DRAFT Stream Function Quantification Tool

A Method to Measure Improvements in Stream Function

Draft Conceptual Model

Prepared By:
Stream Mechanics
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Introduction

This document describes the conceptual underpinnings of a Stream Function Quantification (SFQ) tool that is being developed to assist Interagency Review Teams (IRTs) with developing stream mitigation protocols. The (SFQ) tool is designed to improve stream mitigation by 1) quantifying functional lift resulting from mitigation projects; 2) ensuring that mitigation design matches the restoration potential; and 3) developing stream mitigation credits.

The concepts and methods of this SFQ tool are applicable to stream mitigation and restoration across the country. The concepts described below are a first step. Additional steps by the IRT and a stakeholder group will be needed to complete the SFQ tool. By providing an explanation of the mechanics behind the SFQ, this document provides a means for IRT and technical stakeholder engagement. This document is organized into four sections as outlined below, each with a set of sub-sections, including some with questions or issues for further review.

Section I: Purpose and Approach
The purpose driving SFQ tool development is explained relative to current practices, including a general description of the quantification tool and mention of what is not included in the approach.

Section II: Stream Functions Pyramid Framework Overview
The Stream Functions Pyramid Framework (SFPF) provides the scientific basis of the SFQ tool, which is described in detail in *A Function-Based Framework for Stream Assessment and Restoration Projects* (Harman and others, 2012), published by the US Environmental Protection Agency and the US Fish and Wildlife Service. A condensed description of the SFPF is provided along with information about how it will be applied and adapted to create the SFQ tool.

Section III: Conceptual Model for Determining Functional Lift
The conceptual model for determining functional lift and stream mitigation credit using the SFQ tool is outlined in a 10-step flowchart. A description of each model component follows, accompanied by additional diagrams and tables to illustrate concepts and processes.

Section IV: Next Steps and Outstanding Issues
The document concludes with a description of actions will be required to finalize and implement

the conceptual model. This section also outlines several of the overarching issues and questions that will need to be resolved during the IRT and stakeholder review process.

Section I: Purpose & Approach

The Stream Function Quantification (SFQ) tool is designed to improve stream mitigation by 1) quantifying functional lift resulting from mitigation projects; 2) ensuring mitigation design matches the restoration potential; and 3) developing stream mitigation credits.

Quantifying Functional Lift for Mitigation Practices

Functional lift is defined as the improvement in physical, chemical, and/or biological functions of a degraded stream corridor. It is the difference in stream condition after restoration compared to the pre-restoration condition. This definition of functional lift is consistent with the purpose and intent of the 2008 Federal Mitigation Rule (33 C.F.R. § 332/40 C.F.R. § 230).

In many Corps districts around the country, stream mitigation credits are calculated based on changes to stream channel dimension, pattern and profile. Not surprisingly, stream mitigation activities overwhelming focus on improving channel dimension, pattern, and profile to create a stable channel that does not aggrade or degrade. Mitigation providers have developed many practices to manipulate channel geometry simply to achieve stability but these activities are not connected to the amount of functional lift that can be achieved. The SFQ tool will change this by shifting the focus away from channel form and towards activities that more closely relate to improving stream functions.

Ensuring Mitigation Design Matches Restoration Potential

The SFQ tool will improve stream mitigation by linking stream restoration activities to restoration potential and watershed condition/need. Restoration potential is defined as the highest level of restoration that can be achieved given the condition of the upstream watershed, project constraints, and the condition of the project reach. Restoration potential is linked to the five levels of the Stream Functions Pyramid Framework (described below), so a restoration potential of Level 5-Biology, means that the upstream watershed health can support aquatic life (at a Functioning level) at the project site after stream restoration. The SFQ tool will prevent mitigation providers from establishing project design goals that exceed restoration potential.

Developing Stream Mitigation Credits

The SFQ tool can improve stream mitigation by linking credits to functional lift rather than to channel dimension, pattern, and profile. Many IRTs calculate credits through multiple factors, including: a net improvement factor (functional lift), importance of the stream resource, type of site protection, implementation schedule, stream type (perennial, intermittent, or ephemeral), location within a service area (primary or secondary), and the width and composition of a riparian buffer/vegetation. The SFQ tool can be used to generate credits for the net improvement factor and riparian buffer/vegetation. Through the IRT/stakeholder review process, additional credits can be determined on an as-needed basis for the other factors. And, if the model is developed for the debit side, functional lift can be compared to functional loss at permitted impact sites.

Finally, utilizing the SFQ tool as part of the credit determination method will allow for implementation of alternative restoration approaches, like stormwater best management practices (BMPs). By quantifying functional lift, the tool allows for alternative restoration projects that address one or more lost / diminished functions. Examples may include using stormwater BMPs to reduce runoff, sediment supply, and pollutant loading. Until functional lift is quantified, these alternative approaches are difficult to include in a regulatory framework.

What This Approach Does Not Include

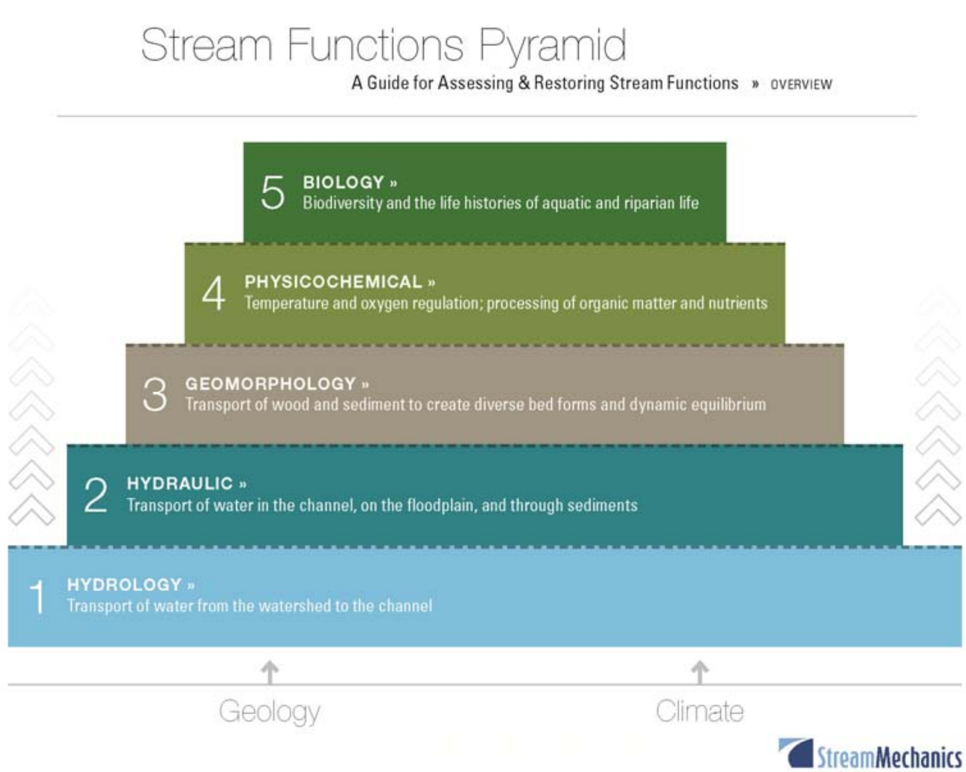
- This is not a wetland assessment methodology and therefore does not include a quantification tool for determining functional lift of wetland mitigation sites.
- The tool does not include a method for calculating functional loss or debits at a permitted impact site. This will be added in the next version.

