DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS, SAVANNAH DISTRICT
100 WEST OGLETHORPE AVENUE
SAVANNAH, GEORGIA 31401

October 27, 2021

Regulatory Division
SAS-2017-00592

PUBLIC NOTICE
Savannah District

The U.S. Army Corps of Engineers, Savannah District (Corps), announces the publication and minimum <u>one-year initial implementation and testing period</u> of the Standard Operating Procedure (SOP) for Compensatory Mitigation (Version 2.0), dated October 2021. This revised SOP has been developed by the Savannah District, Regulatory Division for the purpose of calculating stream and wetland compensatory mitigation pursuant to Section 404 of the Clean Water Act (33 USC 1344). This public notice is being distributed to all interested stakeholders as notification of its implementation and to solicit additional public input for consideration in the continued development of the SOP.

Version 2.0 of the SOP provides updates and revisions to the following SOP components: SOP (User Manual); Stream, Freshwater Forested Wetland, and Saltwater Tidal Wetland Qualitative Assessments (in Microsoft Excel); Qualitative Worksheets for Stream and Wetland Adverse Impacts; User Manual & Supporting Scientific Documentation for the Georgia Stream Quantification Tool (GA SQT) and the GA SQT Workbook (in Microsoft Excel); Georgia Freshwater Forested Wetland Hydrogeomorphic Methodology (GA HGM) User Manual and the GA HGM Workbook (in Microsoft Excel); and the Template Statement of Credit Availability (SOCA). Additional details regarding the updates and revisions to each of the components listed above have been provided in the Revision Logs for each of the respective User Manuals and/or Microsoft Excel Workbooks/Worksheets.

The effective date of Version 2.0 of the SOP is 30 days from the date of this public notice. During this initial implementation period, the Corps will be accepting public comments on the SOP.

As of the effective date, Version 2.0 of the SOP will supersede the previous version (Version 1.0), and apply to all regulatory actions requiring compensatory mitigation for adverse impacts to waters of the United States and for the evaluation of compensatory mitigation actions associated with mitigation banks, in-lieu-fee mitigation projects, and permittee-responsible mitigation sites.

<u>Comment Period</u>: Anyone wishing to comment on this public notice should submit written comments to: Commander, U.S. Army Corps of Engineers, Savannah District,

Regulatory Division, Attention: Mr. Justin A. Hammonds, P.O. Box 528, Buford, Georgia 30515, no later than 13 months (November 27, 2022) from the date of this notice. Comments may also be submitted electronically to CESAS-RD@usace.army.mil. Please refer to the Standard Operating Procedure For Compensatory Mitigation (Version 2.0), dated October 2021, and the Regulatory Division file number (SAS-2017-00592) in your comments. All supporting documents (e.g., appendices, workbooks/worksheets) associated with the SOP are available at the following web address:
https://ribits.ops.usace.army.mil/ords/f?p=107:27:31338347533540::NO::P27_BUTTON_KEY:10

Please ensure that the “Savannah” filter is selected for the USACE District in the Regulatory In-Lieu Fee and Banking Information Tracking System’s Filter Menu after loading the above web address.

If you have any further questions concerning this public notice, please contact Mr. Justin A. Hammonds, District Mitigation Liaison at (678) 804-5227, or via email at justin.a.hammonds@usace.army.mil.

Enclosure
1. Standard Operating Procedure for Compensatory Mitigation (Version 2.0), dated October 2021.

SAVANNAH DISTRICT'S STANDARD OPERATING PROCEDURE FOR COMPENSATORY MITIGATION

Version 2.0 (October 2021)

SAVANNAH DISTRICT'S STANDARD OPERATING PROCEDURE FOR COMPENSATORY MITIGATION

REVISION LOG

Date Edited	Editor	Version Edited	Section Edited	Changes/Updates
10/15/2021	JAH	1.0	5.3	Intermittent/Ephemeral stream type was revised to Non-Perennial.
10/15/2021	JAH	1.0	7.1	A definition for Dewatering was incorporated into this section as a new impact type.
10/15/2021	JAH	1.0	Title page and rest of document	The year (2018) has been removed from the title. Moving forward, this document will be referenced as the "Savannah District's Standard Operating Procedure For Compensatory Mitigation", along with the document version (e.g., Version 2.0) and release date.
10/15/2021	JAH	1.0	5.6	The term "grandfathered" has been revised to "legacy".
10/15/2021	JAH	1.0	1.1 and Footnote 1	This section and footnote were revised to provide clarity of when the current and previous version of the SOP shall be applied to projects (permit applications, mitigation banks, and In-lieu fee mitigation site proposals).
10/15/2021	JAH	1.0	Footnote 6	Use of the Antecedent Rainfall Calculator (also known as the Antecedent Precipitation Tool) was included as a resource to assess the normality of rainfall.

