstable channels, whereas analog and empirical approaches assume equilibrium conditions and therefore are unable to represent the processes and forms associated with channel adjustment. Analytical or predictive design makes use of the equations for continuity, flow resistance, and sediment transport to derive equilibrium channel dimensions for specified values of water discharge, sediment supply, bed material, and bank characteristics. A good example of this approach is the Copeland Method (Soar and Thorne, 2001) which is incorporated into the HEC-RAS models. However, in practice, the use of analytical methods is limited by the availability of the input data required, the quality of that data, and scientific uncertainty in the models employed.

Regional index or condition gradient

A regional index is developed by characterizing a range or gradient of ecological condition that represents regional values of ecosystem parameters of interest in ecological restoration.

Aggregated values that enable discrimination between degraded and non-degraded sites are used to build a reference index, set ecological condition gradients, and define functional endpoints. Reference sites (e.g., poor, fair, good, and excellent) can be selected across the disturbance gradient, using best professional judgement or derived quantitatively from among all the sampled sites based on selected parameters.

Examples of regional indices include the HGM method for developing and applying indices for assessment of wetland functions, Floristic Quality Indices (FQAI), or Indices of Biological Integrity (IBIs) (Miller et al., 2012). Where sites are of similar HGM class/subclass and fall within the reference domain of a regional guidebook (i.e., area from which reference data was collected and to which the models apply), that data in whole or in part, can be used as a basis of comparison to a mitigation site. HGM guidebooks will describe the reference domain in terms of climate, geology, hydro-regime, soils, vegetation, and typical land uses. The demarcation and description of the reference domain can be used to determine if the reference information in the guidebook can be appropriately applied.

Where available, regional datasets can be used to develop ecological condition gradients from a population of sampled sites. For example, water quality and biological data are available from state water quality offices as well as from EPA’s National Streams and Rivers Assessment (NRSA).

6.0 How will the mitigation design achieve the target condition?

The intent of this question is to ensure mitigation work plans describe the proposed actions that will alleviate stressors and improve ecosystem functions at the mitigation site, consistent with the stated goals and objectives and within site and watershed constraints (Figure 1). There is not a one-size-fits-all restoration method or technique that can be universally applied to all wetland or stream restoration projects (Skidmore et al., 2011; Galatowitsch and Zedler, 2014; Stelk et al., 2017); therefore, the provider must prepare a site-specific plan that provides a clear link between the stressors causing the current wetland or stream impairment (baseline assessment), the goals and objectives of the project and the proposed approach to address those problems.

Four restoration principles, originally proposed for streams but also applicable to wetlands, that should be represented in every mitigation plan (after Beechie et al., 2010):

- Wetland and/or stream processes degraded by anthropogenic activities should be restoration targets;
- Mitigation designs and methods should be tailored to the ecological potential of the site which is controlled by processes operating at watershed, riparian/catchment, and reach/site scales.
- Scale of the project should match the scale of the problem. Given most compensatory mitigation actions occur at the site or reach scale while many processes acting upon that site or reach occur at broader watershed scales, watershed-scale processes (Section 4.2) that cannot be addressed in the mitigation project should be considered as constraints on the project;
- Mitigation plans should be consistent with the goals and objectives for the project. Objectives will take time to be realized after implementation, thus there should be a clear and quantitative link between management actions and the expected results.

Mitigation workplans, including project designs, are generally provided as part of a completed draft mitigation plan, banking instrument or ILF instrument or addendum. Because a mitigation plan is unique to each site, reviewers will want to ensure workplan elements are consistent with the specific goals and objectives of the project and that proposed methods are appropriate for the site. The main opportunity to provide comments on workplans will be during the Public Notice comment period for individual permits or during review of the draft mitigation bank instrument or ILF project addendums.

Important elements of an effective mitigation workplan include appropriate consideration of site conditions, landscape context, and the constraints placed on the site by surrounding land uses; and an understanding of the causes and levels of degradation, the effects a particular restoration method might induce, as well as how to make modifications or refinements to the plan (i.e., adaptive management). Reviewers should consider the specific methods that are proposed in the workplan to ensure they are informed by baseline conditions and function-based goals and objectives; appropriate given the aquatic resource class, landscape potential, watershed and site constraints, and logistics; and have the potential to move the site from its current condition to the proposed target condition. Some restoration methods are more commonly used than others (e.g., NCD, planting specific tree/shrub species), and some providers may utilize methods because of their familiarity with the method as opposed to the applicability of the method to the resource class or setting, or its ability to address a stressor. The reviewer should remain open to consider the merits of any method, or set of methods, so long as they have the potential to achieve the desired result. It is important to consider whether the proposed methods can effectively address the root causes of degradation, are consistent with the ecological potential of the site, are appropriate given the existing condition and scale of stressors or impairments, and whether they are consistent with stated objectives (Beechie et al., 2010).

This section provides the reviewer with background information on important elements to be included in wetland and stream workplans, as well as technical information on specific methods and techniques commonly used in wetlands and stream restoration projects.

6.1 Regulatory Context

The Mitigation Rule requires that the mitigation work plan include written specifications and work descriptions for the compensatory mitigation project, including, but not limited to: the geographic boundaries of the project; construction methods, timing and sequence; source(s) of water, including connections to existing waters and uplands; methods for establishing the desired plant community; plans to control invasive plant species; the proposed grading plan, including elevations and slopes of the substrate; soil management; and erosion control measures. For stream compensatory mitigation projects, the mitigation work plan should also include other relevant information, such as watershed size, proposed planform channel geometry, channel hydraulic geometry (e.g., typical channel cross-sections for both pools and riffles), longitudinal profile and channel bed forms, design discharge and riparian area plantings. Any given mitigation plan may include any combination of the requirements in the Mitigation Rule, as well as additional considerations that may be called for based on the type and level of impairment of the wetland and/or stream.

6.2 Wetland Design and Implementation to Achieve Target Conditions

Methods and techniques described in the mitigation work plan should be appropriate to address the level of degradation of the proposed site and address all factors necessary to move the site from its current condition to the proposed target condition. To be self-sustaining, wetland mitigation sites must have functioning hydrologic, soil biogeochemical, and biologic processes (i.e., water source, hydrodynamics, soil, and vegetation) (NRC, 2001). For both ecological and logistical reasons, the evident degradation of the abiotic components of a site needs to be addressed before biological treatments can be properly designed and/or implemented (Bruland and Richardson, 2005b; 2005c; Galatowitsch and Zedler, 2014; Craft, 2016; Stein et al., 2022). Only if abiotic problems with topography, hydrology, soils, nutrients and/or contaminants can be resolved, will there be a reasonable likelihood for successful restoration or enhancement of the biological components of the ecosystem (e.g., target vegetation and animal/insect communities).

Specific methods proposed to address hydrologic, soil and vegetative impacts should be explained and/or evaluated on the basis of the plan's purpose and rationale, its effect on the site, evidence of its past effectiveness and full disclosure of assumptions and constraints (Box G). Generally, stressors to wetland water sources (e.g., ditches, levees, and groundwater pumping) should be characterized by wetland water budgets and addressed in the mitigation plan. Wetland soil restoration needs should be identified based on the stressors affecting the site (e.g., compaction, excavation, agriculture, and contamination) and the comparison of soil properties (i.e., bulk density, texture, organic material, and nutrients, etc.) with reference standard sites and the Soil Survey. Wetland vegetation plans should be compared to reference data and take into account how plantings will adjust to the growing season hydrologic regime (e.g., microtopography needs to be incorporated into the plan to allow plants with different hydrologic tolerances, as well as biogeochemical processes needing different hydrologic regimes, to occur on the site) and how vegetation change over time. The following three sections address some aspects of hydrology, soils, and vegetation that are important to be addressed in wetland mitigation plans.

Box G. Recommended information to address appropriateness of wetland mitigation plan/design.

The following questions should be addressed in context with the site classification (Section 3), baseline watershed and site assessment (Section 4), and the goals and objectives for the project (Section 5):

Hydrology

- Do the methods proposed address degradation of the wetland's water inputs, outputs, and storage capacity as compared to reference wetlands of the same class?
- Are the methods justified (i.e., purpose, rationale, effectiveness, and assumptions)?
- Will these methods restore the hydroperiod of surface and/or groundwater typical for this wetland type?
- What is the growing season hydroperiod during normal, wet, and dry years AND will this support a vegetation community similar to reference standard?

Soils

- Do the methods proposed address degradation of the wetland's soils as compared to mapped soils and reference?
- Are the methods justified (i.e., purpose, rationale, effectiveness, and assumptions)?
- Will these methods restore the soil characteristics (e.g., permeability, structure, hydric characteristics, and bulk density) indicative of this wetland type?

Vegetation

- Do the methods proposed address degradation of the wetland's vegetation community as compared to reference standard?
- Are the methods justified (i.e., purpose, rationale, effectiveness, and assumptions)?
- Will these methods restore a plant community (all strata) typical of the reference wetland class?
- Does the proposed method include a vegetative planting plan that accounts for variations in soil types, site elevations, planting depths, and timing for planting?

6.2.1 Hydrology

Hydrology exerts the greatest influence on wetland structure and function. Thus, a proposed mitigation wetland's water budget (i.e., inputs, outputs, and storage) should be carefully assessed, and appropriate methods identified to restore the wetland's target hydrology. Wetland restoration or enhancement projects should not merely aim to assure the minimal wetland hydrology criterion (e.g., 14 days, five percent of growing season), but rather to restore the optimal hydrologic regime of the target HGM wetland class and vegetative community. Adherence to a single, static hydrology criterion for all wetland types ignores the fact that different wetland types possess different hydroperiods. It is exactly this variability across wetland types that allows them to function differently, thus enhancing the diversity and resiliency of wetland ecosystems on the landscape and the watershed functions to which they contribute. Thus, each wetland mitigation plan should address the target hydrologic (and soil) characteristics of that particular site and propose methods to restore those characteristics, if necessary.

Ideally, wetland mitigation plans should quantify the wetland water budget in terms of inputs (i.e., precipitation, surface, and groundwater inflows), outputs (i.e., evapotranspiration, surface runoff, and groundwater outflows) and change in storage. The water balance equation written below can be used in predicting wetland hydrology (Williams, 1998):

$$\Delta S = P - E - T - Rs - Rg$$

Where ΔS is the change in soil storage of water, which equates to soil saturation; P is precipitation; E is evaporation; T is transpiration; Rs is surface runoff; and Rg is subsurface runoff.

If ΔS is positive and larger than the volume of unsaturated soil porosity, then the soil is saturated. Generally, P is always considered an inflow; E and T are considered water loss terms and are considered outflows. Water can also be lost from a site via surface runoff (Rs) and/or subsurface runoff (Rg) in which case these terms would also be outflows. Wetlands represent areas on the landscape where surface runoff (Rs) or groundwater (Rg) can accumulate and, in these situations, Rs and Rg can be net inflows (in which case the sign in the storage equation above is positive (+)). Thus, wetland site hydrology can be grouped based on the four loss terms in the above equation: E, T, Rs, and Rg. Where all four terms are negative, representing outflows, but precipitation is greater than these terms, then the wetland is considered rainwater driven since rain is the predominant water source. An example of this wetland type would be mineral and organic soil flats. Sites where Rg is positive, representing a net inflow, will have groundwater hydrology like slope wetlands and wetlands in the depression class. In these areas, subsurface flows augment rainfall. Finally, where Rs is positive, or a net inflow, sites are flooded by surface water, as in riverine and fringe wetlands.

Given the discussion of hydrologic stressors and monitoring in Section 4.4, wetland water budgets provide the context for understanding the effects of the stressors and interpreting the data from hydrologic baseline monitoring (albeit short-term). Wetland mitigation plans should attempt to assess wetland water budgets and determine the appropriate water sources and hydrodynamics for the site and place them in one of the seven HGM classes. To date, quantitative water budgets are rarely required by agencies and/or submitted by providers as part of mitigation plans. However, without water budgets the degree of knowledge uncertainty and risk increases (see Section 2.4) since an understanding of hydrologic sources and hydroperiod are essential for an effective plan.

Some potential methods to re-establish water inputs, outputs and storage, based on HGM class are provided in Table 16 as examples of what reviewers might encounter during their review. HGM wetland water sources and hydrodynamics are described in Table 3. Reviewers should consider whether methods proposed to ameliorate hydrologic stresses are appropriate given project objectives, rationale, effectiveness, assumptions, and constraints. For instance, plugging small wetland ditches is often done using a non-porous soil (i.e., clay) or with a length of non-pervious tile. However, large ditches need to be filled by re-grading so that water does not concentrate behind the ditch plug, (which can lead to flanking of the plug) and instead spreads across the wetland (Galatowistch and Zedler, 2014).

Table 16. Examples of potential methods to improve wetland water components by HGM class. (ET= Evapotranspiration: a combination of the evaporation and transpiration terms of the water budget equation representing water losses to the atmosphere).

Potential Methods to Improve Impaired Wetland Hydrology			
HGM class and water source(s)	**Inputs**	**Outputs**	**Storage**
Riverine – (overbank flooding, groundwater, and precipitation)	Breach levees, remove upstream dams, eliminate toe slope ditches and/or groundwater pumping	Fill ditches	Restore micro- and macro-topography relative to reference wetland, and floodplain elevations and soil profile relative to onsite water levels (i.e., no fill and no excavation).
Slope – (groundwater)	Eliminate ditches and/or groundwater pumping, reduce upslope impervious surfaces	Fill ditches, address incision in receiving streams	Restore surface elevations relative to reference wetland and onsite water levels (i.e., remove fill and no excavation), soil profile/ porosity.
Mineral soil flat- (precipitation)	Eliminate ditches and/or groundwater pumping	Fill ditches, remove impediments to outflow, restore native vegetation (ET)	Restore surface elevations, micro- and macro-topography relative to reference wetland and onsite water levels (i.e., remove fill and no excavation). Restore soil confining layers.
Organic soil flat – (precipitation)	Eliminate ditches and/or groundwater pumping	Fill ditches, remove impediments to outflow, restore native vegetation (ET)	Restore surface elevations, micro and macro-topography relative to reference wetland and onsite water levels (i.e., remove fill and no excavation), soil porosity/ organic matter.
Depression – (groundwater, precipitation, and floodwater)	Eliminate ditches and/or groundwater pumping, reduce upslope impervious surfaces	Fill ditches, re-establish natural outlet elevations and cross-sections, restore native vegetation (ET)	Restore surface elevations, contours and depths (concave shape) relative to reference wetland and onsite water levels (i.e., remove fill and no excavation). Restore soil profile.
Estuarine fringe – (tidal flooding)	Eliminate levees, toe slope ditches, and/or groundwater pumping	Fill ditches	Restore surface elevations and slopes relative to reference wetland and onsite water levels (i.e., remove fill and no excavation).
Lacustrine fringe (wind seiche flooding)	Eliminate toe slope ditches and/or groundwater pumping	Fill ditches	Restore surface elevations and slopes relative to reference wetland and onsite water levels (i.e., remove fill and no excavation).

6.2.2 Soils

Restoring wetland soils:

- Ensure spatial variability of soils onsite
- Incorporate microtopography
- Amend soils with organic matter
- Restore soil texture and bulk density
- Improve soil fertility

Soils are often overlooked as a factor that may need restoration (Bruland and Richardson, 2005a; 2005b; 2005c; Richardson et al., 2016). The baseline assessment (Section 4.4) should have included a site verified soils map, soil profile descriptions, notation of hydric soil indicators, and impacts to soil integrity (e.g., tilling, plowing, bedding, land clearing, mining, fill, contaminants). Based on these findings, the mitigation workplan should address soil structure and fertility, in addition to the soil impacts noted. For instance, if the proposed site's soils have been disturbed by land uses that have either removed more than the top 12 inches of the soil or have disturbed and/or compacted the top 12 inches of the soil, then amelioration will have to be undertaken. Reference standard sites, with similar soil types, should be used to compare the proposed site's soils and address the impairment of the mitigation site soils in terms of bringing them back towards reference standard condition. Some important aspects of soil restoration to be considered are:

- Incorporate spatial variability in soil characteristics in order to promote diversity of ecosystem processes and vegetation patterns;
- Incorporate microtopography (similar in height and area to reference standard sites);
- Incorporate soil organic matter and organic amendments to site to improve plant survival, biogeochemical functions, and soil characteristics;
- Soil texture, bulk density, and compaction should be documented in relation to vegetation responses; and
- Soil nutrient concentrations and their availability in soils should be compared to reference standard sites.

These factors should be addressed along with the site's growing season hydrologic regime (Bruland and Richardson, 2005a; Bledsoe and Shear, 2000). Sites that have compacted soils will likely need to have the soils deep-ripped to allow water infiltration and provide a suitable rooting medium. In situations where soils have been excavated or lost due to generations of poor agricultural soil conservation practices, soils may require organic amendment (Bruland and Richardson, 2005c; Richardson et al., 2016).

One other aspect of wetland site design for any HGM class is incorporating topography to allow for hydrologic, soil, and vegetative variability. Particularly in riverine or floodplain wetlands, microtopographic complexity can aid in the wetland's ability to accommodate the varying flood flows and provide a diversity of hydrologic conditions for germination and establishment of plant species with variable flood and soil saturation tolerances. Microtopography, including shallow depressions and mounds caused by flood flow, tree tip-ups, sediment deposits, etc., occurs naturally in wetlands. Macro-topography also occurs naturally and refers to larger surficial features with deeper, more permanent water (e.g., oxbows, meander cut-offs, features that can be seen from aerial photography) (NRC, 2001). Vegetation requiring drier conditions can be planted on micro-highs, and those that can tolerate wetter conditions should be planted in lower elevations on the floodplain (Mitsch and Jorgensen, 2004). Floodplains are typically smoothed during major stream channel restoration projects to decrease roughness and the potential for flood forces to erode the floodplain. However, where wetland restoration is a goal, topographic relief is advantageous and should be incorporated into the plan. Efforts should be made to match the spatial pattern of microtopography (e.g., hummocks and hollows, tussocks) of reference standard wetlands in similar HGM subclasses in the region where the restoration occurs. This is especially important at former agricultural sites or other sites where human land-use has created artificially flat microtopographic conditions (Richardson et al., 2016; Bruland and Richardson, 2005a).

Long-term agricultural activity homogenizes the topsoil, which is most evident for attributes such as organic matter, nitrogen, and cation exchange capacity (Whisenant et al., 1995; Robertson et al., 1997; Gonzales et al., 2000) and often decreases, or eliminates, microtopography. Comparing the spatial distribution of soils in the proposed site against a reference standard site(s) is important since wetland physical environmental variability (which includes soils, soil organic matter, topography, and microclimate, etc.) and plant species richness are positively correlated (Jeltsch et al., 1998; Ettema and Wardle, 2002). More homogeneous soils in the proposed site than those of the reference standard site could be expected to also have lower diversity of soil biota in the vertical profile, which could hinder restoration. Efforts should be made to match the soil organic matter content of reference standard wetlands in similar HGM subclasses of the region where the restoration occurs. If no such information is available, then soil amendments should be considered if soil organic matter concentrations at the restoration site are <2.5% (Richardson et al., 2016; Bruland and Richardson, 2005c).