Section II: Stream Functions Pyramid Framework Overview

The Stream Functions Pyramid Framework (SFPF) provides the scientific basis of the SFQ tool, which is described in detail in *A Function-Based Framework for Stream Assessment and Restoration Projects* (Harman and others, 2012), published by the US Environmental Protection Agency and the US Fish and Wildlife Service. The Stream Functions Pyramid, shown below in Figure 1, includes five functional categories: Level 1 = Hydrology, Level 2 = Hydraulics, Level 3 = Geomorphology, Level 4 = Physicochemical, and Level 5 = Biology. The Pyramid is based on the premise that lower-level functions support higher-level functions and that they are all influenced by local geology and climate. Each functional category is defined by a functional statement. For example, the functional statement for Level 1, Hydrology is “the transport of water from the watershed to the channel,” which supports all other functions.

Many interrelationships exist between these functional categories and the cause and effect relationships flow up and down the Pyramid. These relationships are important and should be considered when developing a mitigation project. However, from a stream assessment and restoration perspective the important question for mitigation practitioners is, “what supporting functions are required to restore a desired level of function?” The hierarchical structure of the Pyramid provides the conceptual foundation to quantify functional lift.

Figure 1: Stream Functions Pyramid



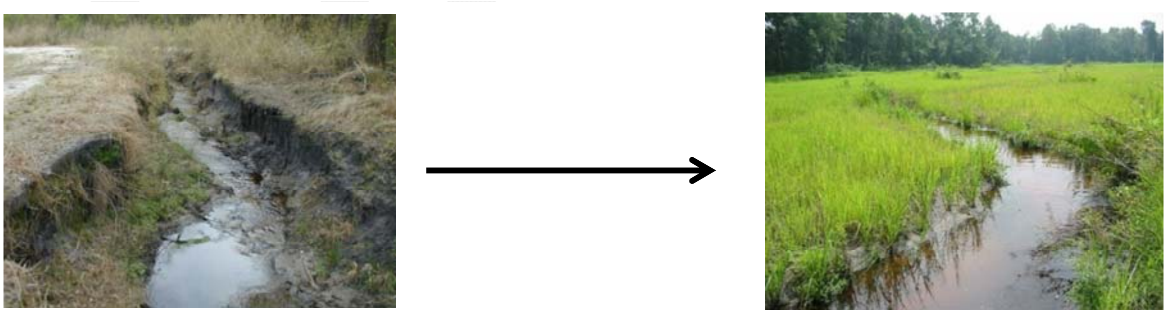
The Pyramid helps clarify the concept of "restoration potential". If a mitigation project is not able to improve a lower-level function like Hydrology, the restoration potential may be limited (i.e. not able to obtain restoration of a higher function like Biology). The practitioner often has no control over the health of the upstream watershed. Therefore, if a major goal is to improve the biological health back to a reference condition, then the site selection criteria must include watershed health. If there are impairments in the watershed that prevent a healthy level of aquatic life, the restoration project will likely not be able to overcome this limitation. Ensuring the proposed project goal matches the restoration potential will determine what the practitioner can and cannot control.

The Stream Functions Pyramid was created to assist regulatory agencies and practitioners in implementing the 2008 Mitigation Rule (33 C.F.R. § 332/40 C.F.R. § 230). There are several definitions and concepts in the Rule that are integral to the structure and implementation of the Stream Functions Pyramid. A few key terms and definitions are described below.

Function - The Rule uses the definition of function from the Clean Water Act, which is "the physical, chemical, and biological processes that occur in ecosystems." The Pyramid splits these functions into a finer level of detail. However, generally, physical functions match with the Hydrology, Hydraulic, and Geomorphology functional categories. Chemical matches with Physicochemical, and biological matches with Biology.

Functional Capacity – The Rule defines functional capacity as the degree to which an aquatic resource performs a specific function. This definition implies quantification of the function. The photos in Figure 2 show a stream restoration project before and a few months after restoration. It is easy to see that the stream after restoration is "better" than the before stream condition. However, the question that mitigation regulators and others often ask is, "How much better is the stream after restoration than before restoration?" This requires quantification and an understanding of how stream functions work together.

Figure 2: Before and after stream restoration project. ***Photos by: Michael Baker Corporation.***

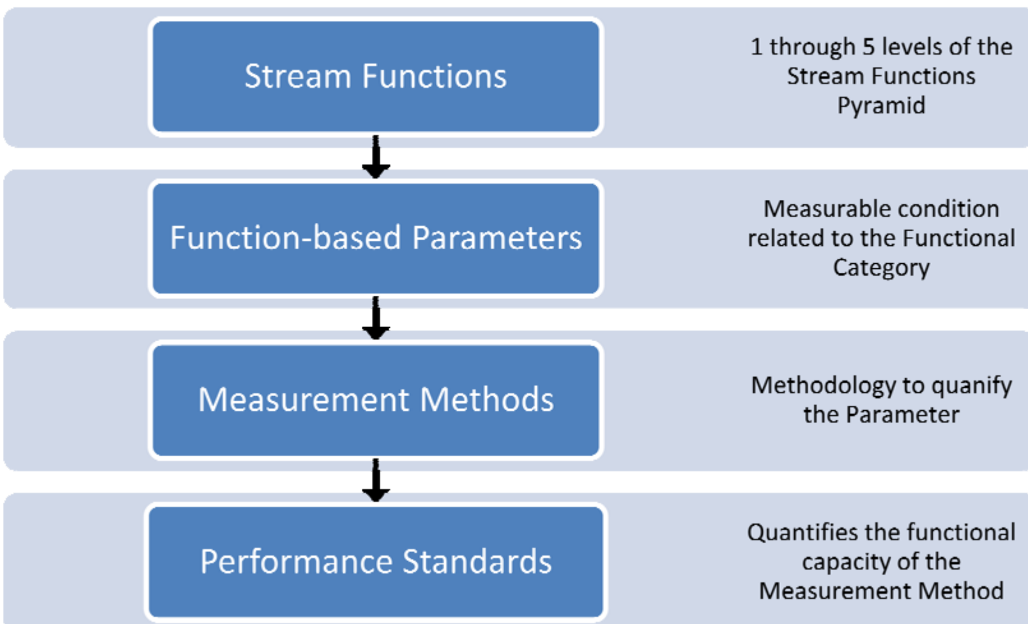


Performance Standards – The Rule requires that performance standards be established for stream mitigation projects. Performance standards establish quantitative and qualitative measures, based on best-available-science, to determine that the mitigation project has met the design goals and objectives, and that functional lift has occurred.

Functional Lift – Functional lift is not explicitly defined in the Rule; however, it is implied through other definitions and requirements. For example, a "credit" must reflect the difference between the restored condition and the baseline condition of a stream mitigation site. This difference is functional lift.

The Stream Functions Pyramid *alone* is a hierarchy of stream functions and does not provide a specific mechanism for addressing functional capacity, establishing performance standards, or communicating functional lift. The diagram in figure 3 expands the Pyramid concept into a more detailed Framework to to quantify functional capacity, established performance standards, and show functional lift. It can also be used to improve project goal setting and to establish debit and credit determination methods.