SAVANNAH DISTRICT'S STANDARD OPERATING PROCEDURE FOR COMPENSATORY MITIGATION

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SAVANNAH DISTRICT'S STANDARD OPERATING PROCEDURE FOR COMPENSATORY MITIGATION

1.0. PURPOSE

1.1. <u>Introduction</u>: This Standard Operating Procedure for Compensatory Mitigation (SOP) contains instructions to aid applicants and mitigation sponsors in the calculation of credits associated with proposed impacts to and/or mitigation activities in waters of the U.S. as regulated under Section 404 of the Clean Water Act (CWA). The SOP is applicable in the geographic boundaries of the State of Georgia[1]. In Georgia, Section 404 of the CWA is administered by the U.S. Army Corps of Engineers, Savannah District, Regulatory Program (Savannah District).

Specifically, this document provides a methodology for both quantifying the functional impairments (i.e., mitigation credits owed), and functional improvements (i.e., mitigation credits generated) to aquatic resources in accordance with the requirements set forth in the Compensatory Mitigation for Losses of Aquatic Resources; Final Rule (2008 Rule; 33 CFR Parts 325 and 332).

This document immediately supersedes the credit calculations outlined in Savannah District's 2018 Standard Operating Procedure for Compensatory Mitigation (Version 1.0), dated April 27, 2018, for all complete applications (i.e., permits and mitigation plans[2]) received after the effective date of the public notice for the SOP. Mitigation requirements for permit applications determined to be complete prior to the effective date will be processed using Version 1.0 of SOP, unless the applicant requests otherwise. Mitigation documents that pre-date the SOP are hereby formally rescinded, with the exception of those referenced in Section 4.0, below.

1.2. <u>Goals</u>: The goals for the SOP are to: 1) provide stakeholders with a consistent, repeatable, functionally-based mitigation credit assessment methodology for aquatic resources; and, 2) establish a transition to functionally-based credit types to facilitate in-kind replacement of aquatic resources. All documents supporting this SOP have been included as appendices, either in their existing form or to be released at a later date, in order to facilitate future updates, as needed.

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[1] This SOP may be used at the discretion of the District Engineer on a case-by-case basis for the purchase of compensatory mitigation outside of the boundaries of the State of Georgia, where appropriate compensatory mitigation is not commercially available in the respective service area(s) for a proposed project impact.

[2] For mitigation banking instrument and in-lieu fee mitigation site proposals, the Public Notice soliciting comment on the Prospectus will be utilized as the threshold for the determination of the applicability of the respective version of the SOP.

2.0. BACKGROUND

2.1. 2004 Savannah District, Regulatory Division's Standard Operating Procedure for Compensatory Mitigation (SOP): The 2004 SOP was developed to provide a consistent methodology for assessing wetland, stream, and open water impacts and mitigation activities. While factors based on ecological function were considered in the development of both the impact and mitigation calculations within the 2004 SOP, overall, these factors generally comprised a very small percentage (less than 50 percent) of the overall calculation of credits owed or generated. At the time it was developed, compensation ratios were not specified as an underlying goal of the 2004 SOP.

2.2. Coordination: In July 2017, the Savannah District published the initial public notice soliciting public comments on the proposed SOP. During the subsequent 90-day public comment period, the Savannah District received multiple comments from Federal and State resource agencies, environmental consultants, mitigation bank sponsors, and non-profit organizations. In addition, the Savannah District participated in a number of working sessions with interested stakeholders, both during and following the public comment period, to solicit more detailed input on the SOP proposal. In response to the receipt of the public comments and input received during stakeholder working sessions, the Savannah District has made revisions, as appropriate, to the SOP (Version 1.0).

3.0. APPLICABILITY

3.1. Resource and Geographic Scope: The SOP has been developed to assess the entire range of projects (both impacts and mitigation) that may occur in freshwater wetlands, streams, saltwater tidal wetlands, and open waters within the geographic boundaries of the Savannah District Regulatory Program.

3.2. Scalability: This SOP can be used for projects of all sizes. The development of the SOP focuses on functional characteristics of the above-mentioned aquatic resources, an approach which provides flexibility in the assessment of a wider range of projects. It also addresses both direct and indirect impacts for projects regardless of scale.

3.3. Project Type: The SOP is applicable to all regulated activities under Section 404 of the CWA, to include the assessment of adverse impacts and mitigation associated with permit applications, mitigation plans, and compliance and enforcement actions taken by the Savannah District[3],[4].

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[3] The SOP may be used at the discretion of the U.S. Environmental Protection Agency for compliance and enforcement cases within the Savannah District in which they serve as the lead federal agency.

[4] This SOP may be used at the discretion of the Savannah District to calculate replacement mitigation associated with the conversion (e.g., removal of real property protections) of existing mitigation sites.