Methods to restore soil characteristics, heterogeneity, and microtopography should be evaluated based on their purpose, expected effect on the site, past effectiveness, and assumptions required in implementation. Thus, if soils on the proposed mitigation site have been scraped, excavated, filled, compacted, drained, subsided, or otherwise modified, the reviewer should look for evidence that the workplan includes measures to restore the soils to pre-disturbed conditions to foster appropriate biogeochemical processes and vegetation growth. If the soil on the proposed site appears intact, then additional work may not be needed.

6.2.3 Vegetation

After the hydrologic and soil conditions for a proposed site have been addressed to restore abiotic processes, the vegetation plan can be implemented. The reviewer should look for the sequencing of activities in the mitigation plan to ensure that the appropriate wetland hydrologic and soil regime are in place prior to planting.

Vegetation plans should be informed by baseline assessments (Section 4.4), the anticipated hydrology on site, and appropriate reference comparisons. A quantitative estimate of growing season hydroperiod in a normal, wet, and dry year should be used to show how the anticipated hydrology of the mitigation site will be appropriate for the plant assemblage proposed and should be compared to reference. The planting plan should be based on reference standard conditions and not just jurisdictional criteria. Most workplans will include vegetation re-establishment plans and plant lists, and most USACE Districts have specific criteria for species composition, density, and survival. In addition to what each District may require in vegetation planting plans, vegetation should also be planted, or allowed to volunteer, to reflect communities inventoried at reference sites of the same HGM class, hydrologic regime, and soil type, but at various successional stages. If an HGM regional guidebook is utilized to assess baseline conditions, and the proposed site is within the reference domain of the regional guidebook, the reference vegetation list can be used as a guide to determine if the workplan's plant list is appropriate for the target condition. If an HGM regional guidebook does not cover the area, or the wetland type being proposed for restoration, then an appropriate reference site(s) should be evaluated to determine the appropriate species mix and the edaphic conditions under which they occur.

Site vegetation plans should account for planting locations of different plant species along the moisture gradient of the site, which often controls successful species reestablishment, including invasive species reintroductions (Ho and Richardson, 2013). These gradients typically correspond to the elevational gradient of the site (i.e., drier species planted at higher, and wetter species on lower elevations) (Galatowisch and Zedler, 2014). Plans should also identify the source of plant material, as plant nurseries closer to the mitigation site will likely have stock acclimated to local conditions or be able to propagate and grow appropriate species under contract. If there is evidence of natural regeneration of desired species, then replanting at a high density may not be necessary. Site plans should also account for either the presence of, or the potential for, invasive plant species. Invasive species can cause substantial problems (e.g., Connell and Slayter, 1977; Klotzli and Grootjans, 2001; Suding et al., 2004). Most effective controls are to remove new populations while small and manageable and before they spread. If invasive plants are present on the site, they will need to be controlled before planting desired vegetation can occur. Any potential method (listed below) for revegetation should be evaluated as above (i.e., purpose, rationale, effectiveness, and assumptions).

Site vegetation plans should also identify proactive measures necessary to facilitate survival and growth of planted vegetation. Both providers and reviewers often assume that simply planting desired vegetation sets up deterministic succession of the plant community that follow trajectories over time leading to conditions representative of a reference ecosystem. However, this assumption of simple and predictable restoration trajectories is unrealistic (Matthews et al., 2009) and unsupported by numerous successional case studies (e.g., Matthews, 1979; Christensen & Peet, 1984; del Moral, 2007). Careful oversight and proactive maintenance (e.g., mowing, herbicide application, invasive species control, re-planting) may be critically important to ensure that the target vegetative community has a reasonable chance of becoming reality. Reviewers should ensure that appropriate site preparation and post-planting maintenance is part of the mitigation plan (see Section 8.2).

Potential methods to restore wetland vegetation include:

- Seeding – collecting seeds from multiple wetlands for genetic diversity;
- Direct planting – availability and location of planting stock; species selection based on presence in reference wetlands and probability that they will establish in the restored site;
- Controlling invasives (depends on biology of invasive)- herbicides, annual removal of individuals, mowing, prescribed burning, and sometimes flooding (e.g., flooding cattails after they have been cut down to stubble may reduce populations); and
- Natural regeneration.

6.3 Stream Design and Implementation to Achieve Target Conditions

A plan for stream mitigation should be based on the results of the watershed and baseline assessments that identify the stressors which affect stream processes (Sections 4.2 and 4.5) and the goals and objectives of the project (Section 5.2). It is important for the provider to incorporate, and the reviewer to understand, how the proposed methods and/or design adequately address the problems with the stream. Hydrology (surface and groundwater flows), hydraulics (energy, shear stresses, sediment), and geomorphology (channel conditions, habitat) are the fundamental stream processes that must be considered in a stream design. Where project objectives relate to improvement of physicochemical and biological functions, reviewers should ensure that workplan elements address degradation of the supporting stream processes.

There are different methods and techniques which can be used to restore impaired stream processes, for instance allowing the stream to self-heal (Kondolf, 2011) or stabilizing stream banks and channel bottoms to prevent bank erosion (Yochum, 2016; Bledsoe et al., 2016; Skidmore et al., 2011; Saldi-Caromile et al., 2004). Stream restoration may be implemented at any scale, ranging from removal of a single passage barrier (e.g., a culvert) to alteration of watershed-wide land use practices (e.g., planting cover crops on agricultural land, stormwater retention in urban areas). As with wetland mitigation plans, stream mitigation providers should provide a discussion/explanation of the purpose, rationale, effectiveness, and assumptions and constraints of any and all proposed method(s). This is particularly important in stream restoration since numerous criticisms have been levied against many aspects of stream restoration and mitigation, including specific stream restoration methods themselves (e.g., Simon et al., 2007), project documentation and record keeping (e.g., Bernhardt et al., 2005; Roni et al., 2008; Miller et al., 2010; Palmer and Hondula, 2014) and project efficacy in terms of both physical stability (e.g., Miller and Kochel, 2010; Palmer et al., 2014) and biological community restoration (e.g., Roni et al., 2008; Palmer et al., 2009; Ernst et al., 2012; Palmer et al., 2014). For example, NCD (Rosgen, 1996), has been criticized as over-simplifying the complexity of fluvial systems (Doyle et al., 1999; Kondolf, 2006; Simon et al., 2007), and there are considerable questions regarding the efficacy of NCD as an appropriate stream restoration technique (Juracek and Fitzpatrick, 2007; Lave, 2009). Although these criticisms have validity, mitigation to offset authorized stream impacts is a fundamental component of the CWA Section 404 program, and regulatory agencies must make the most informed decisions possible to ensure that proposed mitigation projects not only comply with the Mitigation Rule and remain consistent with its fundamental tenets, but also produce ecologically sustainable projects. Reviewers should ask appropriate and pertinent questions of any stream mitigation proposal to determine its ability (if implemented appropriately) to rectify stream impairment and provide adequate mitigation.

Mitigation strategies and design approaches may consist of one, or many, restoration actions that rely on multiple lines of evidence (reference, empirical equations, analytical methods, etc.) to address the problems identified in the baseline condition assessment Ideally, individual actions will address root causes of identified problems at the appropriate scale. Site-specific disturbances may be remedied on small scales; systemic disequilibrium and watershed-scale causes of stream degradation generally require watershed-wide restoration activities to yield measurable benefits. When mitigation actions include land disturbance as part of construction (e.g., mechanized grading), each action (i.e., each distinct project component) needs to be well documented, rationalized, informed by objective reference approaches, and carefully designed.

Typically, stream mitigation plans are submitted with relatively complete stream designs (e.g., 60% designs), accompanied by geomorphic data relating to anticipated stream pattern, profile and channel cross-sectional geometry. Mitigation workplans may involve methods to restore hydrologic connectivity (i.e., longitudinal, lateral, vertical and temporal connectivity); address channel stability (e.g., through various bank stabilization techniques); reconnect channels and floodplains; remove barriers; adjust planform and channel geometry; and add, modify or remove instream structures, among others.

Documentation of the reference approach, restoration techniques, and/or associated design elements should be presented in the mitigation plan to allow the full review of how the mitigation plan addresses impairments and achieves the objectives of the project (Box H). Stream mitigation plans will often be comprised of a variety of project elements which, in total, represent the provider’s plan for addressing the stressors acting on the project site and restoring ecological functions (e.g., through the establishment of longitudinal, lateral, vertical, and temporal connectivity of the stream to its watershed). To evaluate a proposed plan, it may be useful for reviewers to break the plan down into its component parts to determine how the project elements contribute to addressing the stressors and objectives of the project. The following discussion elucidates some aspects of stream hydrologic, hydraulic, geomorphic, physicochemical, and biological restoration for the reviewer to consider. It is not inclusive of all possible techniques but should provide the reviewer with some basic information to discuss with the provider and as context for review of the appropriateness and completeness of a stream mitigation plan. For more detailed information about stream restoration project review, see Skidmore et al. (2011), Bledsoe et al. (2016), Yochum (2016), Cramer et al. (2012), Roni and Beechie (2013), USDA NRCS (2007) and FISWRG (2001).

Box H. Recommended information to address appropriateness of stream mitigation plan/design.

Addressing the following questions should be done in the context of the mitigation site's classification (Section 3), baseline watershed and site assessment (Section 4), and the goals and objectives for the project (Section 5):

Hydrologic

- From what type of hydrologic data were design flows derived (e.g., gauge, ungauged, models, equations)?
- Are impairments to hydrologic connectivity of the stream reach addressed in the mitigation plan? Including:
    - Longitudinal connectivity (e.g., dams, weirs, road crossings, and culverts)
    - Lateral connectivity (e.g., levees, floodplain development)
    - Vertical connectivity (e.g., hyporheic exchange)
- Is the project reach experiencing hydrologic flashiness (based on assessment of contributing watershed imperviousness)?
- Do the methods proposed address the current condition of the stream's low, bankfull and flood flows?
- Will the proposed methods restore the timing, magnitude, frequency, and duration of surface and/or groundwater flows typical for this stream type where these conditions are impaired?

Hydraulic

- What methods were used to address the hydraulics of the reference reach? Were the same methods used for the designed reach?
- Has the provider accounted for expected sediment flows into and out of the project reach under the full range of flow conditions (i.e., low, bankfull, and flood flows)?
- If the provider set a goal of equilibrium conditions, how have they accounted for the hydraulic and sediment capacity and supply conditions upon which the design to achieve equilibrium is based (e.g., modelling)?
- If the provider has NOT set a goal of equilibrium conditions in the project reach, how have they accounted for sediment capacity and supply through the reach (i.e., sediment storage on the floodplain)?
- If the project reach is incised how, and to what extent, will the provider reconnect the floodplain?

Geomorphic

- What methods are proposed to address degradation of the stream's vertical and lateral stability?
- Will channel reconfiguration (planform, slope, and cross-sectional geometry) be required? Has sufficient justification for it been included by the provider?
    - If so, has the provider supplied adequate rationale for using this method?
    - Have the risks associated with this method been evaluated?
- Will bed materials be replaced? If so:
    - With what will they be replaced?
    - What is the rationale for, and the risks associated with, using this method?
- Will streambanks require protection? If so:
    - How will they be protected?
    - What is the rationale for the methods that will be used?
    - Have the risks associated with the methods chosen been considered?
- Will instream structures be used?
    - For what purpose?
    - Have the risks associated with how the structures will affect stream processes been considered?
- Were other less physically disturbing methods to the ecosystem evaluated and justifiably determined inappropriate for the project?

Physicochemical

- Will the methods chosen for other aspects of the project (e.g., hydrology, hydraulics, geomorphology) potentially affect the water quality of the project reach and/or upstream or downstream reaches?
- Are there specific actions proposed to ameliorate on-site or off-site sources of adverse water quality? If so, are the actions/methods rational and likely to succeed?

Biological

- Riparian Vegetation
    - Will planting riparian vegetation be necessary? If so:
        - Is species composition and spatial placement (with regards to hydroregime) appropriate when compared to appropriate reference?
        - Are planting methods and timing appropriate?
        - Are the appropriate species planted in appropriate zones?
- Instream Habitat:
    - Will large wood or instream structures be required for habitat?
    - Have the risks and effects on stream processes associated with creating habitat with structures, been evaluated?
    - Have sufficient intact populations of biota been identified near the project area?

6.3.1 Addressing Hydrologic Connectivity

Connectivity within watersheds is critical for the transport for water, sediment, organic matter, nutrients, and organisms. Longitudinal, lateral, and vertical hydrologic connectivity (i.e., the ability of water to flow freely from upstream to downstream, flow into and out of a floodplain during flood events, and groundwater to flow to the channel during low flows) is critical to ecologic functioning of streams (EPA 2015). In Section 4.5.2.1, aspects of a baseline hydrologic assessment were outlined including data sources (gauged and ungauged sites); flow estimation; important flows needing assessment; and common watershed and reach scale stressors which can affect the magnitude, frequency, timing and duration of flood, and low and bankfull flows (Table 11). Hydrologic information for the workplan and the stream design, if one is planned, should be consistent with that gathered for the baseline assessment.

Longitudinal connectivity restoration often entails the removal of barriers. This could involve removal or modification of dams, weirs, pipeline crossings, bridges, road crossings, culverts, or other infrastructure. If removal of a barrier is proposed, the mitigation plan should also address anticipated changes to channel morphology, stream hydrology and hydraulics, sediment properties and transport, groundwater quality and quantity, instream habitat, floodplain vegetation, and instream biota. When evaluating a draft workplan, reviewers should focus on the stream impairment, its remedy, how and why any proposed method will be used, and the anticipated effects up- and downstream. Reviewers should also be aware of unintended consequences with some restoration methods, such as the propensity for exposed sediments behind former dams to be rapidly colonized by non-native plant species in the absence of diligent management, or the change in the channel bed slope and stream power causing the stream to quickly erode sediments, evolve to an incised stage, and eventually lose contact with its floodplain.

Lateral connectivity, or floodplain reconnection (discussed in Section 6.3.2), is the restoration of the lateral hydrologic connection between the channel and floodplain, allowing for overbank inundation and infiltration to support riparian groundwater tables, among other processes. Natural floodplains can be important nutrient and sediment sinks, a function which is often lost as floodplain-channel connections are severed via channelization, incision, or levee construction. Hydrologic reconnection of floodplains and streams can be achieved by lowering stream banks, removing or breaching levees, raising the channel bed, increasing wood recruitment and log-jam formation, removing infrastructure from floodplains, and/or complete channel reconstruction (e.g., Priority 1 restoration under NCD) or valley restoration.

Vertical connectivity, or the interactions between hyporheic and groundwater flows and surface water, should be considered for habitat design and baseflow maintenance. Sub-surface flow conditions can be characterized through measurement and/or modeling. In some cases, simply identifying the variation in groundwater stage throughout the year may be enough to inform project design. Basic groundwater/hyporheic information can be obtained through installation and monitoring of piezometers or through pump tests (Cramer et al., 2012).

Hydrologic investigations are used to establish design flows (e.g., baseflow, bankfull discharge, flood flows), which serve as the basis for design of channel, habitat, and floodplain components. Hydrologic analyses are foundational in stream restoration design, as virtually every other design analysis requires the input of design discharge(s). Design criteria for various aspects of any project may be defined relative to specified flows extracted from the hydrologic analyses, such as channel-forming flow for channel dimensions, base flow for instream habitat, and flood flow for channel stabilization structures (Skidmore et al., 2011). Flow statistics such as mean low flow (e.g., to determine extent of the low-flow habitat and habitat design), the 100-year flow (e.g., to determine flood inundation risk and channel stability), maximum peak flows for any given month (e.g., to determine risk of inundation during construction months), or minimum flows for any given month (e.g., for passage design), can be statistically derived from existing gauge data or by modeling streamflows from precipitation records to develop a synthetic flow record (Fischenich and McKay, 2011).

The baseline assessment (Section 4.5.2.1) should document hydrologic stressors that affected the movement of streamflows downstream and/or interacting with the floodplain as surface and ground water; and characterize the magnitude, frequency, duration, and timing of current flow(s) that inundates the floodplain of the mitigation project site, along with the shear stress on the channel bed and banks that correspond to that flow. Based on those results, the reviewer should evaluate whether the workplan and/or design accommodates the range of flows delivered from the watershed and the ability of those flows to connect and/or maintain up- and downstream, floodplain and hyporheic habitats.

6.3.2 Addressing Hydraulics and Sediment Transport

For many stream mitigation projects, hydraulics analysis is a critical component of the design phase, and it is necessary to understand existing conditions and the potential effects of proposed designs. The purpose of hydraulic design analysis is to assess flow velocity and channel boundary shear stress, the degree to which the channel is connected hydraulically to the floodplain (water surface profile), and the sediment transport capacity (stream power) through the project reach relative to upstream and downstream reaches.

In watersheds with increasing amounts of impervious surface, the magnitude and velocities of stormflow runoff increases and the timing (delivery) of that runoff decreases. Termed hydrologic flashiness, these flows can occur more frequently and exert greater shear stress which affect sediment flows, channel stability, biological communities, and other stream functions. Often, providers will only assess the bankfull discharge as the flow that moves the most sediment over time. However, in flashy watersheds, frequent stormflow runoff of higher velocities and shear stresses can move more sediment, both in the channel and from source areas, than what might be indicated by only an analysis of bankfull flows (Bledsoe et al., 2017). Providers and reviewers will need to ascertain whether the effects of watershed land use on water and sediment flows have been accounted for in the mitigation workplan, lest these flashy flows undo the work of the provider.

The baseline assessment (Section 4.5.2.2) is meant to identify potential hydraulic and sediment transport problems needing to be addressed, and provides basic information on sediment sources, stressors affecting sediment transport, and the potential for a project reach to experience increased sediment supply via channel evolution. It bears reiteration that the provider will need to identify potential sources of sediment upstream of the site and in connected portions of the watershed (i.e., areas which have conduits for the transport of sediment to the project reach), as well as the characteristics of the sediment likely to be generated at the site, as each of these sources has potential to affect the project design.

Reviewers should consider the methods used to estimate the hydraulics of the channel, floodplain, and up- and downstream reaches; the effects of channel evolution on future water surface elevations, floods, and sediment transport; and the effect of the project on the channel hydraulics up- and downstream of the site. Any models (e.g., WinXSPro, HEC-RAS, HEC-RAS2-D, or Flow 3D) used should be justified and explained in the context of the proposed project. For any methods used to evaluate sediment capacity and supply, the reviewer should have sufficient information to:

- Understand the range of sediment sizes expected to move into the project reach;
- Understand the range of flow conditions necessary to move the expected sediment load (i.e., pulsed flow conditions) through the reach or onto the floodplain;
- Identify sources of the sediment from the upstream watershed;
- Understand the implications of the proposed design on the sediment capacity of downstream channel reaches and its potential effects on downstream infrastructure and/or property owners; and
- Understand how the workplan and/or design account for these conditions.