Figure 3: Stream Functions Pyramid Framework



The Stream Functions are the five levels of the Stream Functions Pyramid graphic that was discussed above and shown in Figure 1. The remainder of the framework is a "drilling down" approach that provides more detailed forms of analysis and quantification of functions. The Function-Based Parameters describe and support the functional statements within each functional category. The Measurement Methods are specific tools, equations, assessment methods, etc. that are used to quantify the Function-Based Parameter. There can be more than one Measurement Method for a single Function-Based Parameter. An example is shown below in Table 1 for Floodplain Connectivity, a Function-Based Parameter. In this example, three Measurement Methods are used to quantify one Function-Based Parameter.

Table 1: Example Measurement Methods used to quantify the Function-Based Parameter of Floodplain Connectivity.

Functional Category	Function-Based Parameter	Measurement Method (Examples)
Level 2: Hydraulics	Floodplain Connectivity	Bank Height Ratio
		Entrenchment Ratio
		Stage / Discharge Relationships

Function-Based Parameters and Measurement Methods can be direct measures of function or simply a structural/condition measure. Parameters and Measurement Methods that directly measure functions are expressed as a rate over time. Structural or conditional Parameters and Measurement Methods describe stream condition at a single point in time.

Importantly, functions often support other functions but function-based parameters not never be used as surrogates for higher level functions. The following example illustrates this core principle:

> *Sediment transport capacity is a parameter that directly measures a function. Bed form diversity, such as the percent of riffles and pools, is a structural measure that can be used as a surrogate for sediment transport capacity. It is much easier to measure bed form diversity than sediment transport capacity, which requires measurements during floods. If the bed forms are similar to reference conditions, the pools are deep, and the riffles are coarse and steeper than the average slope of the channel (for example), then it can be reasonably assumed that sediment transport processes are "Functioning." Note in this example, the surrogate (bed form diversity) is used to describe a function (sediment transport capacity) within the same functional category (geomorphology). This is an acceptable method for using a condition/structural parameter as a function surrogate. However, bed form diversity cannot be used as a surrogate for higher order functions, like the life histories of macroinvertebrate communities within the Biology category. Bed form diversity is a supporting function in that it provides habitat for macroinvertebrates, but it is not a surrogate.*

A list of Parameters and Measurement Methods is provided with additional details in Appendix A of a *Function-Based Framework for Stream Assessment and Restoration Projects*, including a table showing Type of Measurement Method (Tool, Technique, Metric, or Assessment Approach), Level of Effort (Rapid, Moderate, or Intensive), Level of Complexity, and Direct versus Indirect measure of a function. This list of Parameters and Measurement Methods provide a starting point for proposed Parameters and Measurement Methods for the SFQ tool.

Performance Standards are used to determine functional capacity at the Measurement Method level and are stratified by Functioning, Functioning-At-Risk, and Not Functioning. Using the example from Table 1, Performance Standards are added to the three Measurement Methods as shown in Table 2.

Table 2: Example Performance Standards for three Measurement Methods used to quantify Floodplain Connectivity. Note: F = Functioning, FAR = Functioning-At-Risk, and NF = Not Functioning.

Functional Category	Function-Based Parameter	Measurement Method	Functional Capacity Performance Standard F	FAR	NF
Level 2: Hydraulics	Floodplain Connectivity	Bank Height Ratio	1.0 to 1.2	1.3 to 1.5	>1.5
		Entrenchment Ratio	>2.2	2.0 to 2.2	<2.0
		Return Interval	1.0 to 1.4	1.5 to 2.0	> 2.0

Definitions for Functioning, Functioning-At-Risk, and Not Functioning are provided below:

- Functioning – A Functioning score means that the measurement method is quantifying the functional capacity of one aspect of a function-based parameter in a way that **does support** a healthy aquatic ecosystem. A single functioning measurement method, out of several measurement methods, may not mean that the function-based parameter is functioning. Therefore, functional capacity is “rolled up” to the parameter level and not determined at the measurement method level. Results can then be “rolled up” to the functional category level and as a final determination across all functional categories.
- Functioning-At-Risk –A Functioning-At-Risk score means that the measurement method is quantifying or describing one aspect of a function-based parameter in a way that **can support** a healthy aquatic ecosystem. In many cases, this indicates the function-based parameter is adjusting in response to changes in the reach or the watershed. The trend may be towards lower or higher function. A Functioning-At-Risk score implies that the aspect of the function-based parameter, described by the measurement method, is between Functioning and Not Functioning.
- Not Functioning - A Not Functioning score means that the measurement method is quantifying or describing one aspect of a function-based parameter in a way that **does not support** a healthy aquatic ecosystem. A single not functioning measurement method may not mean that the function-based parameter is not functioning.

OUTSTANDING QUESTIONS & ISSUES

1. Selecting Parameters, Measurement Methods and Performance Standards

As described above, Appendix A of a *Function-Based Framework for Stream Assessment and Restoration Projects* provides a list of suggested Parameters and Measurement Methods. These will require input and review by stakeholders.

2. Preserving or Abandoning the Use of Functioning, Functioning-At-Risk, and Not Functioning Terms

The SFPF uses the terms Functioning, Functioning-At-Risk and Not Functioning as a method for stratifying field values into functional capacity. The SFQ tool described below in Section III converts the field values into index values scaled from 0 to 1. This scale could eliminate the need for the Functioning, Functioning-At-Risk, and Not Functioning terms. The current model keeps these terms and uses them as a communication tool. However, this will be revisited during the stakeholder process to determine if the terms are necessary.

Section III: Conceptual Model for Determining Functional Lift

The Stream Function Quantification (SFQ) tool provides a mechanism to connect the Stream Functions Pyramid to measurement of functional lift. The conceptual model described in this section provides an outline for quantifying functional lift and determining mitigation credit. See the flowchart for the conceptual model below (Figure 4) and a description of each model component on the following pages. The steps and the calculations shown in the text and in Appendices will be incorporated into a Microsoft Excel Workbook during the next phase of the project.

I. Determine Programmatic Goals

The first step is to identify the programmatic goal, which is the big-picture funding driver for a program or agency. For an IRT, the primary programmatic goal is to deliver stream and wetland mitigation credits for permitted impacts throughout the state. Other examples of programmatic goals could include: Total Maximum Daily Load allocations, listed or candidate species, addressing watershed needs based on a watershed management plan, species restoration for recreation, e.g., trout, and others. Programmatic goals can be linked to regulatory requirements, but can also be initiatives developed through voluntary efforts.