4.0. REGULATIONS & DISTRICT GUIDELINES

4.1. 2008 Final Rule on Compensatory Mitigation for Losses of Aquatic Resources (Rule): The Rule (Federal Register, Vol. 30, No. 70:19594-19705, April 10, 2008) emphasizes that the process of selecting a location for compensation sites should be informed by: an assessment of watershed needs and how specific wetland and/or stream restoration projects can best address those needs. It also identifies a hierarchical preference for different compensatory mitigation options (i.e., mitigation banks, in-lieu-fee, and permittee responsible sites) to off-set adverse impacts. The Rule further requires measurable and enforceable ecological performance standards for all types of mitigation, so that project success can be evaluated, and regular monitoring is required to document the extent to which mitigation sites are achieving ecological performance standards. The Rule also specifies the components of a complete mitigation plan and emphasizes the use of science-based assessment procedures (i.e., functional and/or conditional assessments) to evaluate the extent of potential aquatic resource impacts and mitigation measures (USEPA/USACE, 2008).

4.2. Savannah District's Guidelines to Evaluate Proposed Mitigation Bank Credit Purchases (Credit Purchase Guidelines): This document provides applicants with the appropriate procedure for evaluating and documenting the purchase of commercial mitigation bank credits when multiple banks and/or service areas must be considered in offsetting a permitted impact. The current Credit Purchase Guidelines are provided in Appendix 11.1. Where compensation is proposed from a mitigation bank or in-lieu-fee program, the Savannah District requires permit applicants to submit a completed Statement of Credit Availability Agreement. This procedure requires applicants to coordinate with the mitigation provider prior to submittal of the mitigation plan to ensure credit availability and accurate accounting. The Template Statement of Credit Availability Agreement is provided in Appendix 11.2.

4.3. Savannah District's Mitigation Service Areas: Guidelines regarding mitigation service areas for new mitigation banking projects will be provided at a future date. Appendix 11.3. is reserved for Mitigation Service Areas.

4.4. Savannah District's Mitigation Plan Guidelines: Guidelines regarding the development, design and implementation of mitigation plans will be provided at a future date. Appendix 11.4. is reserved for the Mitigation Plan Guidelines.

4.5. Savannah District's Monitoring Metrics and Performance Standards: Comprehensive guidelines regarding the development of mitigation performance monitoring plans and the criteria for the assessment of mitigation performance will be provided at a future date. Appendix 11.5. is reserved for Monitoring Metrics and Performance Standards.

4.6. Savannah District's Banking Instrument Template: A document outlining the required components of a complete mitigation banking instrument, will be provided at a future date. Appendix 11.6. is reserved for the Banking Instrument Template.

5.0. CREDITS

5.1. In-Kind Replacement: For the purposes of this SOP, the Savannah District has aligned mitigation credits with specific aquatic resource credit types in order to better replace the lost aquatic resource functions resulting from adverse impacts. In-kind replacement requires that mitigation resources have comparable functions and conditional characteristics as the resource being impacted. The list of credit types, below, will be utilized to achieve in-kind replacement. If in-kind replacement is unavailable at the time of permit issuance, the applicant will propose and the Savannah District will determine, on a case-by-case basis, whether another resource credit type is appropriate for fulfilling the compensatory mitigation requirements for the aquatic resource impacts. "Legacy" credit types are addressed in Section 5.6 below.

5.2. Wetland Credit Types: The Hydrogeomorphic Approach, HGM, (Brinson, 1993, and Smith et al., 1995) is a methodology that helps wetland practitioners classify, group, and assess wetlands and their functional capacities. The goal of HGM is to consistently classify wetlands across diverse geomorphic landscapes and assess shared (i.e., HGM Class) functions of wetlands in comparison to a corresponding reference dataset. For the purposes of in-kind replacement of wetland resources, this SOP utilizes wetland credit classifications based on the HGM Classification, which focuses on the following three characteristics: 1) water source; 2) landscape position; and 3) hydro-dynamics. With the greatest weight given to water source, the following list of wetland credit classifications will be applied to impacts and compensation in the Savannah District: 1) Freshwater Tidal; 2) Saltwater Tidal; 3) Riverine and Lacustrine Fringe; 4) Slope; and 5) Depressional and Flats.

1) Freshwater Tidal Wetlands express a hydrologic regime and hydrodynamics regulated by the ebb and flow of the diurnal tides inland of the Georgia coastline. Specifically, these Freshwater Tidal Wetlands are located in the eleven coastal counties (Brantley, Bryan, Camden, Charlton, Chatham, Effingham, Glynn, Liberty, Long, McIntosh, and Wayne) and in a landscape position adjacent to rivers, streams/creeks, and ditches that are subject to the influence of the tide. Further, these resources exhibit very low substrate salinities as compared to Saltwater Tidal Wetlands, and are subsequently not dominated by salt-tolerant vegetation species typically associated with coastal marshlands.

2) Saltwater Tidal Wetlands express a hydrologic regime and hydrodynamics regulated by the ebb and flow of the diurnal tides along the Georgia coastline. Specifically, these Saltwater Tidal Wetlands are located in six of the eleven

coastal counties (Bryan, Camden, Chatham, Glynn, Liberty, and McIntosh) and located in a landscape position adjacent to rivers, streams/creeks, ditches, and/or the Atlantic Ocean that are subject to the influence of the tide (i.e., lying within a tide-elevation range from 5.6 feet above mean tide level and below). Further, these resources exhibit higher substrate salinities than Freshwater Tidal Wetlands and are typically dominated by one or more salt tolerant vegetative species (as codified in Official Code of Georgia Annotated 12-5-282).