It is important for the provider to identify channel and floodplain dimensions that will accommodate anticipated streamflows without mobilizing channel bed or floodplain substrates to such an extent that channel incision, bank erosion, and avulsion, etc., ensues. Likewise, it is important for the provider to ensure that the sediment capacity in the project reach is sufficient to move the anticipated sediment supply. In other words, project design should maintain stream equilibrium. Velocities and shear stresses that exceed the ability of the bed and bank material to withstand erosion (i.e., competence) will likely result in instability. The range of flow velocities, shear stresses, and/or stream powers for the 2-year to 100-year recurrence interval peak flow events (i.e., 2, 5, 10, 25, 50, 100-year) should be estimated for the channel and floodplain to understand the effects of higher shear stress events on the channel bed, banks, floodplain, and connected sediment sources.

Sediment analyses are used to determine whether sediment transport capacity is balanced with sediment supply. Sediment transport models (e.g., HEC-RAS, BAGS, and POWERSED) can be useful for examining the gross magnitude of sediment that may pass through, be eroded from, and/or stored in a stream reach. They may also be helpful in identifying causes of channel instability and for evaluating the performance of varying design scenarios. However, a high level of knowledge and experience is typically required to effectively collect appropriate sediment transport data, understand the modeling processes, effectively apply sediment transport models and interpret the results in a useful way (Wilcock et al., 2009). A provider may use a sediment transport model to provide evidence of the ability of a reach to move sediment loads. As a reviewer, if sediment transport models are used, be sure that analysis and interpretation of the results are adequately explained in terms of how the results affect the objectives of the proposed design, streamflows, channel conditions, and sediment transport.

Floodplain connection and incised channel restoration

Channel incision and projects proposing to remedy incision are common in the southeastern U.S. Channel incision reduces interaction between the stream and its floodplain, reduces spatial habitat heterogeneity, increases temporal instability, reduces hydraulic retention, degrades water quality, enlarges stream channels, and shifts the fish community structure (Doll et al., 2016). Floodplain reconnection and restoration of incised channels are restoration techniques that affect hydraulic and sediment transport functions. Floodplain reconnection is the restoration of the hydrologic connection between the channel and floodplain, allowing for overbank inundation and elevated riparian groundwater tables (i.e., lateral connectivity). Channel and floodplain processes are integrated and connected floodplains store flood waters and sediment carried by the stream during out-of-bank events, as well as allowing for raised riparian groundwater tables by recharging local shallow groundwater.

Generally, three restoration approaches are used to address incised channels and re-establish hydrologic and hydraulic connectivity through floodplain reconnection (Roni and Beechie, 2013; Skidmore et al., 2011). Site conditions, project goals and objectives, and physical constraints will determine which of these approaches is most feasible. For all approaches, additional space for the channel and riparian zone should be incorporated into design and ongoing land management. These approaches include:

- Lowering the abandoned floodplain (i.e., terrace) to an elevation that allows hydraulic and sediment coupling with streamflow in the existing incised channel.
- Raising the streambed to its pre-incision elevation to restore hydraulic and sediment coupling with the existing floodplain.
- Relocating the channel within the floodplain at the desired bed elevation to allow hydraulic and sediment coupling with the floodplain.

Because of its importance to hydrologic and hydraulic processes, where possible, floodplain reconnection should be incorporated into all stream designs unless justifiable rationale is provided to explain why it cannot be accomplished (e.g., valley confinement, property ownership constraints, adjacent infrastructure). Whatever the approach, floodplain reconnection tends to raise the riparian groundwater table and allow for more frequent overbank flows. This increases sediment and nutrient retention and processing while providing ancillary benefits such as enhanced aquatic and riparian habitat, reduced in-channel erosive power and downstream flooding, and increased aquifer recharge.

From a hydraulic and sediment standpoint, workplans proposing floodplain lowering or reconnection should contain provisions addressing the risk of stream avulsion (i.e., the formation of a new (and unexpected) stream channel across a floodplain due to erosive flows during a flood event). Reviewers should be aware that risk of avulsion can be minimized by establishing floodplain plantings 1-2 years prior to reconnecting the channel to the floodplain, using erosion control measures to ensure floodwaters do not cause avulsion, and/or use of grade control at streambed grade to protect against incision should avulsion occur (i.e., vertical control across the floodplain valley) (Skidmore et al., 2011; Cramer et al., 2012).

If a stream has incised because its base level has been permanently lowered (such as in a tributary where the downstream main river system has lowered its bed) or due to a fundamental change in the flow and/or sediment regimes (common in urbanized and agricultural watersheds), restoring the bed elevation to its former or pre-disturbed condition may be impractical. In such cases, excavating the abandoned floodplain (terrace) to a lower elevation that allows recoupling with the incised stream channel may be effective. This essentially accelerates the channel evolution process, whereby channels first incise, then migrate laterally, eroding into the abandoned floodplain, and ultimately create new floodplain surfaces at elevations adjusted to the new channel elevation.

Baseline data on groundwater levels within the floodplain should be considered in the workplan and design so the new floodplain is constructed at an elevation consistent with the groundwater table, based upon targets established in the project objectives. In some instances, reference wetland and/or anastomosed stream Stage 1 or 8 (SEM) streams may inform the new floodplain and groundwater level proposed in the project design.

6.3.3 Addressing Channel Geomorphic Processes

Most stream mitigation plans contain designs and construction elements to address geomorphic stressors or to address the channel condition caused by stressors (e.g., increased flow velocities from impervious surfaces or decreased sediment loads that lead to channel incision). Baseline assessments (Section 4.5.2.3) characterize existing channel morphology and planform, bedform diversity, aggradational or degradational status, and channel stability; and identify the stressors leading to vertical and lateral instability in the context of appropriate reference standard condition.

Stream geomorphic designs are often based on the idea that natural alluvial channels tend to evolve toward a condition where channel form and dimensions are adjusted to flow and sediment regimes. Identifying the channel form that is appropriate and stable for the valley setting and the bed and bank materials, while maintaining equilibrium, is challenging (Skidmore et al., 2011), especially in watersheds with changing land use patterns. As such, it is important that appropriate reference comparisons (Section 5.3.1) are used to inform the design of channels.

To briefly reiterate from Section 5.3.1., analog design approaches can be applied at any scale (e.g., from multiple reaches down to site-specific features), since fundamentally they represent a known condition. However, the assumptions inherent in the analog approach, acknowledged or not, are that the reference reach itself is in equilibrium and is representative of flow, sediment, and boundary conditions at the project site (Bledsoe et al., 2017; Rosgen, 2006; Skidmore et al., 2011). Empirical equations require similar assumptions as the analog approach; and analytical models, if used, can simulate past, current, future, or synthetic (i.e., scenario-based) conditions to augment the design of target stream geometry during the design process (Miller et al., 2012). A combination of these reference approaches may be prudent to support a particular design.

Efforts to address channel geomorphic processes often involve channel or streambank construction or reconstruction, including bed and bank stabilization, instream enhancement (e.g., habitat, increased hyporheic exchange and water retention time), floodplain reconnection, channel reconfiguration, and barrier removal. Typically, a project design will include one or more of these project elements. When evaluating project elements in a workplan, reviewers should consider whether each element has the capacity to meet project objectives, alleviate stressors and allow or promote stream processes that support and maintain the stream system. Reviewers should ensure that workplans explain details of the design approach and included project elements in terms of how the approach addresses the problems affecting the stream (i.e., watershed stressors vs. local stressors). This discussion should also describe the technical basis for the approach, discuss how assumptions of equilibrium are met in analog reference, discuss confidence intervals associated with empirical equations, and explain any assumptions and levels of uncertainty in the chosen approach(es). To adequately address the complexity of stream restoration projects, it is prudent for providers to include people with engineering, geomorphology, hydrology, hydraulic, stream ecology and biology expertise on their design teams.

While a comprehensive discussion of design is beyond the scope of this document, design elements will need to be carefully considered to anticipate the level of interaction of the reconstructed channel with the flows of water, sediments, nutrients, and organic matter coming from the project reach as well as the upstream watershed. Project elements are the distinct project components (e.g., stream pattern, slope, cross-sectional geometry, and instream structures) that can be designed independently, but together comprise a complete project design. The information below provides a brief discussion of some common project elements which may be included in a workplan and suggestions on how to evaluate those elements (after Skidmore et al., 2011; Roni and Beechie, 2013; Cramer et al., 2012; USDA NRCS, 2007; Bledsoe et al., 2016).

Channel Reconfiguration

Channel reconfiguration is generally defined as significant realignment or complete channel reconstruction to provide a more appropriate channel geometry and planform (Bledsoe et al., 2016). Channel reconfiguration may entail reconnection of a historically abandoned channel, partial channel realignment or complete construction of a new channel (e.g., NCD Priority 1 or 2 restoration). This method is especially valuable in areas with a significantly altered channel geometry and planform (e.g., from channelization) where more passive approaches aimed at restoring natural erosion and depositional processes may not be viable at required time scales. Channel reconfiguration can decrease velocities by reducing slope and increasing sinuosity and is typically accompanied by other stream restoration strategies such as erosion protection and installation of in-stream structures. However, channel reconfiguration may not always be necessary, and in some cases less intensive restoration strategies may provide acceptable results with fewer risks.

Depending on project objectives and the geomorphic context of the reach, modification of the channel may be an appropriate method to accelerate recovery of a sustainable natural channel and floodplain. This is typically accomplished by relocating the existing channel or by modifying channel:

- Planform (the shape/pattern of a channel in map view; planform is defined by sinuosity and meander characteristics),
- Cross-section (the shape, width, and depth of a channel from bank to bank and across the floodplain), and
- Longitudinal profile (the elevation, slope, and shape/pattern along the channel bed).

Planform, cross-section, and profile are integrated and mutually adjusting features. Thus, altering one will affect the others, and alteration of any of these typically results in a change in the hydraulic and sediment transport characteristics of the channel. As such, reviewers should carefully consider proposals to reconfigure channels, as hydraulic responses can be complex. Design considerations for, and risks associated with, each of these elements in the context of channel reconfiguration are discussed below.

Planform: Planform design can be approached using analog, empirical, or analytical methods, or any combination of these reference approaches. Planform is directly related to valley slope and channel slope, as changes to planform affect channel length and channel slope is a function of channel length. As such, planform must be designed in conjunction with channel slope (see discussion of longitudinal profile below).

A critical planform parameter in meandering channels is the ratio between the bend radius of curvature (Rc) and the channel width (W) (USDA NRCS, 2007). In general, when the meander ratio (Rc/W) is between 2.0 and 3.0, meanders operate most efficiently (in terms of energy loss) and tend to migrate rapidly downstream without changing their shape substantially (Skidmore et al., 2011; Harman, pers comm; Jennings, pers comm). Naturally, this meander ratio incorporates the effects of riparian and bank stabilizing vegetation. However, for newly restored stream channels that have relatively nonresistant, unvegetated streambanks immediately following construction, designing and constructing meander bends within this ratio range will likely be riskier and increase the probability that rates of bend migration may be unnaturally high before vegetation has fully colonized the banks and riparian corridor.

Risk of accelerated bend migration often prompts providers to artificially harden the outer banks in constructed bends. Hardening the outer margins of meander bends, whether with rock or rootwads, may be helpful in maintaining a desirable initial cross-section and planform, but such reinforcement can constrain natural bend migration processes by preventing all bank erosion. If the goal of a stream mitigation project is to restore dynamic alluvial processes, then hardening the banks may run counter to that goal. In circumstances where the risk of bend migration immediately following construction and prior to the establishment of a well vegetated riparian corridor is unacceptable, biodegradable materials and deformable bank construction techniques (e.g., coir fabric encapsulated soil lifts) can be used to protect channel bends for a limited number of years following project completion while riparian vegetation takes root. After the riparian vegetation takes hold and begins to mature, it can provide natural stability to the banks (Miller and Skidmore, 1998). Regardless, planform design elements and long-term land management plans should incorporate additional space for the channel and riparian zone to allow the channel to eventually resume meandering across its floodplain.

Channel cross-sectional geometry: Changing a channel's cross-section involves altering its width, depth, or shape across the channel, and can include modification of channel banks and bars. Cross-section modifications are most commonly applied to the main channel but could also include modifications of floodplain elevations or features. Channel slope is an integral component of cross-section design, as the target flow capacity of a channel is determined by the relationship of cross-sectional area and channel slope.

Design criteria for channel geometry parameters generally relate to the channel-forming discharge and express the allowable or desirable range of variation in dimensions, so that the constructed channel is not unnaturally uniform. Allowing for variation of width and depth throughout the reach while still accommodating the channel forming flow, will provide habitat variability as well.

Within an alluvial channel, the shape of the cross-section varies with position in the planform. For example, the cross-section at the apex of a meander bend is typically triangular and asymmetrical, with a deep pool adjacent to the outer bank, while the cross-section at riffles is more trapezoidal and symmetrical. Hence in designing an alluvial channel, providers commonly provide a minimum of three cross-sectional templates corresponding to pools, riffles, and transitional reaches. While the width, mean depth, maximum depth, and asymmetry vary between templates, all should be sized to contain the channel-forming discharge.

Risks associated with designing channel cross-sections are related to the channel's capacity to maintain equilibrium conditions and the ability of the channel to carry target flows and associated sediment loads without causing channel aggradation or degradation. This requires careful adjustment of design channel widths and depths. Channels with similar cross-sectional areas may transport water and sediment flows differently depending on their width and depth ratios. For instance, channels that are wide and shallow may experience aggradation as these channels tend to allow water velocities, and subsequent sediment capacity, to decrease. On the other hand, channels that have narrow widths and greater depths may allow larger flows to remain in the channel thus increasing shear stresses on stream bed and banks and inducing degradation. Both of these channel types may have the same cross-sectional area, therefore reviewers should carefully consider designed channel widths and depths in relation to channel slope to confirm the channel cross-sectional geometry will achieve the target flow conditions.

Longitudinal profile/channel slope: Longitudinal profiles characterize the slope of the channel bed and the variation of that slope through a reach. The slope of a channel is the ratio of change in elevation to distance along the channel, often but not always represented as a percentage. Channel slope will change as a result of any activity that changes the bed elevation at a point or changes the length of channel between two constant elevation points. Channel slope varies among specific bed form features (e.g., riffles vs. pools), and thus characterizes bedform diversity, including the pattern and lengths of important habitat elements (e.g., steps, riffles, runs and pools).

Channel slope is highly integrated with project elements concerned with planform pattern and cross-section dimensions. These three elements together define the three-dimensional geometry of the channel. Slope, cross-section, and planform project elements should be iteratively manipulated to achieve the desired balance between the sediment supply from upstream and the sediment transport capacity of the project reach. Slope is a driving parameter in this regard and must be carefully adjusted to achieve the desired balance between transport capacity and upstream supply over a range of design discharges.

Risks related to modification of channel slope determines whether grade control or stabilization of the channel slope is necessary. Grade control is commonly incorporated in project design to ensure that the design slope is maintained during the period following construction when the new channel is vulnerable to floods and to guard against possible future channel instability associated with post-project slope adjustments. In situations where the risk of channel slope change is unacceptably high, regularly spaced grade controls are commonly featured. However, a provider may be able to avoid using grade control if the alluvial project channel is adequately designed to be in dynamic equilibrium where the channel neither aggrades nor degrades.

Where grade control is unavoidable, design should focus on ensuring the stability of structures by installing their foundation materials at or below the maximum depth of scour and beyond the extent of possible lateral channel migration that might flank the structure. The possibility of a channel avulsing and bypassing the structure should also be assessed. In many circumstances, it may be impracticable to constrain the channel laterally so that it cannot flank the grade control structure, because it would be necessary to install grade control across a significant proportion of the width of the floodplain. Grade control structures can limit future adjustments of the channel and act as barriers to the passage of fish or other wildlife; these risks must also be considered and reduced to an acceptable level. Reviewers need to be aware of the balance between planform, cross-sectional geometry and channel slope to the extent that modifying one will impact the others. Channel reconfiguration raises risks to the stream system within, above and below the project reach, which should also be discussed with the provider.

Bed materials: In stable (equilibrium) alluvial systems, bed material is mobilized during flows approximating bankfull flow. In most stream restoration projects, the sizes of existing sediments making up bed surface and substrate materials should be compared to the sizes that will be mobilized under design flows (see Sections 6.3.1 and 6.3.2 on Hydrology and Hydraulics design considerations). If the provider's incipient motion calculations indicate that a different size of bed material is appropriate (i.e., under design flows), it may be necessary to either use appropriately sized bed material or reconfigure the design channel geometry to achieve the incipient motion conditions desired.

Risks of having inappropriately sized bed material for the project's flow regime may result in an imbalance between sediment supply and transport capacity which in turn may result in aggradation or degradation, or excessive rates of lateral shifting. Either circumstance will result in channel instability, and likely degraded habitat. In situations where gravel may have to be imported to the site, providers and reviewers need to be aware of the source of the imported bed material. In some cases, imported sediment may contain seeds of invasive or undesirable plants. Imported bed material from non-fluvial sources is also likely to be more mobile at project design flows than the same gradation of gravel that has been transported, sorted, and deposited by flowing water.

Streambanks and Lateral stability

Streambank stabilization refers to actions taken to prevent mass failure or further erosion of streambanks by slowing the bank erosional processes or entraining bank materials. Bank stabilization is commonly proposed to reduce sedimentation in the channel resulting from apparently excessive bank erosion rates or to protect further loss of property adjacent to the stream. Long-term bank stabilization may be desirable to protect infrastructure that cannot be relocated out of the zone of lateral migration. In these cases, reviewers should ensure that an appropriate design flow and maintenance schedule is specified within the design criteria to reduce the erosion risk to infrastructure to an acceptable level.

Risks associated with streambank stabilization are similar to those discussed in planform design. In situations where adjacent floodplain area is available, the ideal design objective would be to allow for project stream banks to be free to migrate in the context of a channel in equilibrium (e.g., bank migration at moderate rates under channel-forming flows). However, newly constructed stream banks formed in unvegetated alluvium are prone to erosion, so bank design criteria often include temporary bank protection to stabilize banks immediately after construction and specify the period of time necessary to allow riparian vegetation to mature and provide natural bank protection.

Many restoration designs involve discontinuous bank protection using structures installed at intervals along the bank line that extend into the channel to deflect flow away from the bank (e.g., j-hooks, barbs, and bendway weirs). Various designs for these structures may create and maintain pool habitat through scour processes and accumulate sediment along the protected bank. Some designs may incorporate large wood or other porous features that provide added value of refuge and may trap additional wood and organic debris. While the use of discontinuous structures for bank protection can be advantageous for habitat and sediment processes, these structures may constrain lateral channel movement and natural planform adjustments if overdesigned or built from nonbiodegradable materials.

Reviewers need to be aware that, in general, over-stabilization of streambanks and the planform pattern limits the functional capacity within a stream, including limiting the ability to sustain and renew habitat, and limiting downstream sediment input and wood recruitment from retreating banks. On the other hand, failure to provide adequate temporary protection may expose a newly constructed channel to severe erosion by even moderate flows with unacceptable risks to the project. Reviewers should encourage the use of native materials when bank protection is warranted. For instance, large rock structures should not be used for streams in the Coastal Plain, but rather wood structures might be more appropriate.