II. Select Potential Project Site

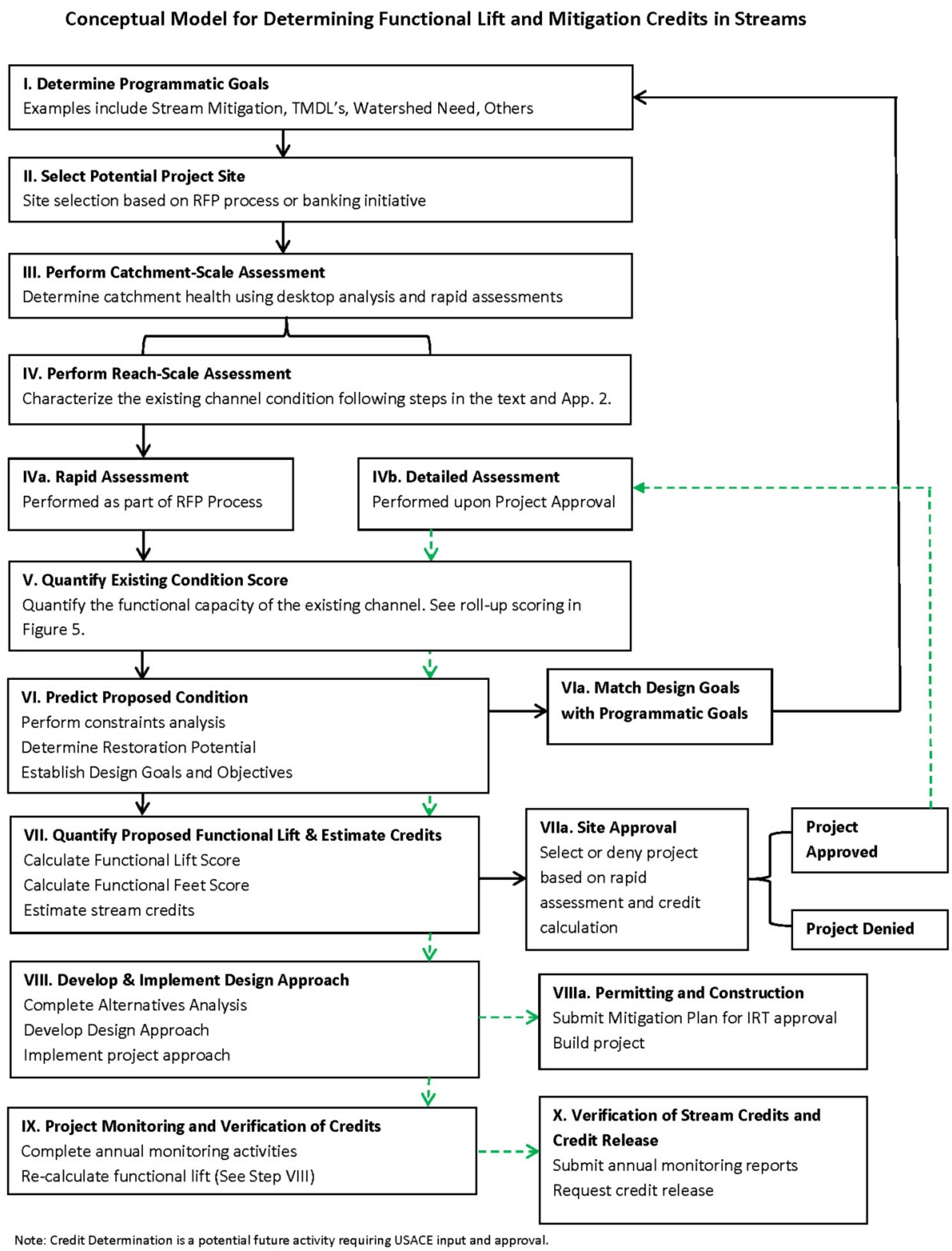
Project sites are locations where restoration activities are performed to achieve programmatic goals. A stream mitigation project site includes the stream reach, the stream corridor, and the adjacent land. Once the project reach is identified, the drainage area or catchment is delineated to include the land area that drains water to the project reach.

III. Perform Catchment-Scale Assessment

The purpose of the catchment-scale assessment is to determine the overall health of the project-reach catchment. The catchment-scale assessment provides data necessary to Quantify the Existing Condition Score (see V below) and provides information to Determine the Restoration Potential (see VI below).

The catchment-scale assessment will likely include Function-Based Parameters and Measurement Methods for Hydrology, Geomorphology, Physicochemical and Biology functional categories. Hydraulics is not included because these functions occur at a reach scale rather than a watershed or catchment scale. Most of this information is expected to come from existing sources. Qualitative and rapid Measurement Methods will be used to determine the index score.

Figure 4: Conceptual Model for Determining Functional Lift and Mitigation Credits in Streams



IV. Perform Reach-Scale Assessment

The purpose of the reach-scale assessment is to determine the existing or baseline function-based condition of the proposed project reach. Using an Excel model, mitigation providers will undertake an assessment of pre-selected Function-Based Parameters using appropriate Measurement Methods. The proposed Function-Based Parameters for each Functional Category include

Level 1 Hydrology	Runoff
Level 2 Hydraulics	Floodplain Connectivity
Level 3 Geomorphology	Bed Form Diversity Lateral Migration Vertical Stability Riparian Vegetation Large Woody Debris Sinuosity
Level 4: Physiochemical	Temperature
Level 5: Biology	Macroinvertebrate Communities

Rapid and detailed assessment approaches are proposed based on the stage of the project. The primary difference between the rapid and detailed assessment is the level of effort required to *measure* the Function-Based Parameters.

- IVa. The rapid assessment will use qualitative or semi-quantitative Measurement Methods to describe the Function-Based Parameters to quickly assess stream condition as part of a RFP process.
- IVb. The detailed assessment will use quantitative Measurement Methods to describe the parameters once the project is approved by the IRT.

The steps and general guidance for developing the Measurement Methods and Performance Standards associated with the Reach-Scale Assessment is provided in Appendix 1.

V. Quantify Existing Condition Score

Utilizing the field value for each Measurement Method from the Catchment Assessment (see III above) and the Reach Assessment (see IV above), an Existing Condition Score is calculated. The Existing Condition Score quantifies the functional capacity of a stream reach being considered for restoration through the following steps. Appendix 2 provides example calculations and additional detail for each of the following steps.

1. Perform Catchment and Stream Assessments (Steps III & IV above).
2. Convert the *field* value associated with each Measurement Method into an i*ndex* value. The index value for each Measurement Method is calculated using a 0 to 1 scale.

3. Average the Measurement Method index values for each Function-based Parameter to create a single index value. For example, there may be three Measurement Methods with three different index values for a single parameter. These three Measurement Method index values will be averaged to create the Function-Based Parameter index value.
4. Average Function-Based Parameter values to create a Functional Category Score, e.g., Hydrology score. The roll-up scoring associated with these steps is shown in Figure 5 (next page).
5. Average Functional Category Scores to create an Overall Score for the project reach.
6. Perform a vertical stability trend assessment and adjust the Overall Score if the trend is towards degradation or aggradation.
7. Calculate the Existing Condition Score measured in functional feet for the project reach. An excel workbook will be created to perform these calculations automatically once the field values are entered (see step 2 above).

OUTSTANDING QUESTIONS/ISSUES:

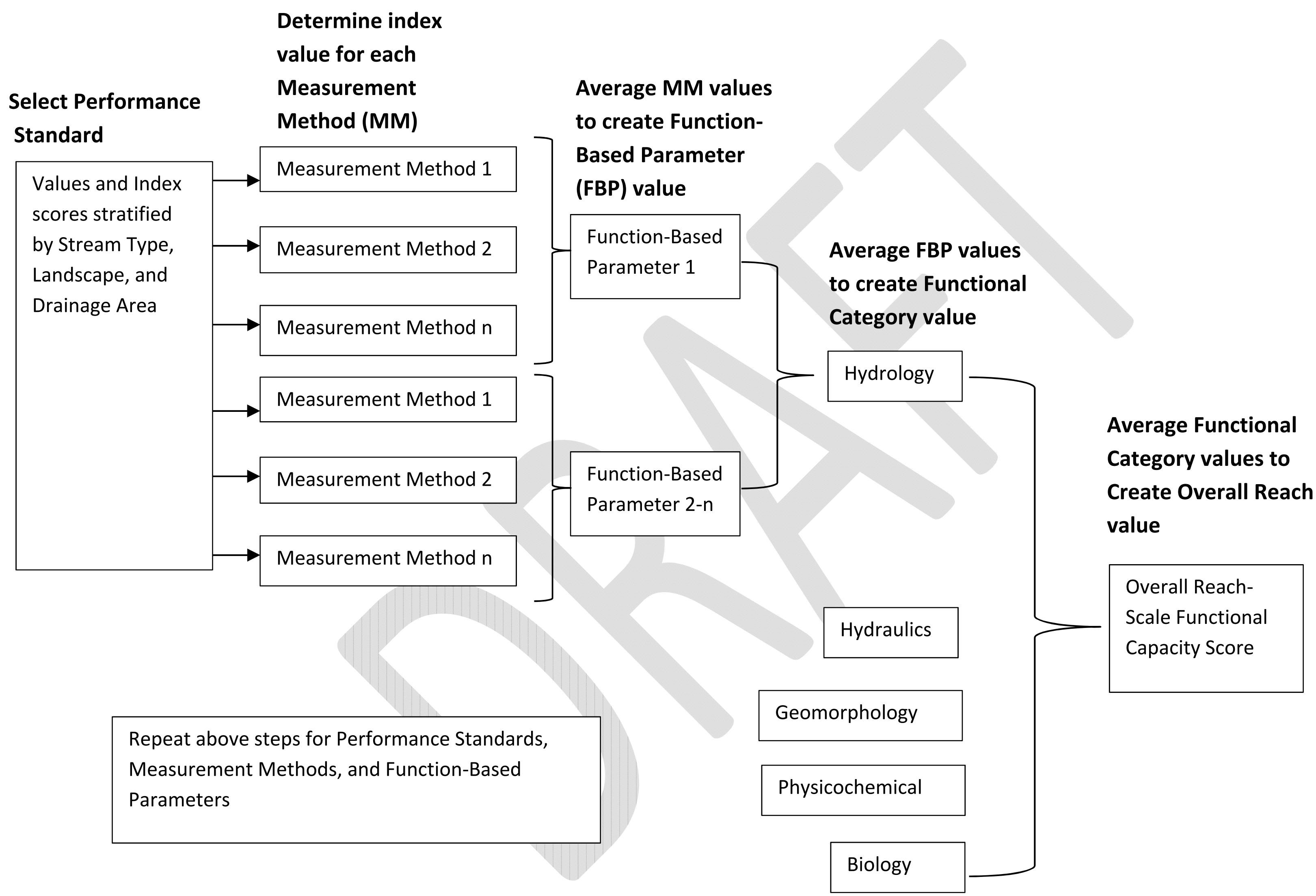
1. Additional Adjustments to Overall Score

Additional adjustments (beyond the vertical stability adjustment) may be added.

2. Modification of Scoring Method

During the stakeholder review process, the idea of summing the functional category scores, rather than averaging the scores, will be evaluated. This means that the overall scores for Hydrology, Hydraulics, etc. will be added rather than averaged. We are not proposing to sum the Measurement Method or Parameter scores. Unresolved in this draft is whether or how to weight certain variables.

Figure 5: Scoring Roll Up



VI. Predict Proposed Condition

The proposed condition is based on 1) a constraints analysis, 2) the restoration potential and 3) design goals/ objectives. Each of the three components is described below.

Constraints Analysis

The purpose of the constraints analysis is to identify anthropogenic activities that will prohibit/limit the restoration of stream functions back to a reference condition. The constraints analysis does not include natural disturbances that may limit restoration. Natural constraints should be identified during the catchment-scale assessment. The most common anthropogenic constraint in stream mitigation is the width of the conservation easement. Landowners are often only willing to place a portion of the valley width into an easement. This may be due to agricultural operations, utilities, transportation corridors, or other land uses that are required to stay in the valley bottom.

The constraints are described in a narrative format and included in the Microsoft Excel Workbook where they will be used in the next phase to determine the restoration potential.

Restoration Potential

Restoration potential is the highest level of restoration that can be achieved given the results from the catchment assessment, results from the reach-scale assessment, and the project constraints. The highest level of restoration refers to a level on the Stream Functions Pyramid. A restoration potential of SFPF Level 5 means that the project has the potential to restore biological functions back to a functioning condition, i.e., a reference condition. This can only happen if the catchment health is good enough to support that level of biology and the constraints do not prevent the practitioner from implementing the required activities.

If the catchment health is somewhat impaired and/or the constraints limit the restoration activities, then the restoration potential will be less than SFPF Level 5. This doesn't mean that there won't be some biological improvement, just not back to what a stream reach in a forested watershed may have. This also doesn't mean that the project shouldn't be pursued; however, the design goals and objectives should focus on lower-level functions rather than biology.

Many stream restoration projects focus on channel stability because the catchment health is unknown or somewhat impaired. There are often lateral or financial constraints as well. In this scenario, the restoration potential is a SFPF Level 3. If the project is exceptionally long and has adjacent sources of nutrient inputs, the upstream catchment will not support reference quality biology, and there are few lateral constraints, the restoration potential is a SFPF Level 4 (physiochemical).

Initially, the practitioner will describe the restoration potential in a narrative format. As the SFQ tool is further developed, it may be possible to automatically select the restoration potential based on the catchment assessment, reach-scale assessment, and constraint inputs.

Design Goals and Objectives

Design goals and objectives can be developed concurrently with the restoration potential. Design goals are statements about why the project is needed. They are general intentions and often cannot be validated. Objectives are more specific. They help explain how the project will be completed. Objectives are tangible and can be validated, typically by the performance standard. Examples of design goals include: restore native brook trout habitat (SFPF Level 3 goal), restore native brook trout biomass (Level 5), restore the stream to a biological reference condition (SFPF Level 5), Reduce sediment supply from eroding streambanks (SFPF Level 3), and reduce nutrient inputs (SFPF Level 4). All of these goals communicate why the project is being undertaken. Example objectives include: increasing floodplain connectivity, establishing a riparian buffer, and increasing bed form diversity. These objectives can't stand alone, but with the goals, they can describe what the practitioner will do to address the functional impairment. The objectives can be quantitative as well. For example: floodplain connectivity will be improved by reducing the bank height ratio from 2.0 to 1.0. Now, functional lift is being communicated and the performance standard is established for monitoring.

The design goals and objectives are communicated in a narrative form and entered into the Excel Workbook. The design goals are then compared to the restoration potential to ensure that the goals do not exceed the restoration potential. For example, it is not possible to have a design goal of restoring native brook trout biomass (SFPF Level 5) if the restoration potential is SFPF Level 3, meaning that the catchment health and constraints will not support brook trout, e.g., because the watershed is developed and water temperature entering the project reach is too high for brook trout. However, the goal could be revised to restore the physical habitat for native brook trout , e.g. riffle-pool sequences, cover from a riparian buffer, and improvements to channel substrate . This is a SFPF Level 3 goal that matches the Level 3 restoration potential. If watershed-level improvements are implemented, over time, the restoration potential could shift from a SFPF Level 3 to 5. Notice however, that this requires reach-scale and watershed-scale restoration.

Ensuring Project Design Aligns with Programmatic Goals

Once the design goals and objectives are established and confirmed against the restoration potential, the goals are compared to the overall program goals. This feedback loop is used to ensure that the restoration potential and design goals are in alignment with the programmatic goals. If the restoration potential and design goals are too far apart, it may be best to select another restoration site. Or, additional resources may be allocated to perform larger projects that have more impact at the watershed scale.