3) Riverine and Lacustrine Fringe Wetlands are wetlands located in a landscape position directly adjacent to rivers and streams, or their impoundments, respectively. The hydrologic regime of Riverine Wetlands is dominated by the frequency and duration of overbank flooding events from the adjacent tributary system. However, not all wetlands located adjacent to rivers or streams are necessarily "Riverine" wetlands, as the hydroperiod of Slope Wetlands adjacent to small, headwater streams (i.e., 1st and 2nd order streams) is not dominated by the frequency and duration of overbank flood events. The hydrologic regime of Lacustrine Fringe Wetlands is regulated by the water level in the adjacent impoundment. The impoundment itself maintains elevated water table levels in fringe wetlands, and additional water sources may include periodic inundation by surface water as the impoundment itself expands or recedes due to variations in rainfall, tributary inflow, etc. The dominant hydrodynamics of Riverine Wetlands is uni-directional and horizontal, largely consistent with the valley gradient. By comparison, the dominant hydrodynamics of Lacustrine Fringe wetlands is also horizontal, but is bi-directional, as the water moves into and out of the wetland with the rise and fall of the lake levels, and under influence of wind generated lake seiches (i.e., standing wave).

4) Slope Wetlands are those wetlands typically located in a landscape position at the foot slope and toe slope of the valley. The hydrologic regime of Slope Wetlands is predominantly regulated by hill slope movement and discharge of groundwater, and is supplemented by direct precipitation. The dominant hydrodynamics of this wetland type is horizontally uni-directional, as water flows along a hydraulic gradient. For the purposes of assessing wetland adverse impacts, Slope Wetlands will include those wetlands at the head of small streams, including areas up-gradient of distinct channel formation through 2nd order stream reaches (Wilder et al., 2013). The determination of stream order will follow the Modified Strahler[5] Stream Order[6] value provided in the Watershed Report Tool for stream reaches identified in the USEPA Waters GeoViewer Application (please refer to the following website: https://epa.maps.arcgis.com/apps/webappviewer/index.html?id=ada349b90c264

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[5] Refer to Strahler, A. N., 1952. Hypsometric (area-altitude) analysis of erosional topography. Bulletin Geological Society of America. 63: 1117-1142.

[6] Refer to McKay, L., Bondelid, T., Dewald, T., Johnston, J., Moore, R., and Rea, A., "NHDPlus Version 2: User Guide", 2012.

96ea52aab66a092593b). Unmapped stream reaches in the NHD dataset will be considered first order streams.

5) Depressional/Flat Wetlands are those wetlands located in a closed depression or on a flat landscape, respectively. The hydrologic regime of these wetlands is predominately dependent on precipitation inputs, but depressional wetlands may also have a secondary groundwater component. The dominant hydrodynamics of these wetlands are vertical, as water enters these wetlands through precipitation events and exits via groundwater recharge and evapotranspiration.

5.3. Stream Credit Types: Stream credit types are based on the association of flow regime and landscape position. The following list of stream credit types will be utilized in the assessment of both impacts and compensation within the Savannah District: 1) Non-Perennial Streams[7]; 2) Perennial Streams (less than three (3) square mile watersheds); 3) Perennial Streams (greater than three (3) square mile watersheds).

1) Non-Perennial Streams are those tributaries that are located in very small catchments (i.e., usually less than 100 acres in size). Non-Perennial Streams can exhibit base flow during a portion of the year (intermittent) under the range of normal climatic conditions[8], or exhibit surface water flows during and shortly after storm events (ephemeral).

2) Perennial Streams (less than 3 square mile watersheds) are those tributaries located in small to medium-sized catchments that, under the range of normal climatic conditions, exhibit continuous base flow throughout the year.

3) Perennial Streams (greater than 3 square mile watersheds) are those tributaries located in medium to large catchments that, under the range of normal climatic conditions, exhibit continuous base flow throughout the year.

5.4. Open Waters, Ditches, and Canals: For aquatic resources whose only function is to move water from one point to another and that function is not adversely impacted, compensation is generally not required. However, the Open Waters, Ditches, and Canals Classification is provided to address authorized impacts that adversely affect functions performed by these aquatic resources. For the purposes of this SOP, impacts to Open Waters, Ditches, and Canals may be assessed as an impaired wetland and/or stream credit type on a case-by-case basis, in consultation with the Savannah District.

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[7] The Savannah District does not currently consider the geomorphic restoration of ephemeral streams to be ecologically appropriate.

[8] The Antecedent Rainfall Calculator and local precipitation record will be used to determine if a project site is under normal climatic conditions. Normal climatic conditions are defined as a range, 30 to 70 percent probability, of an amount of precipitation that could occur for each month of the year. The normal range is established through the statistical ranking of the precipitation record for 30-year period. At the discretion of the Savannah District, the Direct Antecedent Rainfall Evaluation Methodology (DAREM) may also be utilized to further assess the status of climatic conditions for a project site.