Instream Structures

Instream structures are modifications within the stream channel that increase geomorphic complexity and/or vertical channel stability, encourage hyporheic exchange and/or enhance aquatic habitat. Structures vary widely and can include j-hooks, cross-vanes, constructed riffles, and log jams which are similar to those installed for bed and bank stabilization. A common symptom of stream degradation is simplification of the channel and associated loss of aquatic habitat. Many stream restoration projects attempt to increase geomorphic complexity via installation of structures. Structures are placed in a stream or floodplain to improve habitat where it is deficient or for stabilization of the streambed or banks. Placed structures are often intended to serve as analogs to otherwise naturally occurring features. Structures are most appropriate in streams with significant human alteration where natural functions are impaired and are unable to create adequate habitats on their own.

Generally, instream structures will influence stream processes and habitat by controlling or limiting vertical erosion or incision (i.e., grade control) by stabilizing the channel profile, controlling sediment supply or inducing aggradation; controlling or limiting lateral erosion by offering bank protection (discussed previously above); creating or modifying habitat by inducing local scour or promoting hydraulic diversity; and/or modifying flow conditions to direct or converge flow to create desired habitat conditions or protect property or infrastructure (Cramer et al., 2012). Reviewers should be aware of the risks associated with any in-stream structure, which may also affect the hydraulics and geomorphology of the channel. Miller and Kochel (2009) found that approximately 30% of the in-stream structures assessed in 26 reconfigured stream reaches in North Carolina exhibited damage within six years of their installation that partially or completely affected their intended function. Structures placed in a stream channel will affect physical processes in the immediate vicinity of the structure as well as in upstream and downstream locations. Potential effects of instream structures for which the reviewer needs to be aware are:

- Hydraulic effects on water velocity, depth, and shear stresses which may in turn affect other channel processes like erosion and deposition, and habitat conditions;
- Sediment transport effects in the vicinity of the structure or upstream of the structure;
- Bed scour caused by flow acceleration around or over a structure which may be either a desired habitat enhancement objective, or an unwanted consequence;
- Channel planform and profile effects, including decreased erosion which prevents alterations to channel planform or profile, or conversely, alterations to hydraulics and sediment transport that affect the channel planform and bed elevation;
- Effects on wood recruitment where structures increase bank erosion, or where structures entrain wood and alter transport; and/or
- Effects associated with construction and installation of structures, including disturbance of the streambed, banks, or both, and resulting risks to species on-site and downstream. Construction in dry, dewatered conditions can greatly alleviate these risks, though the construction of flow diversions introduces further risks that must also be evaluated and found acceptable.

For any given project, these considerations may not be applicable, but the reviewer should be aware that when structures are proposed as part of a mitigation plan, these aspects of design need to be considered by the provider. A summary of common methods to address stream process alterations at the reach scale is presented in Table 17.

Table 17. Potential stream process restoration methods and design considerations to address stream problems (after Roni and Beechie, 2013).

Process alteration	Potential Methods	Design Considerations
Channel vertical instability	Modify inflowing water and/or sediment; bed and bank stabilization	Design basis for substrate gradations, allowable range of bed scour and fill, specify whether grade control is allowable or required; vertical stability criteria may specify sediment continuity (balance sediment supply, and transport capacity) objectives.
Channel lateral instability and bank instability	Remove encroachment on floodplain/ provide right of way for stream; grade control for mass wasting of banks; bank vegetation/ floodplain roughness	Allowable range of channel shifting, discharge criteria and shear stresses for bank erosion and criteria for geotechnical bank stability, duration for which artificial bank protection and stabilization measures are required.
Unstable channel form and geometry	Channel reconfiguration	Specify the design discharge that the channel is intended to contain and how that discharge was derived (i.e., gauge data; synthetic data; and regional regression data); define reach-averaged values and local variability within reach (i.e., pool, riffle, meander bend) in width, depth, and width/depth ratio; specify a range of values for planform characteristics (pattern, sinuosity, meander wavelength, braiding index, etc.).
Lack of floodplain connectivity / inundation	Floodplain reconnection; re-establish high flows (e.g., reservoir operations)	Flood flow frequencies and durations reaching the floodplain and the extent and location of floodplain inundation; allowable fluvial processes on the floodplain (overbank scour and sedimentation).
Riparian vegetation alteration	Seeding; direct planting; invasive control	Collected seeds from multiple riparian sites; get planting stock from nearby nurseries; herbicides, annual removal of individuals, mowing, prescribed burning, and flooding.
Instream habitat alteration	Large wood placement; instream structures	Large wood to increase channel bed and bank complexity; allow incorporation of beaver; instream structures use to increase bed and bank complexity.

6.3.4 Restoring Physicochemical Attributes

Where a project's goals and objectives include restoration or improvement of physicochemical attributes, reviewers should evaluate the workplan to ensure project elements are appropriate to satisfy these objectives. A combination of enhancement, restoration and/or establishment strategies that reduce nutrient inputs to streams, re-establish riparian functions, provide balanced water and sediment regimes, and increase in-stream nutrient processing and retention will likely be most effective for improving water quality. Some potential restoration methods which could be beneficial for stream water quality include (Bledsoe et al., 2016; Lammers and Bledsoe, 2017):

- Bank stabilization to reduce phosphorus loading in highly unstable streams.
- Floodplain reconnection to increase inundation frequency, provide more opportunity for nutrient uptake, and sediment and nutrient deposition.
- Instream structures (e.g., bendway weirs, drop structures, toe wood, and root wads) to improve dissolved oxygen and encourage hyporheic exchange and nutrient processing through enhanced geomorphic complexity and bedforms, especially during low flow.
- Riparian buffers to remove groundwater nitrate, protect streambanks, supply instream wood and organic carbon to increase in-stream processing, and reduce stream temperatures by shading; and
- Watershed controls to manage flow of water and sediment and reduce nutrient loading.

Much like the considerations for restoring hydrology and hydraulics, a stream's water quality is influenced largely by watershed land uses upstream of that stream reach, and the presence of any stressors should be appropriately considered during compilation of the workplan. The baseline assessment (Section 4.5.2.4) includes an evaluation of these watershed and site-scale stressors, as well as collection of temperature, pH, DO, specific conductance, nutrients, and sediment data at the upstream and downstream ends of the project.

Sediment is a natural constituent of stream ecosystems, as are nitrogen and phosphorus, however abnormally high levels of any of these constituents as a result of anthropogenic disturbances needs to be recognized and addressed in the stream mitigation plan. Some work has been done to assess the effectiveness of certain stream restoration methods to ameliorate the effects of nitrogen and phosphorus nutrients in streams (Lammers and Bledsoe, 2017; Bledsoe et al., 2016). In general, ameliorating phosphorus levels in streams involves control of phosphorus adsorbing sediments along banks and in the watershed. Phosphorus can also be temporarily removed from the system through biological uptake and burial on floodplains. Nitrogen cycles between organic and inorganic forms through plant uptake, organic material decomposition, mineralization, and microbially mediated nitrification (formation of nitrate from ammonia) and denitrification. Denitrification rates are highest in saturated soils and streambeds where water provides a source of dissolved nitrate and anoxic conditions, and when organic carbon is available to serve as an energy source.

Results of studies evaluating the benefits of various stream restoration techniques for amelioration of nutrient issues currently indicate a substantial degree of variability. This variability stems from natural variability in the streams and their watersheds, as well as the practices utilized to restore the stream. Regardless of this variability, potential exists for stream restoration practices to provide water quality benefits.

6.3.5 Restoring Biological Attributes

As stated in Section 4.5.2.5, a stream's biological community is largely influenced by proximity to refugial habitats, as well as hydrologic, hydraulic, geomorphic, and physiochemical conditions which operate at watershed, riparian, and reach scales. The complex interactions of these ecosystem processes contribute to the faunal diversity found in natural streams. From a mitigation planning standpoint, project elements to address these supporting functions have already been described in earlier sections. This section includes project elements related to riparian functions, considered here as a biological attribute, which contribute to the geomorphic stability of, and the organic carbon/detrital inputs to, the channel. Instream structures are also discussed below, specifically in terms of their habitat value for biological communities.

Riparian buffers are protected or replanted vegetated areas adjacent to stream channels that can intercept pollutants in surface and subsurface flow (Bledsoe et al., 2016). The benefits of riparian buffers include increased bank stability, stream shading to reduce water temperatures, supply of in-stream wood and organic carbon to streams, and water quality benefits derived from sequestering and/or transforming elements and compounds that enter the riparian zone from adjacent areas. Restoration of riparian buffers and vegetation plantings are common elements of most compensatory mitigation plans.

Generally, it is beneficial to plant forested buffers that consist of mixed herbaceous, shrub, and tree species typical of a reference standard riparian zone. The reviewer should ensure that riparian buffers are as wide as possible, have as diverse a planted assemblage as possible and be in contact with overland flows and shallow subsurface flows to gain the full effect and benefit from the buffers. If these conditions are not met, the riparian zone/buffer is likely not to achieve its full function. For example, planting riparian buffers along incised streams, with no channel work to address the cause of the incision, is not recommended. The benefits of riparian vegetation roots holding banks together and being in contact with shallow subsurface water flows to uptake nutrients are minimized along incised reaches.

Vegetation - Like other components of the workplan, planting plans for revegetation or enhancement of riparian zones should be guided by the vegetative community speciation and structure demonstrated by applicable reference standard sites. There should not be a one size fits all approach to riparian zone plantings because the soil type(s), valley topography, and hydrologic conditions to which riparian zones are subject differ across ecoregions and position along the hydrographic continuum from headwaters to main stem rivers. Important elements for reviewers to ensure are included in each planting zone of a revegetation plan include:

- **Selecting suitable species and assemblages:** Species selection will typically be based on reference standard riparian systems, which may or may not correspond to the reference streams used for instream biota or geomorphic features. Nevertheless, the provider should rely on reference comparisons to select species and their assemblages. In selecting plants and assemblages, the role of vegetation in providing natural bank protection should also be considered. In this context, the vegetal and rooting characteristics determine the resistance of plants to shear stresses at high flows. Assemblages should be comprised of native species, either planted or volunteers, and invasive species must be controlled.
- **Specifying vegetation growth stage (seed, seedling, rooted stock, etc.):** The planting plan should consider natural successional processes. Many shrubby species can be effectively propagated using cuttings from local sources. In such cases, soil characteristics and depth to groundwater during all seasons must be considered, as cuttings typically need access to saturated soil in order to establish roots, and roots need access to soil moisture. In many cases, ecological function may be best advanced by planting a mix of riparian species that includes seral-stage trees that optimize site potential, such as oak and/or hickory species.
- **Setting the timing for planting:** Many revegetation efforts take place in early spring in an attempt to get the plants established before summer heat and potential drought conditions pose a threat to the plantings.
- **Delineating the planting zones:** The planting zones, which define appropriate locations for varying species and growth types, should extend beyond the channel and riparian corridor to encompass as much of the floodplain as possible. Species selection and the building of assemblages are best based on local reference standard riparian systems. Seeds and rooted stock should be derived from locally adapted native species whenever possible. Plans should specify planting densities, soil amendments, and specifications developed for each zone. Revegetation plans must consider inundation frequencies and durations, the possibility of drought conditions, the lower elevation limit of vegetation on a bank, and the magnitude and duration of shear stresses to which the plants may be exposed during the higher design flows.

Design criteria for vegetation elements of a workplan should factor in potential risks to the growth and survival of riparian vegetation, including risks associated with drought and excessive browsing or grazing. Because riparian vegetative growth and success is so dependent on local soil moisture and streamflow conditions, seasonal and interannual variation in precipitation and discharge can make or break a revegetation effort.

Instream habitat: Stream restoration project goals typically include replacement of, or improvement to, poor physical stream habitat quality using idealized design elements. It is commonly then assumed that aquatic biota will recolonize on their own; an expectation that has been criticized as a “Field of Dreams” approach (Palmer et al., 1997; Hilderbrand et al., 2005). As discussed in Section 4.2, studies indicate that restoring biological condition requires selection of a project site with appropriate water quality and within proximity of potential colonizing species. Without these conditions, efforts to restore instream biological communities may not achieve results. However, assuming the provider has selected an appropriate site, constructing suitable instream habitat may enhance the recovery of reference biological conditions.

Instream habitat elements generally include channel bed features or installed structures intended to provide habitat complexity, forage, refuge, or cover for aquatic organisms. Habitat design criteria should consider the species, life stage, and biologic functions specific habitat elements will address. Design criteria considerations include the selection of materials used to create habitat, the deformability/rigidity of constructed habitat elements, the cost effectiveness (e.g., functional life of constructed elements), and the habitat complexity at multiple scales. Complexity is an important attribute of natural habitat at all scales: planform complexity at the reach scale; variability in width, depth and velocity at the site scale; bed material variability; bedform diversity; and habitat patches, including their lines and edges at a micro-habitat scale. Design criteria for the habitat elements in a restoration project should, therefore, specify the nature and degree of complexity at all scales.

Ideally, materials used to construct habitat elements should be locally derived and consistent with natural materials already in the project or adjacent reaches. For example, the introduction of large boulders would be inappropriate in an alluvial gravel bed stream, while the use of large wood might be out of place in a small stream flowing in an open, semiarid grassland setting. Locally derived materials are less prone to introduction of seeds or spores of non-native and undesirable plant or animal species.

Another form of instream enhancement are beaver dams, which can increase habitat heterogeneity and may increase nutrient retention and cycling by increasing hydraulic retention time and encouraging hyporheic exchange. Use of beaver dam analogues as well as reintroducing beaver to inhabit degraded streams are rapidly expanding restoration practices (Pollock et al., 2007; Pollock et al., 2014; Pollock et al., 2017). Beavers change the hydraulic, geomorphic, physicochemical, and biological aspects of the stream. Incorporating them into a project design would require a great deal of planning from the beginning of the project, as well as management considerations prior to and after restoration work has been completed. More discussion on the effects and accommodation of beaver can be found in Section 8.3.2.

7.0 How will progress toward the target condition be assessed?

Key points associated with performance and monitoring:

- Performance standards are directly linked to the project's objectives to improve ecological functions.
- Performance standards should be reference-based, measurable and verifiable.
- Performance standards should have clear thresholds to meet in a given time period.
- Monitoring should determine that performance standards are met within an agreed upon level of confidence.

The intent of this question is to outline what is needed to determine the ecological success of a mitigation project, including ecological performance standards and monitoring plans. At this point, information has been gathered to classify the site, assess its baseline condition, set the target conditions, and develop a plan to address stressors that are currently impacting the proposed mitigation site. Project goals and objectives should provide a vision for the project and set out the tasks needed to achieve that vision. Performance standards are based on the specific objectives of the mitigation project, and monitoring is used to determine if the project is meeting its performance standards. If monitoring indicates that the site is not responding as anticipated, then it will be necessary to implement adaptive management measures to redirect the site's trajectory (see Section 8.0).

A list of performance standards and detailed monitoring plans are generally provided as part of a completed draft mitigation plan, banking instrument or ILF instrument or addendum. Because each site's mitigation plan is unique, reviewers will want to ensure performance standards are consistent with the specific goals and objectives of the project and that monitoring elements are appropriate to inform ecological success. The main opportunity to provide comments on performance standards and monitoring plans will be during the Public Notice comment period for individual permits or during review of the draft mitigation bank instrument or ILF project addendums. Following completion of the project, regular monitoring reports will be available for review according to USACE District practices for disseminating information to IRT and/or commenting agencies. Credit releases and closeout of a mitigation site will occur once a project has met specific ecological success criteria. As such, review of monitoring reports, credit release requests and information related to project closeout are essential to determine whether performance standards have been met.

Performance standards must represent a range of functions (e.g., wetland hydrology, biogeochemical, and plant and animal habitat; stream hydrologic connection, hydraulic maintenance, geomorphologic form) and each performance standard must tie directly to a project objective. Reviewers should consider whether each performance standard is informed by an appropriate comparison to a reference standard, described using clear and concise wording, scientifically defensible, and supported by objective data collection that is appropriately timed, repeatable and using methods with clearly defined error rates.

Important elements of monitoring plans include the data collection methods and protocols necessary to inform performance standards, and should outline the locations, timing, intensity and scale of sampling. Generally, monitoring plans should clearly and concisely describe the parameters to be assessed; where and how often each will be measured; the specific methods and/or protocols for measuring each parameter; the resources needed (e.g., time, money, equipment, and expertise); how data will be analyzed and interpreted with respect to objectives and performance standards; the level of statistical rigor necessary to determine treatment effectiveness; and how data will be made accessible and understandable for decision-making regarding achievement of performance and/or adaptive management. Monitoring plans should be clearly written and organized to promote accurate interpretation at any point in the life of the project site. When reviewing monitoring plans, reviewers should ensure the same parameters and methods have been used to collect baseline data and post-project monitoring data, and that the timing of monitoring data is appropriate given credit release schedules and project closeout timeframes for the project.

This section provides the reviewer with background information on important elements to be included in performance standards and mitigation plans. It also provides additional considerations for reviewers during the post-project monitoring phase. Technical information and specific suggestions are also provided for performance standards and mitigation plans and organized by functional category for wetlands and streams (Box I).

Box I. Recommended information to address performance standards and monitoring.

Performance Standards

- Does each performance standard tie to a specific project objective?
- Are performance standards provided for the suite of functional indicators (see below) tied to project objectives?
- Is each performance standard informed by appropriate reference standard comparisons?
- Is each performance standard described using clear and concise wording?
- Is each performance standard scientifically defensible (e.g., sensitive to changes in function)?
- Is each performance standard supported by data collection methods that are appropriately timed, repeatable and with clearly defined error rates?

Monitoring Plan

- Are data collection methods for each performance standard outlined in the monitoring plan?
- Have pre-project baseline data been collected for all measures outlined in the monitoring plan?
- Has the timing of data collection (e.g., frequency, duration, and seasonality) been determined?
- Has the location and scale of data collection (e.g., reach, riparian, and watershed) been determined?
- Is the sampling intensity (number and arrangement of locations/plots) appropriate for the chosen parameter?
- Is the sampling of sufficient intensity and precision to detect deviations from performance standards and indicate the need for adaptive management?
- Does the plan outline how data will be analyzed and reported?

Review of post-project monitoring

- Compare the as-builts to the design criteria outlined in the mitigation plan. Was the project built to specifications in the plan? If not, why not?
- Do the results of monitoring show the site is on track to meet performance standards? If not, is adaptive management needed?

Box I (cont'd). Recommended information to address performance standards and monitoring.

Performance standards and monitoring expectations by functional category

Wetland Hydrology:

- Measures that demonstrate timing, duration and frequency of saturation, ponding, and/or flooding, during at least 3 normal rainfall years, similar to hydrologic monitoring data in the same HGM subclass of reference standard wetlands on similar soils.
- Methods should be sufficient to monitor the site's hydrologic sources and gradient (e.g., rain gauges, stream gauges and/or an array of groundwater wells).

Wetland Soils:

- If soils have been disturbed or drained, measures that demonstrate they meet hydric soil criteria for saturation (minimum 14 consecutive days) and anaerobiosis as per National Hydric Soil Technical Standard.
- Measures that demonstrate the soil is accumulating organic material; developing appropriate bulk density, texture, and nutrient concentrations; and soil microtopographic features (shallow depressions and minor hummocks) similar to reference standard.