VII. Quantify Proposed Functional Lift

Once the proposed condition has been determined, the proposed functional lift can be calculated through the following steps.

a. Predict a new index score for each Measurement Method based on the restoration potential. The practitioner can use professional judgment, modeling, monitoring, etc. to make these predictions.
b. Average the Measurement Method Index Scores to produce a Function-Based Parameter score. These scores can be shown beside the Existing Condition scores column for comparison, and as a visual way to show functional lift.
c. Average the Function-Based Parameter index scores to create a functional category score, e.g., Hydrology. An example is shown below in Table 3. Under this scenario, all five functional categories have a Proposed Condition score of Functioning.
d. Average the Functional Category Scores to create an Overall Proposed Condition Index Score (PCS) for the project reach. An example is shown below in Table 3 with a PCS of 0.93. No adjustments are included for the Proposed Condition because the design would not include a headcut (sign of vertical instability) or mid-channel bar (sign of aggradation). However, vertical trend adjustments should be included for the post-restoration monitoring years to verify that the design is performing as intended.
e. Calculate Functional Lift from Index Scores as follows.

    Functional Lift Score (FLS) = PCS – ECS, where:
    PCS equals the Proposed Condition Index Score, and
    ECS equals the Existing Condition Index Score.

    For the example in Table 3, the FLS from the index scores is 0.93 – 0.19 = 0.74. This results in a functional capacity change from Not Functioning (0.19) to Functioning (0.74).
f. Calculate Proposed Functional Feet ($FF_{Proposed}$). Calculating proposed functional feet is more complicated than calculating the existing condition function. The functional feet equations for the existing and proposed conditions are provided below.

    $FF_{Existing}$ = ECS X ESL, where:
    ECS_{final} = Existing Condition Score after adjustments.
    ESL = Existing Stream Length (Impaired condition).

    $FF_{Proposed}$ = (FLS X ESL) + (PCS X NSL), where:
    FLS = Functional Lift Score from Step e. above.
    ESL = Existing Stream Length
    PCS = Proposed Condition Score
    NSL = New Stream Length, calculated as Proposed Stream Length – Existing Stream Length.

    For example, the Existing Stream Length is 3,000 feet and the Proposed Stream Length is 4,200 feet, yielding a New Stream Length of 1,200 feet. Therefore, the $FF_{Proposed}$ is (0.74*3,000)+(0.93*1,200) = 3,336. Note that the functional lift score is multiplied by the existing stream length to represent a functional improvement in that length. The new length is multiplied by the proposed condition score (a higher value) to represent functions that were not there prior to restoration.

g. Calculate Proposed Functional lift in Functional Feet (PFL_{feet}). This is simply the $FF_{Proposed}$ - $FF_{Existing.}$ For the example in Table 3, the proposed functional lift in functional feet is 3,336 – 580 = 2,756.

Table 3: Proposed condition index scores per Functional Category compared to the existing condition.

Existing Condition			**Proposed Condition**	
Functional Category	**Index Score**	**Existing Functional Capacity**	**Index Score**	**Proposed Functional Capacity**
Hydrology	0.8	**Functioning**	0.9	**Functioning**
Hydraulics	0.2	**Not Functioning**	1.0	**Functioning**
Geomorphology	0.4	**Functioning At Risk**	1.0	**Functioning**
Physicochemical	0.5	**Functioning At Risk**	0.9	**Functioning**
Biology	0.6	**Functioning At Risk**	0.9	**Functioning**
Overall Score	0.5	**Functioning At Risk**	0.9	**Functioning**
Vertical Stability Adjustment			No adjustments (See VII-d)	
Degrading Trend	-0.3			
Aggrading Trend	-0.1			
Final Score (ECS_{Final})	0.19	**Not Functioning**	PCS_{Final} 0.93	**Functioning**
Functional Lift Score (FLS) 0.93 - 0.19 = 0.74				

Estimation of Stream Credits

One output of the conceptual model, beyond calculating functional lift, is the calculation of stream credits. One simple idea is to use the functional lift score in functional feet units to equal the credits, i.e., the difference in the restored functional feet and the existing functional feet would equal stream credits, or could be a part of the credit calculation. Many stream mitigation protocols use additional factors, beyond functional lift (sometimes called net-improvement score) to calculate the overall credit. These additional factors include: 1) the overall importance of the resource from an environmental, cultural, or economic perspective, 2) stream type (perennial, intermittent, and ephemeral), and 3) proximity of the mitigation site to impact site. These factors can be discussed and added to the credit calculation if deemed appropriate by the IRT.

Using Stormwater Best Management Practices (BMPs) to produce Stream Credits

There is great interest from the regulated and regulatory communities to develop a method for assigning stream credits to stormwater BMPS. Most agree that in urban environments, stormwater BMPs may provide significant functional lift if used in conjunction with in-channel restoration activities. The conceptual model described above provides a mechanism for assigning stream credits to BMPs by focusing on functional lift rather than a restoration approach like adjusting channel dimension, pattern, and profile. Stormwater BMPs are designed to primarily reduce runoff, nutrients, and sediment. Runoff and nutrients are function-based parameters that are included in the assessment. Sediment supply is currently included as lateral stability, but the Measurement Methods could be expanded to include sediment supply from adjacent, concentrated flow pathways, which are places where the BMPs would be installed. Financial modeling would be needed to determine if the credit ratios are appropriate to incentivize this approach; however, the ratios can be easily adjusted as needed.

VIIa. Site Approval

If a *rapid* assessment methodology is used, then the results from the SFQ tool can be used to approve or disapprove a site for mitigation. This can be used by the IRT and mitigation provider during the prospectus stage of the project. Mitigation providers can use the results to determine if a site will produce enough stream credits to warrant the cost of completing the project.

If the site is approved, then the mitigation provider would cycle back through the reach-scale assessment and perform a more detailed stream assessment. The parameters and measurement methods would be selected based on the project's restoration potential and design goals. Then the provider would re-calculate the proposed functional lift and functional feet scores.

VIII. Develop and Implement Design Approach

Once the site has been approved, the detailed assessment has been completed, and the proposed condition has been predicted, the mitigation provider will develop a proposed design approach. This process should include an alternatives analyses to select the best restoration approach given the restoration potential and design goals.

VIIIa: Permitting and Construction

This task is shown to acknowledge that the project must secure the appropriate federal, state, and local permits and then be implemented through a construction process.

IX. Project Monitoring and Verification of Credits

The mitigation provider is required to monitor each mitigation site and verify that the proposed functional lift is actually achieved. In this approach, the detailed assessment would be completed each year and the functional lift re-calculated in functional feet. Since it takes time for stream restoration projects to become stable and for the permanent vegetation to become established, a mechanism will need to be established to address the change in functional scores from the as-built condition to the last year of monitoring, i.e., it will take several years of monitoring to achieve the proposed functional lift score, especially for vegetation and biology.

X. Verification of Stream Credits and Credit Release

This step is included to show that the annual monitoring reports are used by the mitigation provider to show that the project is performing as proposed. Ideally, the mitigation provider could tie the annual monitoring results to the proposed condition score, recognizing that the scores will increase over time as the stream evolves towards a reference condition and the riparian vegetation matures. In a mitigation banking environment, these reports would be used to request a credit release from the IRT. The step is shown here to allow for future discussions with the IRT about a process to verify the amount of functional lift and to streamline the credit determination and credit release procedures.