5.5. Out-Of-Kind Replacement: If in-kind replacement is unavailable at the time compensation is required, the Savannah District will determine if another resource credit type is appropriate. In these circumstances, applicants may be required to provide compensation at a higher ratio (1.25:1 ratio) than in-kind credit purchases (refer to 33 CFR 332.3(e) and (f)). However, stream credit types will not be approved for the compensation of wetland impacts, and wetlands credit types will not be approved for the compensation of stream impacts.

5.6. Legacy Credits: The Savannah District mitigation program has historically operated using two (2) generic credit types: stream credits and wetland credits. Since promulgation of the 2008 Rule, the Savannah District has recognized the need to diversify mitigation credit types based on aquatic resource classification to ensure compensatory mitigation is providing in-kind functional replacement. In the sections above, we define new mitigation credit types based on aquatic resource classifications to assist in no net loss of in-kind aquatic resources. However, there are large inventories of existing mitigation credits currently available for sale in the mitigation marketplace in Georgia. As a result, the Savannah District has developed the following guidelines regarding the applicability of these credits as compensation for aquatic resource impacts.

As of the effective date of this SOP, all existing, generic credits that have been authorized as part of an approved mitigation instrument (i.e., mitigation bank instruments and/or In-Lieu-Fee mitigation projects) will be considered “legacy credits”. Any legacy credits proposed as compensatory mitigation will continue to provide valid, in-kind compensation (e.g., generic wetland credits for slope wetland impacts) and be sold in accordance with the terms and conditions associated with the approved mitigation instrument and any applicable instrument modifications.

The only exception to this legacy credit status will be for Saltwater and Freshwater Tidal Wetland credits in coastal areas (see Section 5.6.1 below). Once the required credits are calculated using the SOP, an equivalent number of legacy credits will be determined through the application of a conversion factor. The conversion factor has been set to eight (8) credits per acre for wetland adverse impacts, and twelve (12) credits per linear foot for stream adverse impacts. These conversion factors are based on the results of research on compensatory mitigation in Georgia conducted by the University of Georgia, River Basin Center[9] and the Savannah District's internal review of the adverse impact and restoration/enhancement mitigation factors in the Wetland and Open Waters Worksheets of the 2004 SOP.

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[9] University of Georgia, River Basin Center. 2017. “No Net Loss In The U.S. Army Corps Savannah District,”

5.6.1. Legacy Credits in Coastal Areas: Legacy wetland credits servicing any portion of Georgia’s eleven coastal counties (Brantley, Bryan, Camden, Charlton, Chatham, Effingham, Glynn, Liberty, Long, McIntosh, and Wayne) shall be considered out-of-kind for impacts to Saltwater and Freshwater Tidal Wetlands. Exceptions will be granted if legacy credits were generated from Saltwater Tidal Wetland or Freshwater Tidal Wetland areas that meet the respective resource definitions outlined in this SOP, or a provision in the approved banking instrument for a bank where legacy credits were generated, establishes intent to compensate for Saltwater or Freshwater Tidal Wetland impacts.

6.0. AQUATIC RESOURCE ASSESSMENTS FOR ADVERSE IMPACTS

6.1. Qualitative Resource Assessments for Adverse Impacts: The Savannah District has developed qualitative assessments to establish the existing qualitative functional capacity score of wetlands and streams proposed for all permitted impacts (including General and Standard Permits). For each of the following qualitative assessments, the Savannah District developed a dichotomous questionnaire (i.e., Yes/No) to categorize the function/condition of a wetland or stream. These responses are then converted into a categorical score (i.e., High, Moderate, Low) for each of the functions listed below. Each of the questions related to a function is equally weighted in the assessment, as is each of the functions. The following qualitative assessment methodologies will be utilized to establish the existing function/condition score:

6.1.1. Freshwater Wetland Qualitative Assessment: The framework of the wetland qualitative assessment is based on the functions outlined in “A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Forested Wetlands in Alluvial Valleys of the Coastal Plain of the Southeastern United States” (Wilder et al., 2013). Specifically, this qualitative assessment focuses on the following list of functions: 1) Water Storage; 2) Biogeochemical Transformation; 3) Maintain Wetland Vegetative Community; and 4) Maintain Wetland Faunal Community. The total Freshwater Wetland Qualitative Functional Capacity Score is a result of the following basic composite functional attribute score combinations:

- “High” (H) function (e.g., H-H-H-H; H-H-H-M; H-H-H-L; H-H-M-M);
- “Moderate” (M) function (e.g., H-H-L-L; H-M-M-M; M-M-M-M; M-M-M-L; M-M-L-L);
- “Low” (L) function (e.g., H-L-L-L, M-L-L-L; L-L-L-L).

The Freshwater Wetland Qualitative Functional Capacity Score is then utilized in the Qualitative Worksheet for Wetland Adverse Impacts. See description below in Section 7.1.1 to determine the mitigation requirement for a given wetland impact. Refer to Appendix 11.7 for the Freshwater Wetland Qualitative Assessment Worksheets.