Wetland Vegetation:

- Measures that demonstrate plant survival to sapling stage; species composition and density (e.g., establishment of native species in all strata); response of herbaceous components of vegetative community to hydrologic changes (i.e., Weighted Prevalence Index) and trending towards a hydrophyte dominated community; relative abundance or cover of various age classes, including evidence of recruitment; and an expectation for maximum allowable invasive plant species cover.
- All performance standards should be similar to, or along a trajectory towards, reference standard.

Stream Hydrologic Functions:

- Measures that demonstrate the timing, rate of change (flashiness), duration and frequency of low, high and design flows comparable to reference standard condition.

Stream Hydraulic Functions:

- Measures that demonstrate sediment transport in the channel and across the floodplain are as designed and in an equilibrium condition.

Stream Geomorphic Functions:

- Measures that demonstrate that boundary conditions in the restored reach are as designed and comparable to reference standard condition.

Stream Physicochemical Functions:

- Measures that demonstrate water quality (pH, DO, temperature, and nutrients) has not declined after project from baseline condition.
- Measures that demonstrate water quality parameters are improving towards reference standard condition.

Stream Biological Functions:

- Measures that demonstrate benthic macroinvertebrates and/or fish and riparian vegetation are improving towards reference standard condition.

7.1 Regulatory Context

The Mitigation Rule requires the mitigation provider to identify ecological performance standards that will be used to assess whether the mitigation project is achieving its stated objectives, and also to clearly describe the monitoring methods to document its performance. Performance standards are defined as "observable or measurable physical (including hydrological), chemical and/or biological attributes that are used to determine if a compensatory mitigation project meets its objectives" and are described in the Mitigation Rule at 40 CFR §230.95(a) as needing to be clearly tied to the project objectives, the desired resource class or type, and the functions expected of that resource type. Further, the Mitigation Rule stipulates in 40 CFR §230.95(b) that:

(b) Performance standards must be based on attributes that are objective and verifiable. Ecological performance standards must be based on the best available science that can be measured or assessed in a practicable manner. Performance standards may be based on variables or measures of functional capacity described in functional assessment methodologies,

measurements of hydrology or other aquatic resource characteristics, and/or comparisons to reference aquatic resources of similar type and landscape position. The use of reference aquatic resources to establish performance standards will help ensure that those performance standards are reasonably achievable, by reflecting the range of variability exhibited by <u>the regional class of aquatic resources</u> as a result of natural processes and anthropogenic disturbances. Performance standards based on measurements of hydrology should take into consideration the hydrologic variability exhibited by <u>reference aquatic resources</u>, especially wetlands. Where practicable, performance standards should take into account the expected stages of the aquatic resource development process, in order to allow early identification of potential problems and appropriate adaptive management. [emphasis added]

The Mitigation Rule also recognizes that monitoring is necessary to adequately capture the trajectory towards performance standards and determine if adaptive management is needed. The Mitigation Rule states that monitoring plans should include a description of parameters to be monitored, a schedule for reporting those results, the length of the monitoring period, the party responsible for conducting monitoring and submitting reports and the frequency of those reports to the USACE District Engineer (40 CFR §230.96). The length of the monitoring period must be sufficient to demonstrate that the site has met performance standards but should not be less than five years. The Mitigation Rule further specifies that a longer monitoring period must be required for aquatic resources with slow development rates (e.g., forested wetlands, bogs) (40 CFR §230.96(b)).

7.2 Performance Standards

Performance standards allow evaluation of progress towards project objectives (e.g., full achievement, partial achievement, or failure). Each performance standard should identify: (1) the attribute being measured (i.e., *what is measured?);* (2) the condition or parameter that defines success (e.g., quantity, coverage, composition, growth rate) (i.e., *how is it measured?*); and (3) the period of time within which success must be reached and the period of time over which success must be sustained (i.e., *when is success achieved?)* .

While efforts have been made in some regions to create broadly applicable performance standards (e.g., USACE, 2012), they need to be considered on a site-specific basis to accommodate the variety of aquatic resource types, landscapes, stressors and treatments implemented as part of mitigation efforts. Therefore, each mitigation project will potentially have a unique set of performance standards specific to the class(es) of aquatic resource on site and the mitigation project goals and objectives.

Performance standards should be compared to either reference data from a reference network (Brooks et al., 2016), or reference sites of similar wetland and/or stream class in similar landscape positions (Section 5.3). Using or assembling a network of multiple reference sites establishes a range of natural conditions within which performance can be assessed. If reference data are not available from a reference network and need to be collected from project-specific reference sites, careful review of those sites for their appropriateness and similarities to the proposed mitigation site must be undertaken. Poor selection of reference sites could lead to inconclusive comparisons of performance standards with reference data. For example, if hydrologic restoration for a proposed riverine low gradient forested wetland was being attempted, and the objective was to re-establish the natural hydroregime, the reference site(s) would need to have similar landscape position, mature vegetation, and hydrologic sources (particularly flood regime) as the proposed target mitigation site. Choosing a reference site adjacent to an incised channel, regardless of the maturity of the vegetation, would lead to different flood frequency, durations, and extents, and potential erroneous or misleading hydrologic performance standards when compared to the target condition (see Section 5.3).

To help determine the effectiveness of a provider's performance standards, reviewers should evaluate if the performance standards address:

(1) **A single measure or aspect of condition/function that is sensitive to change due to the management proposed** - Each performance standard should represent one element of function that is responsive to mitigation activities, such as recruitment of native plant communities, appropriate hydrology during the growing season, or suitable soils/substrate. Although compensatory mitigation strives to restore fully integrated functional ecosystems, measuring specific elements is often more practical and enforceable, and can be more easily tied to adaptive management.

(2) **Objective and repeatable measurement** – To the extent possible, standard acceptable protocols should be used so that providers and IRT members understand and agree on how to measure to produce data in a consistent, repeatable manner.

(3) **Clear targets or benchmarks anchored to reference** – Performance should be assessed relative to a defined target and should include an expected timeframe to meet that target (e.g., at year five following construction, three years after the first five-year flow event). The target can be based on conditions at reference standard sites or relative to regional or ambient condition (e.g., comparable to the 75th percentile of the ambient condition range). In the case of re-establishing forested systems, performance standards may need to be set based on early successional stages of the particular wetland class, subclass, or riparian zone.

(4) **Quantifiable targets with known certainty** - Standard protocols are typically associated with specific error rates that provide known levels of confidence. These error rates may result from the variability during data collection or analysis (e.g., inherent errors in species identification or instrument measurements) and should be accounted for during data interpretation and performance standard development.

(5) **Clear and concise wording** – The period of monitoring for performance often exceeds the tenure of individual reviewers, IRT members, or even some providers. Therefore, the language of each standard should be written so that an uninitiated staff person can readily interpret the intent of the standard and reach a clear determination of compliance. For example:

    At the end of year three, at least 80% of Area A shall have a natural ground cover vegetation score within 10 percent of the median reference population score.

    - *If this standard is not met, the site will be re-evaluated within 120 days of the original field assessment; and*
    - *If the standard is still not met, metric (i.e., parameter) level analysis and/or causal assessment shall be conducted to identify likely reasons for failure*.

(6) **Scientifically defensible** – Standards should be grounded in sound scientific principles and preferably informed by peer-reviewed studies. If links to peer-reviewed literature are not available, analysis of data from past mitigation projects and/or reference comparisons can also provide scientific rationale and support for development and ongoing refinement of performance standards.

(7) **Appropriate timing** - Performance standards can be phased over time. For instance, it is advisable that performance of structural aspects of the stream (e.g., planform, cross-section, and instream structures) or wetland (e.g., ditch plugs, levee breaches, and constructed microtopography) be evaluated earlier in the restoration process to establish that hydrologic and hydrodynamic processes are in place. Physicochemical and biological aspects of the project can be evaluated later, once the physical and hydrologic elements are established. Such a phased approach may be more conducive to earlier identification of problems that require remedial action or adaptive management (Stein et al., 2022).

7.3 Monitoring

Monitoring, in one form or another, occurs throughout the life of the project. There are essentially three stages of monitoring that are pertinent to the compensatory mitigation program: baseline monitoring; implementation monitoring; and effectiveness monitoring.

Baseline monitoring is accomplished early in the project as the baseline condition assessment (Section 4.0). The existing condition of the proposed restoration wetland or stream is described in terms of functional capacity and the stressors acting on the functions of the project site. The baseline condition assessment sets the benchmark from which changes to the wetland and/or stream, as a result of the mitigation project, will be measured.

Implementation monitoring provides verification that the project was actually constructed as designed and approved by applicable permitting authorities. It is accomplished by comparing the as-built plans with the 100% drawings and the design criteria discussed in the mitigation plan, as well as a possible site visit. The mitigation plan should include implementation monitoring requirements, including scaled, as-built plans from a professional engineer (PE) or Professional Land Surveyor (PLS), 100% design plans, and a field confirmation of the design criteria in the approved mitigation plan for both stream and wetland mitigation projects. The design criteria (e.g., amount of fill in ditches, size, shape and spacing of levee breaches, and number and species of tree seedlings planted) are important to monitor to determine if the plan was appropriately implemented and/or constructed and should be documented in as-built plans compiled following implementation monitoring.

Effectiveness monitoring is used to evaluate whether the project has improved aquatic resources (e.g., habitat conditions or stream processes) and whether the project has, or is on target to, achieve its goals and objectives, performance standards, and target condition. Reviewers should evaluate monitoring plans carefully to determine whether monitoring measures link mitigation actions (and their anticipated functional improvements) to objectives and performance standards.

Just as the methods and/or treatments chosen for a mitigation plan are dependent on site and watershed impairments, the choice of monitoring strategies is dependent on the objectives of the project, the actions taken on the site, and the performance standards selected to represent the level of ecological lift expected (i.e., the target condition). Similar to consideration of performance standards, standardized monitoring plans are difficult to prescribe due to the variability in aquatic resource types, effects of perturbations from a spectrum of sources, and the variety of methods available to assess performance.

Despite this variability, all monitoring plans should include the data collection methods and protocols necessary to inform performance standards, and should outline the locations, timing, intensity and scale of sampling. Monitoring plans should be clearly written and organized to promote interpretation at any point in the life of the project site and accommodate personnel changes in both the provider's team as well as among the IRT. Generally, monitoring plans should clearly and concisely describe:

- The parameters to be assessed, including where and how often each will be measured;
- How data will be analyzed, interpreted and reported with respect to objectives and performance standards;
- The resources (e.g., time, money, equipment, and expertise) needed;
- How data will be analyzed and reported to determine the need for adaptive management; and
- The level of statistical rigor to determine treatment effectiveness.

Specific consideration should be given for how a monitoring plan may inform the need for adaptive management. If adaptive management measures are triggered when a site is not achieving, or on track to achieve, performance standards, then the monitoring plan needs to have adequate monitoring intensity across a site to determine site conditions compared to performance standards, and analysis of the monitoring data to indicate statistical difference. Some authors have advocated that adaptive management be predicated on designing and monitoring ecological restoration using principles of experimental design, so that adequate data are gathered and statistically analyzed to identify effective alterations to a mitigation project (Galatowitsch and Zedler, 2014; Roni and Beechie, 2013). For aquatic resource restoration and rehabilitation, this means testing the hypotheses the project design is based on, demonstrating a good understanding of watershed processes, and appropriately addressing adverse changes in these processes and ecological functions. Monitoring for performance, and subsequently using that data for adaptive management, if necessary, is something for which every project should strive, and for which every reviewer should be aware.

Reviewers should also consider the time frame proposed for post-project monitoring. The Mitigation Rule requires a minimum of 5 years of monitoring. However, since many of the aquatic ecosystems in the southeastern U.S. are forested (either as wetlands or riparian zones), a 10-year monitoring period may be prudent to determine appropriate establishment and growth of trees. A 10-year monitoring period is also important to capture a degree of hydrologic variability. Resilient aquatic ecosystems adjust to dry periods, extremely wet periods, low flows and high flows. This range of climatic and hydrologic conditions is important to monitor effectively to assess the long-term sustainability and resiliency of the proposed project.

The monitoring plan should outline reporting requirements. Monitoring reports must be submitted to USACE, but the content and level of detail for those reports will be commensurate with the scale and scope of the mitigation project, as well as the mitigation project type. They may include plans (such as as-built plans), maps and photographs to illustrate site conditions. Monitoring reports may also include the results of functional, condition or other assessments used to provide quantitative or qualitative measures of the functions provided by the mitigation project. It is important for the reviewer to collect and evaluate these monitoring reports, not only for their adequacy, but also as a record of progress for the site. When reviewing monitoring reports, reviewers should consider whether the results of monitoring show the site is on track to meet performance standards, and if not, whether the triggers for adaptive management have been met.

7.4 Wetland Performance Standards and Monitoring

As laid out in Section 4.4.2, hydrology, soils, and vegetation data form the basis of comparison for monitoring after the mitigation plan has been implemented. Specific hydrologic, soils and vegetation parameters should be identified to inform performance standards, and monitoring of these parameters should be used to document the effectiveness of the mitigation treatment at achieving performance standards as the site trends towards the target condition. Selected parameters serve as indicators for hydrologic (i.e., flooding, ponding, and/or saturation), soils (e.g., saturation, anaerobiosis, and structure), and vegetation (e.g., growth, species composition, and structure) processes, and the assumption is that as these parameters trend toward a target condition the underlying functions also improve.

Ideally, performance standards would include direct measures of function (e.g., the quantity of one or more imported elements and compounds removed or sequestered per unit area during a specified time period (e.g., $g/m^2/yr$) or sediment retention per unit area per unit time (e.g., $g/m^2/yr$) (Ainslie et al., 1999)). However, direct measures of functions are often costly, time consuming, and likely to require monitoring that exceeds the proposed monitoring period. Thus, direct functional measures may not be practical in many instances, and indirect measures, or indicators, associated with the performance of a function are used as proxies for direct measures of wetland processes.

Attributes of a site's hydrology, vegetation, and soils are monitored for performance because it is assumed that if these abiotic and biotic components are in good condition, relative to reference, appropriate functions will develop in time. Existing HGM regional guidebooks contain lists of indicator parameters and a discussion of each indicator's relationship to wetland function. These indicators could be used to inform performance standards if they meet the criteria above (i.e., objectively measured, quantifiable and reference-based targets, defensible, and concise). HGM functional capacity indices are scaled to reference standard conditions, so the published threshold values can be used to inform performance standards. For example, optimal flooding, vegetation, and habitat structural characteristics can be expressed as thresholds (e.g., flood frequency should occur every other year, tree density should be 200 stems/acre, and ground cover should not exceed 20%). However, if additional indicators need to be measured to adequately assess performance (e.g., flood duration, early successional ground cover, shrub/sapling density) and meet the criteria above, they should be included in the mitigation plan, measured during the baseline assessment, and represented by an appropriate reference site.

Other assessment methods, like the California Rapid Assessment Method (CRAM; CWMW, 2013), Ohio Rapid Assessment Method (ORAM; Mack, 2001), and Habitat Evaluation Procedures (HEP; USFWS, 1980) for wildlife habitat, among others, also include indicator parameters which might be useful in assessing performance because they are associated with targets and or threshold values scaled to reference. Many wetland assessment methods have strong reference datasets for wetland vegetation, and many include a number of vegetation-related indicators. However, they often lack detailed hydrologic and soil standards. Thus, establishing abiotic performance standards for a given site or regional subclass will require more detailed monitoring, site specific information and comparison to reference data, literature, and previous mitigation projects. Scientific literature and/or experience with similar mitigation sites should be considered if available. However, in some situations this information may not be available for any given site. Thus, nearby reference sites may be needed to develop hydrologic, vegetative and soil performance standards that account for natural variability among aquatic resource types. Any comparisons between reference and mitigation site condition should be conducted using a statistical analysis approach (e.g., t-test of soil redox values, or ANOVA with a multiple comparison test when more than one site is assessed) (Stein et al., 2022).

More specific criteria for wetland hydrologic, soils, and vegetation performance standards are provided below.

Hydrology Performance Standards

Hydrologic performance standards should include concisely worded statement(s) that tie the measured frequency, duration, extent and timing of flooding, ponding, and/or saturation to the target hydroperiod exhibited by a reference standard site or dataset. At a minimum, hydrologic criteria should be based on appropriate water sources and hydrodynamics for the particular class/subclass and characteristics of a given mitigation site. Because many wetland classes do not have reliable quantitative hydrologic indicators, direct measures of hydrologic processes are necessary to document the appropriate hydrologic regime for the site has been established. This is particularly important for groundwater dependent wetlands which require connection with subsurface water (often of specific chemical composition) during key portions of the growing season.

In addition to the hydrologic criteria above, the Water Features Table in the Web Soil Survey can provide insightful information on the hydrologic regime under which the mapped soils formed (USDA NRCS, 2011). Although the information in the Water Features Table may not be resolute enough to use directly as wetland hydrologic performance standards, water sources and hydrodynamics can be fine-tuned for each site by comparing the mitigation site's hydrology with a reference standard site that has similar landscape position, soils, and water features.

Monitoring considerations: The hydrology at a proposed wetland compensatory mitigation site is perhaps the most important parameter to be measured and assessed. As discussed previously in Section 4.4.2, continuous surface and groundwater monitoring devices, as well as rain gauges, should be installed to assess baseline condition, compare to reference data and establish normal rainfall (Sumner et al., 2009; Sprecher and Warne, 2000). Monitoring plans should include these elements to monitor changes in hydrologic criteria throughout the life of the compensatory mitigation project.

Monitoring schemes should be established to capture direct measures (e.g., flood and/or groundwater frequency and duration) of hydrologic processes to establish the expected hydrologic regime for the site and provide the necessary data to inform performance standards. Depending on a wetland's conceptual water budget (see Section 6.2.1), monitoring should encompass measures of rainfall, groundwater, ponding and flooding. Monitoring wells are typically arrayed perpendicular to the predominant water source to determine gradients. For instance, wells in a riverine wetland are often placed perpendicular to the channel to detect extent of flood flows as well as the contribution of upslope water sources moving down gradient towards the channel. Flats, on the other hand, may require fewer wells to indicate that vertical movement of water through the soil profile and demonstrate that soil saturation is occurring. For more detail on wetland hydrologic monitoring, see the *Engineering Handbook No. 650, Hydrology Tools for Wetland Identification and Analysis* (USDA NRCS 2021).

The *Technical Standard for Water Table Monitoring of Potential Wetland Sites* (USACE, 2005) indicates that short-term (i.e., <10 years) evaluation of wetland hydrology requires consideration of the normality of precipitation that falls during the monitoring period. USACE (2005) further asserts that short-term water table monitoring data must be interpreted in relation not only to the normal precipitation range based on long-term records, but also on the amount of precipitation that fell during and for at least three months prior to the requisite monitoring period each year. EPA Region 4 considers year-round groundwater monitoring to be most appropriate in the southeastern U.S. Thus, evaluation of precipitation in previous years prior to monitoring is recommended.