Section IV: Next Steps

The conceptual model described above is just the first step towards improving stream mitigation by linking functional lift to the development of mitigation credits. There are many details that must be included and additional tools and documents that are needed. A list of next steps is provided below as a "road map" for further model development and implementation.

1. Receive input on conceptual model (this report) from various IRTs and stakeholders.
2. Develop rapid assessment methodology.
    a. Create final list of Function-Based Parameters. Proposed list provided in Appendix 1.
    b. Select and/or develop rapid Measurement Methods and Performance Standards for a select regions.
3. Develop detailed assessment methodology.
    a. Select and develop Function-Based Parameters, Measurement Methods and Performance Standards for various design goals associated with a detailed assessment.
4. Develop Microsoft Excel Workbook to show all steps in the conceptual model and to perform calculations. Develop for rapid and detailed assessment methods.
5. Develop a user guide explaining how to perform the assessments.
6. Test the assessments and functional lift tool on several mitigation projects.
7. Revise the functional lift tool based on the test results and create a final Excel Workbook and user manual.

References and Acknowledgments

Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2011. *A Function-Based Framework for Developing Stream Assessments, Restoration Goals, Performance Standards and Standard Operating Procedures.* U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds. Washington, D.C. EPA 843-K-12-006

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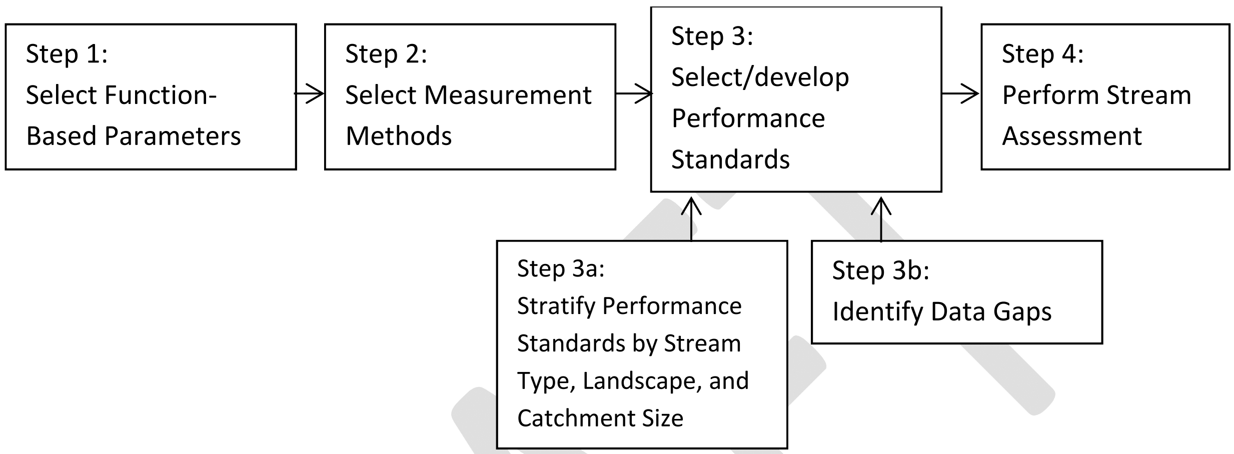
APPENDIX 1.

To develop an assessment method using a SFQ tool, Function-Based Parameters and Measurement Methods must be selected and Performance Standards developed. This can be accomplished by following the steps in figure A1-1 below. A description of each step follows.

A1-1: Steps for developing reach-scale assessment method



<u>Step 1: Select Function-Based Parameters</u>

The following function-based parameters (see Table A1-1 on next page) have been selected for consideration to use during the Rapid Assessment phase, which is associated with a RFP process or prospectus stage of a project. These parameters may be deleted and others added as the SFQ tool is further developed and tested. The parameters selected are for perennial streams within alluvial valleys, e.g., valley slopes less than 2%. These parameters can be measured across landscape settings (Mountain, Piedmont, Coast); however, their performance standards will vary based on stream type and catchment size.

Table A1-1: Function-Based Parameters by functional category and rationale for their selection.

Functional Category	Function-Based Parameter	Rationale for Selection
Level 1 Hydrology	Runoff	Provides an estimate of the quantity and rate of water delivered by the watershed to the channel. Can be improved in small watershed-scale restoration projects with best-management practices or projects that restore a large percentage of the watershed.
Level 2 Hydraulics	Floodplain Connectivity	Connects the stream with the adjacent floodplain, increases flooding/ floodplain inundation. An important driver of many other functions in Levels 2 through 5. Practitioner can directly manipulate through restoration activities.
Level 3 Geomorphology	Bed Form Diversity	Provides a description of channel complexity and aquatic habitats, e.g., riffles, runs, pools, and glides. Can be used as a surrogate for effects of sediment transport processes. Practitioner can directly manipulate through restoration activities.
	Lateral Migration	Provides an evaluation of streambank (lateral) stability and sediment supply. Practitioner can directly manipulate through restoration activities.
	Vertical Stability	Provides an evaluation of channel bed stability and determines the potential for bed degradation or aggradation. This is a critical parameter for determining overall stability and channel evolution. It can affect many functions throughout the Pyramid.
	Riparian Vegetation	Provides a description of the width and character of riparian vegetation throughout the stream corridor. Included in Level 3 because of its role in providing lateral stability and supporting Level 4 functions like denitrification. Practitioner can directly manipulate through restoration activities.
	Large Woody Debris	Used in addition to Bed Form Diversity to describe channel complexity. Provides sediment storage, bed material sorting, organic matter, etc. Practitioner can directly manipulate through restoration activities.
	Sinuosity	Used in addition to Bed Form Diversity to describe channel complexity. Important parameter for influencing Level 4 functions like denitrification. Practitioner can directly manipulate through restoration activities.
Level 4 Physicochemical	Temperature	Used to determine thermal regulation of stream, which is important for Level 5 functions. Requires multi-year assessments. Cannot be directly manipulated through restoration activities.
Level 5 Biology	Macroinvertebrate Communities	Primary indicator of aquatic health in perennial streams. Cannot be directly manipulated through restoration activities.

Proposed Function-Based Parameters for Detailed Assessment

These parameters may vary based on design goals. For example: if the design goal is to restore a targeted fish species (a Level 5, Biology goal), then parameters from Level 4 that support that species would be selected (e.g., water quality). This process is then repeated for the remaining three levels. This process aligns the parameters (and ultimately the measurement methods and performance standards) with the design goal and restoration potential. An example of how this process works is provided below in Table A1-2.

Table A1-2: Parameter, Measurement Method, and Performance Standard Selection by Goal

Functional Category	**Level 5: Biology**	**Level 4: Physicochemical**	**Level 3: Geomorphology**	**Level 2: Hydraulics**	**Level 1: Hydrology**
Design Goal (Why)	Restore a species of interest or to reference condition	Reduce nutrient loadings (N, P, or N&P)	Reduce sediment supply	Increase floodplain inundation	Increase base flow duration
Restoration Potential	Level 5	Level 4	Level 3	Level 2	Level 1
Design Objectives and Function-Based Parameters	Develop objectives by selecting function-based parameters that must be “Functioning” in order to meet the goal. Select parameters within and lower than the goal’s Functional Category.				
Select/Develop Measurement Methods	Select or Develop Measurement Method(s) for each parameter.				
Select/Develop Performance Standards	Select or Develop Performance Standards for each measurement method based on stream type, catchment size, and landscape setting.				