6.1.2. Saltwater Wetland Qualitative Assessment: The framework of the Saltwater Tidal Wetland Qualitative Assessment is based on the functions outlined in “A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing the Functions of Tidal Fringe Wetlands Along the Mississippi and Alabama Gulf Coast” (Shafer et al., 2007). Specifically, this qualitative assessment focuses on the following list of functions: 1) Wave Energy Attenuation; 2) Biogeochemical Cycling; 3) Nekton Habitat Utilization; 4) Marsh-Dependent Wildlife Habitat; and 5) Plant Community Structure and Composition. The total Saltwater Wetland Qualitative Functional Capacity Score is a result of the following basic composite functional attribute score combinations:

- “High” function (e.g., H-H-H-H-H; H-H-H-H-M; H-H-H-H-L; H-H-H-M-M);
- “Moderate” function (e.g., H-H-H-L-L; H-H-M-M-M; H-H-L-L-L; H-M-M-M-M; M-M-M-M-M; M-M-M-M-L; M-M-M-L-L);
- “Low” function (e.g., H-L-L-L-L, M-M-L-L-L; M-L-L-L-L; L-L-L-L-L).

The Saltwater Wetland Qualitative Functional Capacity Score is then utilized within the Qualitative Worksheet for Wetland Adverse Impacts. See equation below in Section 7.2.1 to determine the mitigation requirement for a given wetland impact. Refer to Appendix 11.8 for the Saltwater Wetland Qualitative Assessment Worksheet.

6.1.3. Stream Qualitative Assessment: The framework of the stream qualitative assessment is based upon the functions outlined by Fischenich (2006), “Functional Objectives for Stream Restoration” and Harman et al. (2012), “A Function-Based Framework for Stream Assessment and Restoration Projects”. Specifically, this qualitative assessment focuses on the following list of functions: 1) Hydrology; 2) Hydraulics; 3) Geomorphology; 4) Physio-chemistry; and 5) Biology. The total Stream Qualitative Functional Capacity Score is a result of the following basic composite functional attribute score combinations:

- “High” function (e.g., H-H-H-H-H; H-H-H-H-M; H-H-H-H-L; H-H-H-M-M);
- “Moderate” function (e.g., H-H-H-L-L; H-H-M-M-M; H-H-L-L-L; H-M-M-M-M; M-M-M-M-M; M-M-M-M-L; M-M-M-L-L);
- “Low” function (e.g., H-L-L-L-L, M-M-L-L-L; M-L-L-L-L; L-L-L-L-L).

This Stream Qualitative Functional Capacity Score is then utilized within the Qualitative Worksheet for Stream Adverse Impacts. See description below in Section 7.2.2 to determine the mitigation requirement for a given stream impact. Refer to Appendix 11.9 for the Stream Qualitative Assessment Worksheets.

6.2. Quantitative Resource Assessments For Adverse Impacts: The District Engineer (DE), and/or his/her designee, may utilize quantitative functional assessments (e.g., Hydrogeomorphic Methodologies (HGM), Stream Quantification Tools (SQT), etc.) to determine the appropriate amount of compensatory mitigation for a given impact, at his/her discretion. If the use of a quantitative functional assessments is not initiated by the DE or their designee, then applicants will use a qualitative assessment (described above in Sections 6.1.1 through 6.1.3) to determine the type and amount of compensatory mitigation required for a project impact.

7.0. ADVERSE IMPACT CALCULATIONS

7.1. Adverse Impact Worksheet Definitions: Key terms applicable to the Wetland & Stream Qualitative and Quantitative Adverse Impacts worksheets are defined below. These worksheets are intended to support clear and consistent methodologies for impact credit calculations. Each worksheet has been developed with drop-down lists, text hover tips, and input validation rules to assist the user with the completion of the worksheets.

Clearing and Grubbing is defined as a mechanized land clearing practice in which natural vegetation (i.e., trees, shrubs/sapling, woody vines, and herbs), roots, and woody debris are removed from the wetland. This activity also includes the displacement of surface soil horizons within the wetland associated with the use of a root rake or similar device used to remove rooted vegetation.

Conversion of Kind is defined as converting tidal wetlands to non-tidal wetlands, or non-tidal wetlands to tidal wetlands, when the conversion is directly associated with a discharge of dredge and/or fill material (e.g., converting Saltwater Tidal Wetlands to freshwater wetlands by installing a tide gate).

Dewatering (Stream and Pump Diversions) – Short-term/Temporary is defined as the alteration of stream flows from the existing channel for the purposes of constructing a structure (e.g., culvert) in the stream bed and/or banks. Dewatering shall only be used for temporary or short-term durations (e.g., less than or equal to 90 days, less than 1 year). As a general rule, mitigation will be required for dewatering of streams, where the alteration of stream flows meets or exceeds 60 days. Diversions may include the construction of coffer dams (and bypass pumps), piped diversions, or the construction of impervious lined temporary diversion channels. Dewatering for greater than or equal to 1 year is considered a permanent loss of stream function, and thus does not qualify under this impact type. This secondary adverse impact type does not include any temporary fills or placement of structures, as those would be considered primary adverse impacts and thus assessed separately.