The USACE (2005) outlines three methods for evaluating precipitation normality within any given year and cites Sprecher and Warne (2000) for detailed descriptions. One of those methods, which considers the three-month period prior to water table rise, is referred to as the Direct Antecedent Rainfall Evaluation Method (DAREM) and was recommended by the authors for wetland hydrology assessment based on their evaluation of wetlands in North Carolina and Minnesota that had long-term (40-45 years) records of both water table data and precipitation data. The USDA also recommends using DAREM for analysis of short-term precipitation normality in the NRCS Hydric Soils Technical Standard (NTCHS, 2015). Thus, normality of rainfall data should be interpreted using either one of the techniques outlined in Sprecher and Warne (2000), including the DAREM Method.

Note however, that USACE has recently developed an automated tool for evaluating precipitation normalcy based on the combined method referenced by Sprecher and Warne (2000). The ease of use and general endorsement of this tool make it arguably the preferred method to assess precipitation normality. The USACE Antecedent Precipitation Tool (APT) was developed in 2021 to facilitate comparison of antecedent precipitation conditions at a given location to the range of normal precipitation conditions that occurred during the preceding 30 years (Gutensen and Deters, 2022). The APT automates a method of evaluating 30-day rolling totals of precipitation combined with weighting factors in the NRCS Engineering Field Handbook (i.e., the combined method in USDA NRCS (2021), which is described by Sprecher and Warne (2000)).

Soils Performance Standards

Soil performance should be based on site verified soil series correlated with the appropriate soil series information in the Web Soil Survey. In cases with disturbed soils, performance standards should document the restoration of soil structure (e.g., bulk density and soil texture), fertility (e.g., nutrients), and organic matter composition. At a minimum, soil series on both the mitigation site and the reference site should be verified by a certified soil scientist. It is assumed that if a site is appropriately inundated, saturated and/or ponded in at least three of five normal rainfall years, and the site compares to reference data or similar sites, then the site will continue to have functioning hydric soils.

Section 6.2.2 outlined a list of appropriate soil characteristics to include in the mitigation plan, including soil variability; microtopography; soil organic matter, with soil amendments if necessary; techniques to restore soil texture, bulk density to compacted soils; and soil nutrient concentrations. Potential soil performance standards that could accompany these aspects of soil restoration are:

- Matching the soil description for soils typical of reference wetlands in the same landscape position and HGM class/subclass;
- Microtopographic relief similar in height, spatial pattern and area to reference standard sites;
- Soil nutrient concentrations and their availability in soils similar to reference standard sites;
- Soil organic matter contents similar to reference standard;
- Meet hydric soil criteria according to the National Hydric Soils Technical Standard; and/or

- Indicators of recovering soil structure (e.g., bulk density), soil nutrients (e.g., soil nitrogen and phosphorous), and organic matter content similar to soil descriptions in SSURGO.

Monitoring considerations: Soil monitoring will need to be implemented to ascertain if the performance standards for the site's soils have been met, and the monitoring plan should outline the parameters that will be used to inform performance standards (e.g., related to soil variability; microtopography; soil organic matter with soil amendments if necessary; techniques to restore soil texture, bulk density to compacted soils; and soil nutrient concentrations).

If the wetland mitigation site has been hydrologically and/or edaphically altered or has soils with only hydric inclusions or marginal soils, then the methods for assessing the level of saturation and anaerobiosis outlined in the latest version of the NRCS Hydric Soils Technical Standard should be utilized to establish that soils on-site are meeting the present definition of hydric soils. As noted in NTCHS (2015), "the Hydric Soils Technical Standard requires proof of (1) anaerobic conditions and (2) soil saturation for at least 14 consecutive days for most soils, (3) during normal rainfall periods when soil microbes are active." Further, it describes three methods to document anaerobic conditions in soil: IRIS tubes, oxidation-reduction potential measurements using platinum tipped redox electrodes, and alpha-alpha-dipyridyl dye.

Microtopographic depressions and hummocks are important to establish vegetation and promote biogeochemical cycling by providing shallow (<0.03 m) areas of prolonged inundation or ponding (i.e., hollows) and hummocks (<1.5 m tall) (Richardson et al., 2016). For monitoring performance standards related to microtopography, the areal coverage of hollows and hummocks should be compared to reference standard sites of similar wetland class on a per area basis (e.g., a visual comparison of the number of depressions and hummocks per 0.04 ha plot or 10m X 10m plot to the reference sites). Plots should correspond to the vegetation plots used to monitor vegetation.

Soil structure (i.e., texture and bulk density) should be monitored by digging a soil pit in each vegetation plot and/or mapped soil series on the site. In addition, a soil sample within the top 25 cm (10 in) should be sent for analysis of soil organic matter, nutrients, and bulk density (Bledsoe and Shear, 2000). Monitoring of SOM will likely only need to be done after implementation of the mitigation treatment and, assuming soil amendments were added, at the end of the monitoring to show progress in these soil parameters.

Vegetation Performance Standards

Specific vegetative performance standards may include parameters of plant community structure (e.g., strata, density, and composition), sustainability (e.g., saplings composition and densities), and invasive species control; and will vary based on the target condition and reference data. Vegetation performance standards should reflect values observed in reference standard sites, or sites on a trajectory to achieve reference standard vegetation, of similar wetland class and subclass. Preferably, reference standard vegetation data from existing sources (e.g., HGM regional guidebooks, National Wetland Condition Assessment data, published literature, university studies) should be used as a basis of comparison, but providers may need to use vegetation data from reference sites to inform targets. Vegetation data from at least three reference sites with similar hydrologic regime and soils and in close proximity to the proposed mitigation site is recommended to inform performance standards. For woody vegetation, performance standards may need to reflect a trajectory towards target condition, since the time required for forested sites to fully mature often exceeds the monitoring period for a project. Vegetation trajectory curves have been compiled from reference wetland sites of various age classes in Arkansas and the Lower Mississippi

Valley (Klimas et al., 2004; 2008; Smith and Klimas, 2002) by substituting space (many sites of different ages) for time.

Overall, vegetative performance standards should reflect a long-term goal of a self-maintaining plant community. Typically, vegetation species composition, density, and survival (of planted species) are used to demonstrate the ability of a mitigation site to develop into a characteristic plant community (assuming the planted species are similar to reference sites). Some studies have validated the shrub-sapling density and ground vegetation coverage as responsive performance criteria (Berkowitz, 2013). Relative abundance or percent cover are common indicators of plant community structure. Plant community sustainability, another important vegetation parameter, can be measured by indicators of community self-recruitment (e.g., seedlings and saplings of dominant mature canopy species in the understory). Often, invasive species control may be necessary, and performance standards can include parameters limiting invasive species coverage, and/or abundance(e.g., maximum allowance of invasive species coverage). The weighted prevalence index (PI) could also be used as a performance measure for both vegetative community and hydrology, as it incorporates herbaceous species present and their wetland plant indicator status (i.e., obligate wetland, facultative wet, facultative, and upland) to produce an index that uses the plant community as an indirect indicator of site wetness (i.e., the more obligate and facultative plants sampled, the lower the index indicating increased site wetness).

Vegetative performance standards should be tied to specific project objectives, informed by the baseline assessment, workplan and data from reference sites. For example, baseline assessments may reveal that a site is completely cleared of native vegetation, as is the case with agricultural fields, and a project objective is to restore the native vegetation community, as compared with reference. Performance standards should focus on survival, composition, and sustainability of native species. In another example, a proposed site has been selectively timbered and still has forested community structure minus some important species, and the project objective focuses on the enhancement or re-establishment of select species to complete the community composition and sustainability. Performance measures may focus on the survival or within-stand recruitment of select planted species instead of the vegetation community as a whole. Each project will be different and vegetative performance, as those above, need to be incorporated based on objectives and appropriateness.

Monitoring Considerations: Most USACE Districts have vegetative monitoring schemes that address establishment, survival and sometimes growth of planted vegetation. However, vegetation composition on any given proposed compensatory mitigation site will vary along with soil and hydrologic conditions. In fact, Bledsoe and Shear (2000) determined that plant species composition in riverine wetlands was based on growing season hydrology and microtopography on a scale of 10cm. This emphasizes the need to pair hydrology, soils, and vegetation data in the same plot(s). In addition to, or in lieu of, USACE District vegetative monitoring protocols, reviewers should look for and/or recommend the following vegetation sampling and monitoring criteria:

- Each vegetative stratum should be monitored and sampled individually. It is acceptable for trees and woody vines to be sampled from larger plot sizes than the herbaceous stratum (e.g., $100m^2$ vs. $1m^2$);
- Each unique and separate planting area or cover type/polygon (e.g., monitoring unit) should be monitored and reported on individually. Do not rely on only average values tabulated across the entire mitigation area;

- The level of sampling per area should be determined by using a species-area curve, rather than an arbitrary pre-determined number of plots (see Kent and Coker, 1992);
- If species-area curves are not used, at least two percent of each cover type within the mitigation area should be sampled;
- Sampling should occur in homogeneous areas with consistent mitigation treatments and should not overlap transition areas;
- Herbaceous layer sampling should be included to provide not only insight into vegetative community development in general (e.g., diversity, evenness), but also to allow calculation of weighted prevalence indices for each community type on the proposed mitigation site. Weighted prevalence indices provide early information about the evolution of those communities toward ones dominated by hydrophytes, and in turn, the degree of wetness in the sampled area. The herbaceous community responds rapidly to changes in site wetness; thus, it can be used in league with hydrologic monitoring data to assess hydrologic development of the site.
- Sampling must be sufficient to recognize areas of invasive plant coverage;
- Ground and shrub layer sampling must be sufficient to determine level of recruitment; and
- If the provider is comparing vegetation monitoring data to analog reference sites, the monitoring plan should outline the sampling and analysis plan for these sites as well.

7.5 Stream Performance Standards and Monitoring

Given the inherent variability and highly dynamic nature of streams, it is difficult to establish a static set of performance standards for a given point in time (e.g., achieve reference planform by year five). The choice of performance standards depends on the results of the classification, baseline assessment, objectives of the project, and the mitigation activities proposed in the workplan. The ultimate goal of any stream mitigation project is to re-establish hydrologic, hydraulic, geomorphic, physicochemical, and biological functions. As indicated in Section 6.3, there are a wide variety of methods which can be implemented to improve degraded stream conditions. Therefore, measuring the ecosystem response to any method requires careful consideration of the baseline condition, appropriate indicator parameters, and the availability of reference stream information for each function. Performance standards need to be informed by objective, verifiable indicators of stream function, and tied to reference standards or reference conditions. To this end, the following discussion lays out considerations for reviewers when determining if a particular project has appropriate parameters to ascertain the performance of a project.

Similar to wetlands, direct measures of stream functions would be advantageous, but are often complex, time consuming and costly to obtain. Measuring point-in-time indicators of function is often more practical for compensatory mitigation sites. These indicators typically represent one element of function (e.g., recruitment of native riparian vegetation, bedform diversity), and this link should be described as part of the documentation, so the reviewer and provider are clear about what is being measured and why. For instance, bank height ratio (BHR) can be used as an indicator of floodplain/ lateral connection, with the explanation that low BHR (e.g., 1.0-1.2) is an indicator of the stream's ability to access its floodplain. Similarly, density, composition, and areal coverage of riparian vegetation can be used as indicators of riparian processes, including floodplain roughness, availability of floodplain habitat for fish species during floods, or large wood recruitment. These indicators can be measured objectively and consistently to document trends in recovery of the stream project. Often, multiple indicators will be used to provide a more complete picture of function (e.g., stream pattern, longitudinal profile, and cross-sectional geometry all contribute to assessment of geomorphology functions).

Specific benchmarks or threshold values to inform performance may be available (e.g., through university and/or scientific studies; local, state, or federal agency reports; peer-reviewed literature sources), but reviewers should ensure they are applicable. Stream Quantification Tools (SQTs) have been developed for a number of states in EPA Region 4, including Tennessee, Georgia, North Carolina and South Carolina, using various field indicators to generate index values and condition scores based on reference curves that represent disturbance gradients (TDEC, 2018; Somerville et al, 2021; Harman and Jones; 2016; South Carolina Steering Committee, 2021). Several other references include lists of potential or recommended indicators which represent aspects of stream functions that could be used for monitoring or as performance standards (e.g., Roni and Beechie, 2013; Fischenich, 2003; Fischenich, 2006; Harman et al. 2012). Ideally, performance standards should be based on locally applicable (i.e., regional reference) values determined from resources that have developed under similar climatic regimes, geological conditions/soil types, and biological communities, etc., and that are located in similar positions within the stream network.

In the absence of a specific stream assessment protocol with reference data, the following indicators could be used, with site-specific performance standards informed by appropriate reference analogs within the same stream class:

- Bedform diversity (sequences of riffle, run, pool, and glide) appropriate for flow and stream type;
- Channel planform appropriate for valley type, stream type, and substrate type;
- Bank stability (height, bank angle, evidence of mass wasting and/or toe erosion, and consolidation of bank materials) and lateral migration rates appropriate for flow type and stream type;
- Substrate composition, embeddedness;
- Evidence of aggradation/degradation;
- Full annual hydrograph appropriate for the stream type and watershed position, including peak stormflows, rate of change (flashiness), recessional flows, and baseflows. Specific parameters may include floodplain connectivity/inundation, frequency and duration of saturation or depth of inundation, attenuation, and flow parameters relative to dynamic equilibrium, and species life history needs (e.g., timing);
- Plant community condition using indicators such as prevalence index, age-stand distribution, evidence of recruitment, and all applicable strata present;
- Indices of biotic community condition (e.g., IBI/MMI, O/E) for bugs, algae, fish (Stein et al., 2022).

The purpose of restoration is to address the stressors affecting the project reach, and there are numerous stressors that affect various stream functions (see Section 4.5). Table 18 lists examples of common restoration actions used to address certain stressors and the potential physical and biological measures which could be used as indicators to develop performance standards. These actions provide a means for reviewers to compare the proposed objectives and restoration actions with appropriate performance and monitoring parameters. While providers will likely propose monitoring parameters other than, or in addition to, those in Table 18, reviewers should evaluate whether there are performance standards and monitoring tied to each project objective. The reviewer should keep in mind that the results of the baseline assessment, or the identification of stressors, will affect not only the actions needed to achieve the target condition, but also how the effects are demonstrated. The potential performance measures in Table 18 are listed as either physical or biological and represent various aspects of stream functions which may be sensitive to change as a result of a stream mitigation action. Specific thresholds or numeric values to define performance standards for these indicators will have to be based on comparison to reference standard conditions.

Table 18. Restoration actions (Roni and Beechie, 2013) or practices (Bledsoe et al., 2016) typically used to alleviate common stream impairments along with examples of indicators which can be used to assess the progress of restoring physical (hydrologic, hydraulic, geomorphic, water quality) and/or biological processes and functions.

Restoration Actions/Practice	Potential Performance Measures
Removal of barriers, dams, culverts and road crossings	**Physical**: change in channel morphology and elevation, sediment storage and composition. **Biological**: presence/absence of migratory fish species, seasonal species abundance and diversity; riparian vegetation composition and age structure.
Reconnect floodplain/ Floodplain connection	**Physical**: flow connection with main channel, channel morphology and elevation, habitat, sediment storage, wood and organic retention. **Biological**: fish abundance and diversity, fish passage and migration, macroinvertebrate and periphyton communities
Remove and/or setback levee/ Floodplain connection/ Riparian buffer	**Physical**: channel and floodplain morphology, topography and habitat; sediment and wood delivery and storage, duration of floodplain inundation **Biological**: Composition and age structure of riparian vegetation and vegetation diversity; and abundance of fish, macroinvertebrates and periphyton
Aggrade incised channels	**Physical**: Channel geometry, elevation and morphology, connectivity of floodplain habitats and their area and density, wood, water and sediment retention. **Biological**: Fish abundance and diversity, fish passage and migration, macroinvertebrate and periphyton communities
Road removal, stabilization, resurfacing	**Physical**: pool depth, scour, fine sediment, turbidity and water quality, streamflow and bankfull width **Biological**: fish survival, macroinvertebrate diversity and abundance.
Riparian buffer planting/ Riparian buffer	**Riparian area**: tree or plant survival, species composition, density and biomass; tree growth, height and diameter **In channel**: shade, temperature, organic inputs (leaf litter and woody debris), bankfull width, bank stability, channel migration, pool depth
In-stream structure placement/ In-stream enhancement	**Physical**: channel morphology, habitat area and composition (pool and riffle depth, area and number), wood abundance. **Biological**: fish abundance, diversity, growth and survival.
Reconstruction of channel/ Bank and bed stabilization/ Riparian buffer/ Floodplain reconnection/ In-stream enhancement	**Physical**: Channel bed (vertical) and bank (lateral) stability; channel geometry, slope change, sinuosity, and morphology; flow velocities, sediment and wood storage; connectivity of floodplain habitats and their area and density; wood, water and sediment retention. **Biological**: Fish abundance and diversity, fish passage and migration, macroinvertebrate and periphyton communities

Stream mitigation performance should be evaluated based on the trajectory of indicators relative to appropriate reference standards conditions over extended time periods (e.g., 10 years or more) that preferably includes at least one 10-year flow event or larger. Streams in watersheds with highly variable (flashy) flows in unconfined valleys and/or with rapidly changing land use and hydrology may need to be monitored longer than streams with more consistent flow patterns that have coarse substrates and/or occur in confined valleys. This is due to the effect flashy flows may have on sediment and geomorphic functions (e.g., flashy flows increase water velocities and sediment transport capacities which in turn could affect stream geomorphic stability and habitats).

Monitoring considerations: Implementation monitoring can typically be addressed by reviewing the "as-built" plans, as compared to the approved design plans, to evaluate whether the project was implemented as it was designed and approved. Typically, 60% design plans are used to develop the mitigation plan, which is an appropriate level of detail for planning. However, before a stream design is implemented, a 100% design is completed and used in the field for construction purposes. Any changes to the 100% design due to unexpected issues encountered in the field (e.g., trees to be kept or removed, bedrock outcrops, and unexpected infrastructure) are included in the "as-built" plan which represents what was actually implemented in the field; this represents the "final" project. The as-built plans should be considered carefully in the context of how any design changes may affect the objectives and performance standards detailed in the mitigation plan.

The primary reason to monitor the site after construction is to assess the effectiveness of the management action and progress toward project goals and objectives. In addition, if monitoring reveals that performance standards are not being attained within the timeframe expected, then steps may be required to fix a system or a component of the system that is not successful (i.e., adaptive management). Because each project is likely to have aspects that differ from other projects, a one-size fits all monitoring scheme cannot be prescribed, just as with performance standards. Various authors have offered guidelines for monitoring stream restoration projects (Roni and Beechie, 2013; Skidmore et al., 2011; Bledsoe et al., 2016; Saldi-Caromile et al., 2004; Cramer et al., 2012; FISRWG 2001). Reviewers are encouraged to refer to these references as more complete treatments of stream restoration monitoring. A brief list derived from the previous references is listed below. Generally, an effective monitoring plan should include:

(1) Selection of a monitoring design that will be robust to represent the achievement of performance standards for the entire site;
(2) Specification of the number of sites and duration of monitoring (e.g., collecting at least 10 years of hydrologic data will provide more confidence that a range of flow events have occurred before project closeout);
(3) Sufficient monitoring duration for riparian vegetation of up to, or exceeding, 10 years of monitoring to ensure desirable (i.e., target) tree, shrub and herbaceous species become established;
(4) Selection of a sampling scheme that occurs at multiple locations within a mitigation site and uses statistical principles to achieve an appropriate ability to detect change (i.e., statistical power);
(5) Parameters measured at the channel cross-section and longitudinal scale; and
(6) Graphical analysis and interpretation of results to show trends in data.