Step 2: Select Measurement Methods

The Measurement Methods will be selected once the conceptual model has been approved by the IRT. The team will propose a suite of Measurement Methods to the IRT first, and then to a group of stakeholders for input and advice. Measurement methods may differ depending on whether the reach is being considered for a project as part of a Rapid Assessment or a Detailed Assessment.

Step 3: Select and/or develop Performance Standards

Performance Standards will be selected or developed for each Measurement Method. The selection or development of these Performance Standards may be stratified by stream type, landscape setting, and drainage area. For example, bed form diversity is an important Function-Based Parameter within the Geomorphology functional category. Examples of quantitative measurement methods used to describe bed form diversity include pool spacing and pool depth variability. However, as slope increases, the spacing between pools typically decreases, so one performance standard cannot be used for all stream types. Likewise, pool spacing varies by drainage area. In this example, the parameter and Measurement Methods stay the same, but the Performance Standard varies based on stream type and drainage area.

There will be some Measurement Methods that currently do not have Performance Standards. For example, the Large Woody Debris Index is a Measurement Method for Large Woody Debris, a Function-Based Parameter within the Geomorphology Category. Other performance standards may be tied to the reference condition, meaning that the reference condition will need to be determined. These are data gaps that will have to be dealt with by either collecting the necessary data, requesting others to collect the data, or by selecting a different Measurement Method if data cannot be collected.

Step 4: Perform Stream Assessment

The rapid and detailed reach-scale assessment of existing conditions will require field work. Field forms will be developed for the practitioner to complete with the results entered into a Microsoft Excel Workbook. These forms will be created during the second phase of the project.

APPENDIX 2: Detailed description and examples of Quantifying the Existing Condition Score

Utilizing the field value of each Measurement Method from the Catchment Assessment and the Reach Assessment, an Existing Condition Score is calculated. The Existing Condition Score quantifies the functional capacity of a stream reach being considered for restoration through the following steps.

1. Perform Stream Assessment.
2. Convert the *field* value associated with each Measurement Method into an i*ndex* value. The index value for each Measurement Method is calculated using a 0 to 1 scale.
3. Average the Measurement Method index values for each Function-based Parameter to create a single index value. For example, there may be three Measurement Methods with three different index values for a single parameter. These three Measurement Method index values will be averaged to create the Function-Based Parameter index value. An example calculation is shown below in Figure A2-1.
4. Average Function-Based Parameter values to create a Functional Category Score, e.g., Hydrology score. The roll-up scoring associated with these steps is shown on Figure 6 in the main text. An example is shown below in Table A2-1.
5. Average Functional Category Scores to create an Overall Score for the project reach.
6. Perform a vertical stability trend assessment and adjust the Overall Score if the trend is towards degradation or aggradation.
7. Calculate the Existing Condition Score measured in functional feet for the project reach. An excel workbook will be created to perform these calculations automatically once the field values are entered (see step 2 above).

An example of how two Measurement Methods and their associated Performance Standards will be converted into an index value is shown below in Figure A2-1 for Floodplain Connectivity (Function-Based Parameter) in the Hydraulic Functional Category. The Measurement Methods are Bank Height Ratio and Entrenchment Ratio.

Figure A2-1: Example of Index Calculation for Floodplain Connectivity using two Measurement Methods.

Bank Height Ratio (BHR)

Field	≥2	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0
Index	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

Entrenchment Ratio (ER) for a C4 Stream Type Target

Field	<2.0			2.0		2.1		2.2 to 3	3.1 to 4	4.1 to 7	≥8
Index	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0

BHR: Field Value of 1.8 yields an index value of 0.2

ER: Field Value less than 2.0 yields an index value of 0.0

For the Floodplain Connectivity Function-Based Parameter, the two index scores are averaged to get a Parameter score. Therefore Floodplain connectivity = (0.2+0.0)/2 = 0.1.

Create Function-Based Parameter (FBP) Score

Once each Measurement Method is scored, the index values are averaged to create the Function-Based parameter score. An example of FBP scores is shown in Table A2-1. The scores are then color-coded green, yellow, and red to show functional capacity as Functioning, Functioning-At-Risk, or Not Functioning, respectively.

Table A2-1: Example Existing Condition Assessment Results for Function-Based Parameters (FBP)

Functional Category (FC)	Performance Standard	Measurement Method and Score	Function-Based Parameter	FBP Score
Hydrology	From SFPF and Phase 2	From catchment & reach	Runoff	0.8
Hydraulics		From reach	Floodplain Connectivity	0.1
Geomorphology		From reach	Bed Form Diversity	0.3
		From reach	Lateral Migration	0.4
		From reach	Vertical Stability	0.1
		From reach	Riparian Vegetation	0.5
		From reach	Large Woody Debris	0.7
		From reach	Sinuosity	0.2
Physicochemical		From catchment & reach	Temperature	0.6
		From catchment & reach	Nutrients	0.4
Biology		From catchment & reach	Macroinvertebrates	0.6
		From catchment & reach	Fish	0.6

Calculate Functional Category Score and Overall Score

The next step is to roll-up the scores from the Function-Based Parameter level to the functional category level as shown below in Table A2-2. Each parameter score within a functional category is summed and divided by the total number of parameters to create an average value for that functional category. Functional capacity results of Functioning, Functioning-At-Risk, and Not Functioning are shown for each functional category.

The index score for each category is summed and divided by five (the total number of functional categories) to create an Overall Score.

Perform Vertical Stability Trend Assessment / Overall Score Adjustment

The next step is to determine if an overall adjustment is needed based on the vertical stability trend. If the channel is moving towards stability or functional recovery, no adjustment is needed. However, if the reach-scale assessment shows that headcuts are present in the reach, or there are other signs of channel degradation, then the Overall Score is reduced by a to-be-determined factor (i.e. 0.3). If the reach-scale assessment shows that the channel is aggrading and causing lateral stability problems and/or smothering of habitats, the score is similarly reduced by a to-be-determined factor (i.e. 0.1). These values will need to be determined with expert and stakeholder input; however, a degradation trend should have a higher reduction value than aggradation.

In the example below, the Overall Score is 0.49. However, if the reach-scale assessment showed that headcuts were prevalent along the reach, this would negatively affect many functions throughout the Pyramid. The Overall Score could be reduced by 0.3 feet (for example) to yield an Existing Condition Score (ECS) of 0.19.

Table A2-2: Example Existing Condition Assessment Results for Functional Category Level.

Existing Condition (Category)		
Functional Category	**Index Score**	**Functional Capacity**
Hydrology	0.80	**Functioning**
Hydraulics	0.20	**Not Functioning**
Geomorphology	0.37	**Functioning At Risk**
Physicochemical	0.50	**Functioning At Risk**
Biology	0.60	**Functioning At Risk**
Overall Score	0.49	**Functioning At Risk**
Vertical Stability Adjustment		
Degrading Trend	-0.3	(Example)
Aggrading Trend	-0.1	
Existing Condition Score (ECS)	0.19	**Not Functioning**
Existing Stream Length (ESL)	3,000	
Functional Feet ($FF_{Existing}$)	580	

The last step is to convert the existing stream length into functional feet. This calculation is simply the existing stream length, measured in feet, multiplied by the ECS. In the example below, the existing stream length is 3,000 feet and the ECS is 0.19, yielding 580 functional feet. Note, if the stream was functioning perfectly, the functional feet would equal the stream length of 3,000 feet.