Duration refers to the temporal loss of wetland/stream functions associated with length of time during which an impact (primary or secondary impact) persists. The categories for the duration factor are as follows: 1) **Permanent/Reoccurring**[10] is defined as persisting greater than or equal to one year (i.e., 365 days); 2) **Short-Term – Less than 1 Year** is defined as persisting less than one year (i.e., less than 365 days, but greater than 90

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[10] The temporal assessment of reoccurring impacts is not limited to consecutive days.

days); 3) **Temporary – Less than (or equal to) 90 days** is defined as persisting 90 days or less.

Hydrologic Alteration - Drain is defined as an impairment which results in the reduction of the hydro-period of a wetland, when associated with a discharge of dredge or fill material. This factor includes extensively changing the duration, degree, and/or frequency of the wetland's hydro-period.

Hydrologic Alteration - Impound is defined as the detention or retention of surface hydrology in a wetland and/or stream through the construction of a dam, weir, levee, or other man-made structure or activity.

Primary Adverse Impacts refers to the list of impact categories that are associated with the adverse modification of wetlands, streams, and/or open waters. Specifically, primary impacts are those impacts that are associated with discharge of dredged or fill material as regulated under Section 404 of the CWA. The list of Primary Adverse Impacts for Wetlands includes the following: 1) Discharge of Dredge Material; 2) Discharge of Fill; and, 3) Clearing and Grubbing. The list of Primary Adverse Impacts for Streams include the following: 1) Discharge of Fill; and 2) Primary Morphological Change.

Primary Morphological Alteration is defined as the hardening of the banks of the stream (either one or both), and/or the construction of perpendicular at-grade rock fords across the stream bed. Examples of hard engineering include placement of rip-rap, gabions, concrete structures, sheet-piles, or other hardening structures below the ordinary high water mark along the banks or bed of the stream. This does not include constructed riffles or instream structures incorporated as bed form and grade control features in natural channel restoration designs.

Secondary Adverse Impacts refers to the list of impact categories that are associated with the adverse modification of wetlands, streams, and/or open waters, which result from a discharge of dredged or fill material as regulated under Section 404 of the CWA. In accordance with the National Environmental Policy Act, the Savannah District will assess all reasonably foreseeable impacts to waters of the United States which fall within the Federal Scope of Analysis for a Section 404 Permit. The list of Secondary Adverse Impacts for Wetlands includes the following: 1) Hydrologic Alteration – Drain; 2) Hydrologic Alteration – Impound; 3) Conversion of Kind; and, 4) Vegetative Conversion. The list of Secondary Adverse Impacts for Streams includes the following: 1) Hydrologic Alteration - Impound; 2) Secondary Morphological Alteration; and 3) Dewatering (Stream and Pump Diversions) – Short-term/Temporary.

Secondary Morphological Alteration is defined as a reasonably foreseeable, functionally adverse change in the stream bed and/or banks as a result of an upstream or downstream primary adverse impact. Secondary morphological alterations may include changes in the stream bed and/or banks that result in losses of longitudinal habitat diversity (e.g., filling of pools, headcut migration through riffles), losses of the existing percentages of aquatic habitat (e.g., % of riffles and pools), loss of stream bank stability (e.g., increased Bank Erosion Hazard Index values), and loss of floodplain connectivity (e.g., increased Bank Height Ratio and/or decreased Entrenchment Ratio).

Stream Qualitative Functional Capacity Score (SQFC Score) refers to the existing, pre-impact stream function score, as determined using the Stream Qualitative Assessment Worksheet.

Stream Qualitative Functional Capacity Impact (SQFC Impact) refers to the product of the SQFC score and Type of Impact, as determined using the Qualitative Worksheet for Stream Adverse Impacts.

Total Stream Qualitative Functional Capacity Impact (Total SQFC Impact) refers to the product of the SQFC Impact and Duration, as determined using the Qualitative Worksheet for Stream Adverse Impacts.

Total Wetland Qualitative Functional Capacity Impact (Total WQFC Impact) refers to the product value of the Wetland Qualitative Function Capacity Impact and Duration, as determined using the Qualitative Worksheet for Wetland Adverse Impacts.

Type of Impact refers to the characterization of the impact. Specifically, the impact will be categorized as either a primary adverse impact or secondary adverse impact.

Vegetative Conversion is defined as associated clearing of the natural, forested vegetative community within a wetland, in conjunction with but outside of the limits of a discharge of dredge or fill material. This activity is limited to cutting vegetation at an elevation above the soil surface within wetlands, and does not include soil displacement (i.e., grubbing, and/or mechanized land clearing).

Wetland Qualitative Functional Capacity Score (WQFC Score) refers to the existing function score of a wetland prior to the impact, as determined using the Wetland Qualitative Assessment Worksheet.