Since streams are intimately linked to the conditions in upstream and downstream reaches, mitigation actions in a specific reach may affect, and be affected by, upstream or downstream areas positively or negatively. For example, trapping sediment in one reach may result in downstream incision due to sediment starvation. As such, reviewers should consider whether providers have proposed an appropriate domain of analysis, or the extent, that should be assessed when evaluating mitigation performance. Upstream and downstream areas should be evaluated based on their hydraulic/geomorphic condition, channel evolution class, and degree of sediment continuity with the reach of interest (i.e., the mitigation or impact reach) (Stein et al., 2022). Ideally, the upstream domain should be defined as a distance equal to 20 channel widths or to the next upstream natural or engineered grade control, whichever comes first. Downstream domain should be defined as the closest of the following: at least one reach downstream of the first grade-control point (but preferably the second downstream grade control location); the nearest downstream tidal backwater/lentic waterbody; the nearest downstream equal-order tributary; or a two-fold increase in drainage area.

Hydrologic monitoring should begin prior to implementation of the workplan and should continue throughout the effectiveness monitoring period to document the delivery and variability of low, bankfull and flood flows to the channel and the floodplain. Similar to the monitoring approach for riverine wetlands, this monitoring should be conducted using stage or water level recorders, as well as shallow groundwater wells on the floodplain to document frequency and duration of inundation. Other monitoring approaches may be considered, such as wildlife cameras to capture flood events or modelling to simulate flows, however the method should be accompanied by the rationale for how it is representative of the site and informs the hydrologic performance standards.

Geomorphic monitoring can be completed using established cross-sections along a stream reach that are monitored with sufficient frequency to observe changes in channel morphology and geometry. Longitudinal surveys can be used to measure bed complexity and aggradation or degradation through time. These surveys should be of sufficient length (e.g., 20 times bankfull width or two meander wavelengths) to capture bedform morphology and thalweg variability (e.g., pool-riffle sequences) throughout the mitigation project reach. Where there are multiple stream classes or differences in mitigation actions, cross-sections and longitudinal surveys should be collected within each. Finally, bank heights and angles can be measured or obtained from cross-sections to assess bank stability and erosion through time. All surveys, whether cross-section surveys or longitudinal surveys, should be tied to fixed benchmark elevations.

Physicochemical monitoring should collect temperature, DO, flow rate, depth data, and any additional water quality constituents needed to monitor the specific objectives and performance standards of the project. Physicochemical, riparian vegetation and instream biology monitoring should be consistent with the data collected during the baseline assessment and should be sufficient to inform performance standards for the project. The response of biological communities to stream restoration efforts varies widely (Dyste and Valett, 2019; Griffith and McManus, 2020a; 2020b), thus monitoring timeframes for biological parameters may not occur at the same frequency, or as early in the monitoring period, as physical parameters. For additional information related to riparian vegetation monitoring, see the vegetation sub-section in Section 7.4 above.

8.0 How will the site be managed to sustain the target condition?

Restoration of aquatic resources is not an exact science. Aquatic ecosystems are complex and heavily influenced by landscape scale processes and stressors (e.g., hydrologic flows, sediment supplies, and forest patch sizes and corridors). Due to this complexity, many uncertainties exist in siting, planning, implementing, and monitoring any given compensatory mitigation project, including the effects of site and landscape-scale stressors (see Section 2.4). Monitoring and adaptive management are extremely important to achieving the goal of ecologically sustainable and resilient aquatic ecosystems to compensate for losses due to permitted impacts.

> In a best-case scenario, required site protections, financial assurances, maintenance and long-term management plans will facilitate the sustainability of the site. However, adaptive management measures may also be needed given the level of uncertainty inherent in mitigation projects.

This question outlines administrative components of a mitigation plan, including site protection mechanisms and financial assurances, as well as maintenance plans, long-term management plans and adaptive management plans. Although not specifically ecological, these management considerations are critical to the ability of the restored aquatic resource to persist on the landscape. If these components are addressed appropriately, responsibilities related to maintenance, funding, site protection and management will be clearly articulated, and mitigation projects are more likely to be self-sustaining once performance standards have been achieved. These components are generally provided as part of a completed draft mitigation plan, banking instrument or ILF instrument or addendum. The main opportunity to provide comments on these components will be during the Public Notice comment period for individual permits or during review of the draft mitigation bank instrument or ILF project addendums.

Review considerations for these components are similar for both wetland and stream compensatory mitigation projects (Box J). Reviewers will want to ensure that maintenance plans, adaptive management plans and financial assurances provide the funding and management necessary to achieve ecological success at project closeout. In the event a project is not meeting its performance standards, it is critically important that the information provided in these components is sufficient to diagnose and address problems. For example, reviewers will want to ensure the adaptive management plan outlines specific courses of action to rectify problems with the mitigation site and any additional monitoring that may be required to assure that the remedies are sufficient. Financial assurances should adequately cover costs involved with planning, constructing, monitoring and achieving the agreed upon performance standards. Reviewers will want to ensure site protection mechanisms and long-term management plans are appropriate to protect, fund, and manage the site in the long-term and ensure a sustainable and resilient aquatic ecosystem is maintained on the landscape.

Box J. Information to assess adequacy of wetland and stream mitigation project management.

Maintenance Plan
- What are the aspects of the project that will need maintenance?
- Does the plan outline the types of maintenance activities, their timing and costs?
- Do these activities contribute to goal of site sustainability?

Adaptive Management Plan
- Does the plan outline how monitoring data will be analyzed to identify potential challenges?
- Does the plan outline how and when adaptive management measures will be planned and implemented?
- If appropriate, have beaver been accounted for and incorporated into the site?

Financial Assurances
- Are specific mechanisms and dollar amounts specified?
- Are these sufficient to ensure successful completion of the project?

Long Term Management Plan
- Does the plan contribute to goal of site sustainability?
- Does the plan include any land uses that would be counterproductive to the goal of restoring a self-sustaining ecosystem?
- Does the plan outline the long-term management needs and financing mechanisms?

Site Protection Mechanism
- What type of mechanism is proposed (e.g., conservation easement, restrictive covenant, other)?
- Will the mechanism protect the site in perpetuity?

8.1 Regulatory Context

The Mitigation Rule requires site protection, maintenance, long-term management, adaptive management, and financial assurances be included in a mitigation plan or instrument. Additional regulatory context is provided for each element below.

8.2 Maintenance Plan

Maintenance plans describe and outline a schedule of maintenance requirements to ensure the continued viability of the resource once initial construction is completed (40 CFR §230.94(c)(8)). The maintenance plan should account for activities that will need to take place on the project site for the duration of the monitoring period, and should include the types of maintenance activities, their timing, and estimated costs. Maintenance activities should support the goal of making the compensatory mitigation site ecologically sustainable and resilient, and there should be nothing in the maintenance plan that allows land uses or management techniques that may damage the restored stream or wetland's structure or function. Routine maintenance activities could include maintaining or replacing monitoring equipment, signage and fencing, replanting dead vegetation, management of invasive species, routine burns and/or vegetation management in fire-adapted sites, maintaining access to monitoring stations and for field inspections, etc. Maintenance may also be needed for structures, if any are installed as part of the mitigation plan. Unexpected or repeated needs for maintenance during the monitoring period may indicate problems that require resolution (e.g., erosion around the sides of ditch plugs, erosion around or underneath stream structures, and repeated die-off of planted vegetation), and these non-routine maintenance activities should be addressed under an adaptive management plan (see Section 8.3).

8.3 Adaptive Management Plan

According to the Mitigation Rule, adaptive management means the development of a management strategy that anticipates likely challenges associated with compensatory mitigation projects and provides for the implementation of actions to address those challenges, as well as unforeseen changes to those projects (40 CFR §230.94(c)(12) and §230.97(c)). Adaptive management requires consideration of the risk, uncertainty and dynamic nature of compensatory mitigation projects (see Section 2.4), and guides the process by which project modifications are implemented to optimize performance and reduce project uncertainty (i.e., *will mitigation actions be effective?).*

An adaptive management plan should identify specific measures that ensure aquatic resource functions are maintained, outline how monitoring results will be analyzed to identify potential problems, and identify implementation measures to rectify those problems. Plans should be informed by both a provider's and IRT reviewers' experiences with similar projects in which performance was not attained without modifying the plan, and monitoring results which indicate performance standards are not being achieved. For instance, if soil conditions of a riparian or wetland area are not properly prepared and amended after site construction, experience has shown that vegetative plantings will likely fail. This can be anticipated and a plan put in place to rectify the problem should it happen. In another example, hydrologic monitoring of a riverine wetland site may indicate the target flood regime is not occurring with the frequency, duration, and magnitude expected. For this example, the results of the monitoring (see Section 7.3) are crucial to diagnosing the change and providing information on when adaptive management measures may be needed. If not achieving performance standards, providers will need a plan to address the deficiencies and achieve performance.

8.3.1 Examples of Conditions Requiring Adaptive Management

Most importantly, adaptive management will be needed if monitoring results indicate performance standards and target conditions not being met. Some additional examples of challenges to wetland and/or stream projects that may require adaptive management might include:

- Large flood events that may destroy floodplain/riparian vegetation, avulse into a new or old channel, or erode unprotected streambanks;
- Establishment of invasive species which threaten to dominate and/or alter the target condition of the site;
- Droughts, which may delay or prevent the establishment of appropriate channel forming flows and biological communities (e.g., by slowing their development or restricting movement, particularly of fish) or lead to drying conditions which will carry fire. In some wetland types, like mineral soil flats, fire is a natural ecosystem process. However, in other wetland types, like cypress domes or wetlands with organic soils, fire may diminish the functions of the wetland.
- Upstream or surrounding watershed disturbances occurring after construction that may result in changes to sediment or hydrologic processes (e.g., the delivery of large sediment loads or flashier flows to the site);
- Damage due to trespass (e.g., off-road vehicle damage to stream channels or wetlands, unwanted cattle access to streams)

8.3.2 Beaver

Although not an anthropogenic stressor, and in fact an ecological enhancement to many aquatic resource functions (Naiman et al., 1988; Gurnell, 1998; Meetenmeyer and Butler, 1999; Pollock et al., 2007; Burchsted et al., 2010; Polvi and Wohl, 2013; Pollock et al., 2014), beaver *(Castor canadensis)* can present adaptive management challenges for aquatic resource mitigation sites. Although beaver may affect wetlands via alterations to planted vegetation, hydroperiods and nutrient quality (Bason et al., 2017), they primarily affect stream mitigation sites in the southeastern U.S., where the construction of beaver dams is perceived to disrupt the design and function of the restored stream reach and associated riparian zone.

Because of their potential benefits to stream stability and biology, reviewers should ensure adaptive management measures first consider a careful examination of both present and anticipated effects of beaver-constructed structures on the mitigation site, adjacent lands and existing infrastructure before destroying the structures. Ideally, this examination should be coordinated with the USACE and the other IRT member agencies. Beavers are a natural part of the historic ecosystem, and their presence on a site should not automatically be considered an impairment. Not only do beaver provide woody debris and habitat diversity for the larger system, but they also provide stream stability and reduce erosion by reducing water velocities and shear stress on stream banks. Unless there is a compelling reason to remove beaver dams from the system, reviewers may want to recommend other actions, such as re-evaluating and adjusting mitigation credits allocated for the project to reflect ecosystem conditions affected, or caused, by the beaver activity. In general, reviewers should consider a three-step process for addressing issues with beaver present on either proposed or implemented compensatory mitigation sites:

(1) If beaver are present on a site being proposed for a mitigation project, reviewers should consider how workplans, maintenance plans, long-term and adaptive management plans could accommodate their presence. Ideally, beavers should be allowed to remain, and reviewers should work with the IRT and the mitigation provider to incorporate the beaver-modified landscape into the mitigation plan.
(2) If construction of a stream channel is undertaken as a mitigation activity on a mitigation site and beaver construct a dam on a portion of the constructed reach, reviewers should work with the IRT and the mitigation provider to see if modifications could be made to accommodate the beaver, while also endeavoring to allow the mitigation provider equitable mitigation credit. If the potential exists for beaver to colonize a project site, reviewers should consider how long-term and adaptive management plans accommodate their presence.
(3) If beaver move into a mitigation site and construct a dam that floods adjacent property or endangers critical infrastructure, then reviewers should work with the mitigation provider and IRT to determine if the beaver need to be managed and/or removed from the site. Beaver can be difficult to successfully eradicate, which presents long-term management challenges from both a mitigation site performance and financial standpoint. Reviewers should work with the mitigation provider and IRT to modify mitigation plans, as necessary.

8.4 Financial Assurances Plan

The financial assurances plan describes the mechanism and dollar amounts that will be provided by the sponsor and demonstrates how they will ensure a high level of confidence that the compensatory mitigation project can be completed in accordance with approved plans and performance standards (40 CFR §230.94(c)(13)). Financial assurances are an important mechanism for managing the risk of project failure, including failure to complete the project, to meet performance standards or to maintain the mitigation project. Holding all forms of compensatory mitigation to equivalent standards, including financial assurances helps to reduce uncertainty, including risk of project failure (USACE, 2016a). These plans are typically worked out between the mitigation provider and USACE Districts and cannot be modified without prior notice to USACE. For information on financial assurances for compensatory mitigation see *Implementing Financial Assurances for Mitigation Project Success* (USACE 2016a).

8.5 Long-Term Management Plan

The long-term management plan outlines how the compensatory mitigation project site will be managed after performance standards have been achieved to ensure the long-term sustainability of the resource (40 CFR §230.94(c)(11)). This is a very important aspect of the compensatory mitigation program since many ecosystem functions will likely not fully develop within the typical monitoring period. Therefore, the long-term management plan should account for the continued maturation of the mitigation site and identify any long-term management or maintenance needs on site. There should be nothing in the long-term management plan that allows land uses or management techniques that may damage the site’s structure or function. This restriction on potentially damaging management should also be incorporated into the conservation easement and/or deed restriction to provide some legal enforceability to the long-term management of a site. If stressors are likely to persist or potentially arise during the long-term management phase of the project, the long-term management plan should include a discussion of how the site will be adaptively managed to ameliorate any adverse effects.

The long-term management plan must also include long-term financing mechanisms (e.g., endowments or trusts) and identify the party responsible for site ownership and long-term management of the mitigation project (40 CFR §230.97(d)). In fact, the responsible party must be identified in the permit conditions authorizing the project, bank or ILF instrument. The permittee or sponsor may transfer the long-term management responsibilities to a public or private land stewardship entity approved by the USACE District Engineer after final performance standards are met. Reviewers should work with USACE to ensure that adequate financial and legal (e.g., land use restrictions on project site) resources have been put in place to ensure site sustainability.

8.6 Site Protection Mechanism

The site protection mechanism is a description of the legal arrangements and instrument, including site ownership, that will be used to ensure the long-term protection of the mitigation project site (40 CFR §230.97(a)). The long-term protection of mitigation sites should be arranged through appropriate real estate instruments, such as conservation easements or transfer of title to public or private land managers. The real estate instrument should restrict or prohibit incompatible uses (e.g., clear cutting, all-terrain vehicle access). Typically, these mechanisms will be conservation easements or restrictive covenants. These plans are typically worked out between the mitigation provider and USACE Districts and cannot be modified without prior notice to USACE. Key aspects of site protection mechanisms and securing them for a site are outlined in the *Compensatory Mitigation Site Protection Instrument Handbook* (USACE, 2016b).

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Appendix A. EPA Region 4: Information to Consider for Wetland Mitigation Projects

Section 3.2 (Box A): Recommended information to inform HGM wetland classification

Hydrogeomorphic classification:
- What is the HGM classification of the existing wetlands on site?
  - Geomorphic position. Data source?
  - Water sources. Data source?
  - Hydrodynamics. Data source?
  - Applicable HGM regional guidebook? Rationale?
- Does the site classification suggest that a different wetland type would be appropriate?

Soils information to support classification:
- Geomorphic position
- Flooding (frequency, timing and duration)
- Ponding (timing, frequency and duration)
- Seasonal high-water table (depth and timing)

Section 4.2 (Box C): Recommended information to evaluate watershed-scale stressors

Watershed scale issues that must be addressed include:

Sediment and water quality functions
- Are land uses impacting sediment supply to the stream reach or wetland?
- Are land uses potentially impacting water quality from urban or agricultural runoff?
- Are any upstream or downstream impediments (e.g., dams, weirs, perched culverts, road crossings) affecting sediment/organic matter transport and/or timing?
- How much of the proposed site is contiguous to natural land cover, indicating adequate buffers?
- Are any water quality impairments occurring in the contributing catchment or watershed?

Hydrologic potential
- What is the propensity for site hydrology and wetness?
- Are land uses altering runoff processes (e.g., flashy hydrographs) to the stream reach or wetland?
- Are any upstream or downstream impediments (e.g., dams, weirs, perched culverts, road crossings) affecting flow characteristics (i.e., magnitude, duration, frequency, timing, rate of change)?
- Does soil data support wetland conditions?

Landscape connectivity
- Are land uses impacting the connectivity of stream and wetlands to adjacent habitats?
- Are any upstream or downstream impediments (e.g., dams, weirs, perched culverts, road crossings) limiting biota movement (i.e., longitudinal connectivity)?
- Are any impediments limiting flow access to floodplain (lateral connectivity) during flood events?
- Is the site located within an ecologically connected hub or corridor that identifies both aquatic and terrestrial connectivity?

Can the mitigation provider ameliorate adverse landscape-scale conditions with onsite management to reduce or remove the effects of those conditions on restoration site potential?

Section 4.4 (Box D): Recommended information to evaluate wetland baseline condition.

Information below is in addition to, and complementary of, the results of the watershed analysis:

- Is the site in the reference domain of an existing HGM regional guidebook?
- Is the wetland of similar class and subclass to that in the HGM guidebook? List the wetland functions of the site and how they have been impaired.
- If HGM guidebook is used, what are the results?
- Was a rapid assessment method used? If so, which one and what were the results?
- What stressors are present on the site (e.g., clear-cut, ditching, fill)?
- Has plot-level vegetation data been appropriately stratified and sampled at a sufficient intensity? If so, how was the information interpreted? What effect have stressors had on vegetation?
- Has site-specific soil mapping and soil verification been completed? What effect have stressors had on soils?
- Have soil profile descriptions, notation of hydric soil indicators, and impacts to soil integrity (e.g., tilling, plowing, bedding, land clearing, mining, and fill) been provided?
- Is there available hydrologic monitoring data, depending on HGM class and soils (e.g., surface water ponding, shallow groundwater/water table data)? For what duration?
    - Are there active stream stage recorders? For what period of record is data available?
    - Are there rain gauges in proximity to the site? For what period of record is data available?
    - Are there active ground water wells? How long have they been active and at what frequency/ interval is the data available?
- Have results from hydrologic monitoring been graphically represented with rainfall data?
- What effect have the stressors had on ground and/or surface water hydrology?

Section 5.0 (Box F): Recommended information to identify appropriate target condition.

- What are the goal statements outlining the expectations for the project considering the aquatic resource class(es), baseline conditions and the identified stressors and impairments affecting the site?
- Given the conditions in and around the site (from baseline assessment), will the proposed site support the target functions/condition(s)?
- Are goals and objectives tied to specific functions?
    - For wetlands, consider hydrologic, biogeochemical and habitat functions
    - For streams, consider hydrologic, hydraulic, geomorphic, physicochemical and biological functions
- Are the objectives:
    - Specific to the aquatic resource class(es) on site?
    - Measurable (as indicators of functions outlined above)?
    - Achievable given current and projected site-specific and watershed stressors?
    - Relevant and supportive of the goals of the project?
    - Time bound to the monitoring and performance period of the project?
- What reference approach(es) was (were) used to establish target condition(s)? Are there reference aquatic resources, including reference standard sites or regional references (e.g., HGM regional guidebooks), to which the target condition can be compared?
- Is (are) the reference site(s) the same class and representing the least-altered condition to which the biology can be compared?

Section 6.2 (Box G): Recommended information to address appropriateness of wetland mitigation plan/design.

The following questions should be addressed in context with the site classification (Section 3), baseline watershed and site assessment (Section 4), and the goals and objectives for the project (Section 5):

Hydrology

- Do the methods proposed address degradation of the wetland's water inputs, outputs, and storage capacity as compared to reference wetlands of the same class?
- Are the methods justified (i.e., purpose, rationale, effectiveness, and assumptions)?
- Will these methods restore the hydroperiod of surface and/or groundwater typical for this wetland type?
- What is the growing season hydroperiod during normal, wet, and dry years AND will this support a vegetation community similar to reference standard?

Soils

- Do the methods proposed address degradation of the wetland's soils as compared to mapped soils and reference?
- Are the methods justified (i.e., purpose, rationale, effectiveness, and assumptions)?
- Will these methods restore the soil characteristics (e.g., permeability, structure, hydric characteristics, and bulk density) indicative of this wetland type?

Vegetation

- Do the methods proposed address degradation of the wetland's vegetation community as compared to reference standard?
- Are the methods justified (i.e., purpose, rationale, effectiveness, and assumptions)?
- Will these methods restore a plant community (all strata) typical of the reference wetland class?
- Does the proposed method include a vegetative planting plan that accounts for variations in soil types, site elevations, planting depths, and timing for planting?

Section 7.0 (Box I): Recommended information to address performance standards and monitoring.

Performance Standards

- Does each performance standard tie to a specific project objective?
- Are performance standards provided for the suite of functional indicators (see below) tied to project objectives?
- Is each performance standard informed by appropriate reference standard comparisons?
- Is each performance standard described using clear and concise wording?
- Is each performance standard scientifically defensible (e.g., sensitive to changes in function)?
- Is each performance standard supported by data collection methods that are appropriately timed, repeatable and with clearly defined error rates?

Monitoring Plan

- Are data collection methods for each performance standard outlined in the monitoring plan?
- Have pre-project baseline data been collected for all measures outlined in the monitoring plan?
- Has the timing of data collection (e.g., frequency, duration, and seasonality) been determined?
- Has the location and scale of data collection (e.g., reach, riparian, and watershed) been determined?
- Is the sampling intensity (number and arrangement of locations/plots) appropriate for the chosen parameter?
- Is the sampling of sufficient intensity and precision to detect deviations from performance standards and indicate the need for adaptive management?
- Does the plan outline how data will be analyzed and reported?

Review of post-project monitoring

- Compare the as-builts to the design criteria outlined in the mitigation plan. Was the project built to specifications in the plan? If not, why not?
- Do the results of monitoring show the site is on track to meet performance standards? If not, is adaptive management needed?

Performance standards and monitoring expectations by functional category

Wetland Hydrology:

- Measures that demonstrate timing, duration and frequency of saturation, ponding, and/or flooding, during at least 3 normal rainfall years, similar to hydrologic monitoring data in the same HGM subclass of reference standard wetlands on similar soils.
- Methods should be sufficient to monitor the site's hydrologic sources and gradient (e.g., rain gauges, stream gauges and/or an array of groundwater wells).

Wetland Soils:

- If soils have been disturbed or drained, measures that demonstrate they meet hydric soil criteria for saturation (minimum 14 consecutive days) and anaerobiosis as per National Hydric Soil Technical Standard.
- Measures that demonstrate the soil is accumulating organic material; developing appropriate bulk density, texture, and nutrient concentrations; and soil microtopographic features (shallow depressions and minor hummocks) similar to reference standard.

Wetland Vegetation:

- Measures that demonstrate plant survival to sapling stage; species composition and density (e.g., establishment of native species in all strata); response of herbaceous components of vegetative community to hydrologic changes (i.e., Weighted Prevalence Index) and trending towards a hydrophyte dominated community; relative abundance or cover of various age classes, including evidence of recruitment; and an expectation for maximum allowable invasive plant species cover.
- All performance standards should be similar to, or along a trajectory towards, reference standard.

Section 8.0 (Box J): Information to assess adequacy of wetland and stream mitigation project management.

Maintenance Plan
- What are the aspects of the project that will need maintenance?
- Does the plan outline the types of maintenance activities, their timing and costs?
- Do these activities contribute to goal of site sustainability?

Adaptive Management Plan
- Does the plan outline how monitoring data will be analyzed to identify potential challenges?
- Does the plan outline how and when adaptive management measures will be planned and implemented?
- If appropriate, have beaver been accounted for and incorporated into the site?

Financial Assurances
- Are specific mechanisms and dollar amounts specified?
- Are these sufficient to ensure successful completion of the project?

Long Term Management Plan
- Does the plan contribute to goal of site sustainability?
- Does the plan include any land uses that would be counterproductive to the goal of restoring a self-sustaining ecosystem?
- Does the plan outline the long-term management needs and financing mechanisms?

Site Protection Mechanism
- What type of mechanism is proposed (e.g., conservation easement, restrictive covenant, other)?
- Will the mechanism protect the site in perpetuity?

Appendix B. EPA Region 4: Information to Consider for Stream Mitigation Projects

Section 3.3 (Box B): Recommended information to address stream characterization.

What is the stream's watershed/landscape context?

- Where does the stream sit in the watershed?
    - e.g., determine Strahler stream order (ensure appropriate mapping resolution) and watershed size
- What is the current valley type (e.g., very confined, confined, partially confined, unconfined)?
    - Data sources? How was valley type determined?
- In what ecoregion does the site occur?

What is the flow permanence?

- Is the stream reach perennial, intermittent, or ephemeral? Data sources?

What is the geomorphic context?

- What classification approach(es) was/were used?
- Were all relevant data provided to support classification? (e.g., entrenchment ratio, width/depth ratio, sinuosity, bed materials, slope, number of channels)
- What are the stable stream types for the given valley type? How does that compare to the existing stream type?
- What is the Stream/Channel Evolution stage?
    - Model used?
    - Justification for stage?
    - Field indicators noted?

Section 4.2 (Box C): Recommended information to evaluate watershed-scale stressors

Watershed scale issues that must be addressed include:

Sediment and water quality functions

- Are land uses impacting sediment supply to the stream reach or wetland?
- Are land uses potentially impacting water quality from urban or agricultural runoff?
- Are any upstream or downstream impediments (e.g., dams, weirs, perched culverts, road crossings) affecting sediment/organic matter transport and/or timing?
- How much of the proposed site is contiguous to natural land cover, indicating adequate buffers?
- Are any water quality impairments occurring in the contributing catchment or watershed?

Hydrologic potential

- What is the propensity for site hydrology and wetness?
- Are land uses altering runoff processes (e.g., flashy hydrographs) to the stream reach or wetland?
- Are any upstream or downstream impediments (e.g., dams, weirs, perched culverts, road crossings) affecting flow characteristics (i.e., magnitude, duration, frequency, timing, rate of change)?
- Does soil data support wetland conditions?

Landscape connectivity

- Are land uses impacting the connectivity of stream and wetlands to adjacent habitats?
- Are any upstream or downstream impediments (e.g., dams, weirs, perched culverts, road crossings) limiting biota movement (i.e., longitudinal connectivity)?
- Are any impediments limiting flow access to floodplain (lateral connectivity) during flood events?
- Is the site located within an ecologically connected hub or corridor that identifies both aquatic and terrestrial connectivity?

Can the mitigation provider ameliorate adverse landscape-scale conditions with onsite management to reduce or remove the effects of those conditions on restoration site potential?

Section 4.5 (Box E): Recommended information to evaluate stream baseline condition.

Information below is in addition to, and complementary of, the results of the watershed analysis.

Hydrologic (Summary of hydrologic analyses conducted, data sources and period of record)

- How were flood flows, low flows, and bankfull flows calculated? Was a stream gauge used to evaluate the period of record for the site? If not, how were streamflow estimates made (e.g., Manning's equation, regional regression equations, StreamStats, hydraulic models, runoff and streamflow models)?
- Was floodplain groundwater elevation established? Is the groundwater flowing across the floodplain towards the channel? At what time of year?
- What watershed and site scale stressors affect the hydrology of the site?

Hydraulic

- Were hydraulic models used? If so which ones? Was the confidence in the model results explained?
- Were sediment transport models used? If so, which ones? Was the confidence in the model results explained?
- What watershed factors contribute to the sediment supply?
  - Severe bank erosion in the channel network? Mass wasting?
  - Channel incision upstream?
  - High availability of coarse sediment in bed or banks?
  - What flow and sediment retention areas exist in the upstream watershed? (e.g., reservoirs, ponds, low head dams)
- How will the evolution of the upstream channels effect sediment supply? What is the CEM / SEM stage above the reach? Below the reach?

Geomorphic

- Methods used to complete channel stability assessment? Results?
- What is the current planform; longitudinal profile; and dimension of the project reach?
- What are the causes of channel instability? How were they determined?
- How do channel impairments effect stream and floodplain habitat? Is the channel laterally constrained?
- Extent of channel alteration (e.g., enlargement, floodplain encroachment, or channelization) of the project reach?

Physicochemical

- Are state surface water quality standards being met? If not, how often and under what conditions are they out of compliance?
- What are the sources of nutrients and other pollutants in the watershed and are they effecting the site?
- Is this reach on the 303(d) list or other TMDL for any of the following impairments: sediment, nutrient, metals & toxics, temperature, or flow modification?
- Can the components of existing water quality that are limiting biological productivity be addressed at the mitigation site (e.g., mass wasting, flooding, streamflow, shade, vegetation, and soils)?

Biological

- Biological community parameters sampled? Protocol? Results?
- Are habitat features altered? Cause of those alterations?
- Are there high-quality sites upstream and downstream of the proposed site? Would this project connect the upstream and downstream sites?
- Are there sources of beneficial organisms that can migrate from the upstream or downstream portions of the watershed to repopulate the site? Proximity of those source areas to the mitigation site?
- Are there invasive species (animals, plants, and algae) that will migrate from the upstream or downstream portion of the site that would affect long term characteristics of the site communities?
- What is the percentage and average width of the intact riparian area contiguous to the site?

Section 5.0 (Box F): Recommended information to identify appropriate target condition.

- What are the goal statements outlining the expectations for the project considering the aquatic resource class(es), baseline conditions and the identified stressors and impairments affecting the site?
- Given the conditions in and around the site (from baseline assessment), will the proposed site support the target functions/condition(s)?
- Are goals and objectives tied to specific functions?
  - For wetlands, consider hydrologic, biogeochemical and habitat functions
  - For streams, consider hydrologic, hydraulic, geomorphic, physicochemical and biological functions
- Are the objectives:
  - Specific to the aquatic resource class(es) on site?
  - Measurable (as indicators of functions outlined above)?
  - Achievable given current and projected site-specific and watershed stressors?
  - Relevant and supportive of the goals of the project?
  - Time bound to the monitoring and performance period of the project?
- What reference approach(es) was (were) used to establish target condition(s)? Are there reference aquatic resources, including reference standard sites or regional references (e.g., HGM regional guidebooks), to which the target condition can be compared?
- Is (are) the reference site(s) the same class and representing the least-altered condition to which the biology can be compared?

Section 6.3 (Box H): Recommended information to address appropriateness of stream mitigation plan/design.

Addressing the following questions should be done in the context of the mitigation site's classification (Section 3), baseline watershed and site assessment (Section 4), and the goals and objectives for the project (Section 5):

Hydrologic

- From what type of hydrologic data were design flows derived (e.g., gauge, ungauged, models, equations)?
- Are impairments to hydrologic connectivity of the stream reach addressed in the mitigation plan? Including:
  - Longitudinal connectivity (e.g., dams, weirs, road crossings, and culverts)
  - Lateral connectivity (e.g., levees, floodplain development)
  - Vertical connectivity (e.g., hyporheic exchange)
- Is the project reach experiencing hydrologic flashiness (based on assessment of contributing watershed imperviousness)?
- Do the methods proposed address the current condition of the stream's low, bankfull and flood flows?
- Will the proposed methods restore the timing, magnitude, frequency, and duration of surface and/or groundwater flows typical for this stream type where these conditions are impaired?

Hydraulic

- What methods were used to address the hydraulics of the reference reach? Were the same methods used for the designed reach?
- Has the provider accounted for expected sediment flows into and out of the project reach under the full range of flow conditions (i.e., low, bankfull, and flood flows)?
- If the provider set a goal of equilibrium conditions, how have they accounted for the hydraulic and sediment capacity and supply conditions upon which the design to achieve equilibrium is based (e.g., modelling)?
- If the provider has NOT set a goal of equilibrium conditions in the project reach, how have they accounted for sediment capacity and supply through the reach (i.e., sediment storage on the floodplain)?
- If the project reach is incised how, and to what extent, will the provider reconnect the floodplain?

Section 6.3 (Box H cont'd): Recommended information to address appropriateness of stream mitigation plan/design.

Addressing the following questions should be done in the context of the mitigation site's classification (Section 3), baseline watershed and site assessment (Section 4), and the goals and objectives for the project (Section 5):

Geomorphic

- What methods are proposed to address degradation of the stream's vertical and lateral stability?
- Will channel reconfiguration (planform, slope, and cross-sectional geometry) be required? Has sufficient justification for it been included by the provider?
  - If so, has the provider supplied adequate rationale for using this method?
  - Have the risks associated with this method been evaluated?
- Will bed materials be replaced? If so:
  - With what will they be replaced?
  - What is the rationale for, and the risks associated with, using this method?
- Will streambanks require protection? If so:
  - How will they be protected?
  - What is the rationale for the methods that will be used?
  - Have the risks associated with the methods chosen been considered?
- Will instream structures be used?
  - For what purpose?
  - Have the risks associated with how the structures will affect stream processes been considered?
- Were other less physically disturbing methods to the ecosystem evaluated and justifiably determined inappropriate for the project?

Physicochemical

- Will the methods chosen for other aspects of the project (e.g., hydrology, hydraulics, geomorphology) potentially affect the water quality of the project reach and/or upstream or downstream reaches?
- Are there specific actions proposed to ameliorate on-site or off-site sources of adverse water quality? If so, are the actions/methods rational and likely to succeed?

Biological

- Riparian Vegetation
  - Will planting riparian vegetation be necessary? If so:
    - Is species composition and spatial placement (with regards to hydroregime) appropriate when compared to appropriate reference?
    - Are planting methods and timing appropriate?
    - Are the appropriate species planted in appropriate zones?
- Instream Habitat:
  - Will large wood or instream structures be required for habitat?
  - Have the risks and effects on stream processes associated with creating habitat with structures, been evaluated?
  - Have sufficient intact populations of biota been identified near the project area?

Section 7.0 (Box I): Recommended information to address performance standards and monitoring.

Performance Standards

- Does each performance standard tie to a specific project objective?
- Are performance standards provided for the suite of functional indicators (see below) tied to project objectives?
- Is each performance standard informed by appropriate reference standard comparisons?
- Is each performance standard described using clear and concise wording?
- Is each performance standard scientifically defensible (e.g., sensitive to changes in function)?
- Is each performance standard supported by data collection methods that are appropriately timed, repeatable and with clearly defined error rates?

Monitoring Plan

- Are data collection methods for each performance standard outlined in the monitoring plan?
- Have pre-project baseline data been collected for all measures outlined in the monitoring plan?
- Has the timing of data collection (e.g., frequency, duration, and seasonality) been determined?
- Has the location and scale of data collection (e.g., reach, riparian, and watershed) been determined?
- Is the sampling intensity (number and arrangement of locations/plots) appropriate for the chosen parameter?
- Is the sampling of sufficient intensity and precision to detect deviations from performance standards and indicate the need for adaptive management?
- Does the plan outline how data will be analyzed and reported?

Review of post-project monitoring

- Compare the as-builts to the design criteria outlined in the mitigation plan. Was the project built to specifications in the plan? If not, why not?
- Do the results of monitoring show the site is on track to meet performance standards? If not, is adaptive management needed?

Performance standards and monitoring expectations by functional category

Stream Hydrologic Functions:

- Measures that demonstrate the timing, rate of change (flashiness), duration and frequency of low, high and design flows comparable to reference standard condition.

Stream Hydraulic Functions:

- Measures that demonstrate sediment transport in the channel and across the floodplain are as designed and in an equilibrium condition.

Stream Geomorphic Functions:

- Measures that demonstrate that boundary conditions in the restored reach are as designed and comparable to reference standard condition.

Stream Physicochemical Functions:

- Measures that demonstrate water quality (pH, DO, temperature, and nutrients) has not declined after project from baseline condition.
- Measures that demonstrate water quality parameters are improving towards reference standard condition.

Stream Biological Functions:

- Measures that demonstrate benthic macroinvertebrates and/or fish and riparian vegetation are improving towards reference standard condition.

Section 8.0 (Box J): Information to assess adequacy of wetland and stream mitigation project management.

Maintenance Plan

- What are the aspects of the project that will need maintenance?
- Does the plan outline the types of maintenance activities, their timing and costs?
- Do these activities contribute to goal of site sustainability?

Adaptive Management Plan

- Does the plan outline how monitoring data will be analyzed to identify potential challenges?
- Does the plan outline how and when adaptive management measures will be planned and implemented?
- If appropriate, have beaver been accounted for and incorporated into the site?

Financial Assurances

- Are specific mechanisms and dollar amounts specified?
- Are these sufficient to ensure successful completion of the project?

Long Term Management Plan

- Does the plan contribute to goal of site sustainability?
- Does the plan include any land uses that would be counterproductive to the goal of restoring a self-sustaining ecosystem?
- Does the plan outline the long-term management needs and financing mechanisms?

Site Protection Mechanism

- What type of mechanism is proposed (e.g., conservation easement, restrictive covenant, other)?
- Will the mechanism protect the site in perpetuity?