Wetland Qualitative Functional Capacity Impact (WQFC Impact) refers to the product of the Wetland Qualitative Function Capacity Score and Type of Impact, as determined using the Qualitative Worksheet for Wetland Adverse Impacts.

7.2. <u>Qualitative Worksheets for Adverse Impacts</u>: The Qualitative Worksheets for Adverse Impacts utilize the following factors: 1) Type of Impact; and, 2) Duration of Impact. For each of these factors, the Savannah District developed a series of index values, on a 0.00 to 1.00 scale, to quantify the functional/conditional loss of the aquatic resources (please refer to Appendices 11.10 and 11.11 for the indices of wetland and stream adverse impacts). In order to determine mitigation credits required, the Qualitative Worksheets for Wetland and Stream Adverse Impacts (please refer to Appendices 11.12 and 11.13) are calculated as follows:

7.2.1. Equations for Qualitative Worksheet for Wetland Adverse Impacts:

a. Equation 1: (WQFC Score)(Type of Impact) = WQFC Impact

b. Equation 2: (WQFC Impact)(Duration) = Total WQFC Impact

c. Equation 3: (Total WQFC Impact)(Acres) = Total Wetland Credits Owed

7.2.2. Equations for Qualitative Worksheet for Stream Adverse Impacts:

a. Equation 1: (SQFC Score)(Type of Impact) = SCFC Impact

b. Equation 2: (SQFC Impact)(Duration of Impact) = Total SQFC Impact

c. Equation 3: (Total SQFC Impact)(Linear Feet) = Total Stream Credits Owed[11,12]

8.0. MITIGATION ACTION CALCULATIONS

8.1. Quantitative Mitigation Assessments: Quantitative mitigation assessment methodologies are required to establish baseline functions for wetland and/or stream resources associated with mitigation projects. Quantitative assessment methodologies will be utilized to establish both the existing and proposed functional scores for each of the following aquatic resource types:

8.1.1. Georgia Interim Freshwater Wetland Hydrogeomorphic Methodology (GA HGM): For the assessment of all freshwater wetland resources proposed for mitigation credit generation, mitigation sponsors will utilize the GA HGM to establish baseline conditions, estimate the proposed conditions, and verify that the proposed conditions have been achieved. The GA HGM was developed through the selection of function-based parameters as outlined in Wilder et al. (2013). All parameters were selected based upon their anticipated sensitivity to a measurable net lift of functions resulting from restoration/enhancement actions as documented during the monitoring period. In addition to the parameters selected from Wilder et al. (2013), a soil saturation threshold parameter was developed to assess wetland hydrologic functions. The list of parameters selected as part of the GA HGM has been provided in Table 1. As a guiding principle for this assessment methodology, wetland credit generation associated with restoration or enhancement actions will be based on a calculation of the proposed

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[11] If the impact incurred is to a Non-Perennial Stream with ephemeral flow, the Total 2018 Stream Credits Owed are prorated to 50 percent.

[12] If the impact incurred is to a Non-Perennial Stream with intermittent or ephemeral flow, the Total Legacy Stream Credits Owed are prorated to 60 percent.

net functional lift from baseline, existing conditions. Refer to Appendices 11.14. and 11.15. for GA HGM Workbook and User Manual.

8.1.2. Georgia Interim Saltwater Wetland Hydrogeomorphic Methodology: This assessment methodology will be provided at a future date. Appendices 11.16. and 11.17. are reserved for the Georgia Interim Saltwater Wetland HGM Workbook and User Manual.

8.1.3. Georgia Interim Stream Quantification Tool (GA SQT): For the assessment of all stream resources proposed for mitigation credit generation, mitigation sponsors will utilize the GA SQT to establish baseline conditions, estimate the proposed conditions, and verify that the proposed conditions have been achieved. The GA SQT was developed through the selection of function-based parameters as outlined in the Tennessee Stream Quantification Tool (TDEC, 2017), North Carolina Stream Quantification Tool (Harman et al., 2017), and Wyoming Stream Quantification Tool (USACE, 2017). All parameters were selected based upon their anticipated sensitivity to a measurable net lift of functions resulting from restoration/enhancement actions as documented during the monitoring period. In addition to the parameters selected from Tennessee Stream Quantification Tool, a series of macro-invertebrate parameters was developed to assess stream biological functions. The list of parameters selected as part of the GA SQT has been provided in Table 2. As a guiding principle for this assessment methodology, stream credit generation associated with restoration or enhancement actions will be based on a calculation of the net functional lift from baseline conditions. Refer to Appendices 11.18 and 11.19 for the GA SQT Wookbook and User Manual & Scientific Support for the GA SQT.

Table 1. Selected Function-Based Parameters for the GA HGM

Functional Category	Function-Based Parameters	Measurement Method
Hydrology/Water Storage	Soil Saturation	Water Table Measurements (measurements every 8 hours)
Maintain Vegetative Community	Wetland Vegetation Composition	Vegetative Plots
	Wetland Vegetation Structure	Vegetative Plots
Biogeochemical Transformation/Maintain Faunal Habitat	Large Woody Debris (LWD)	Pieces of LWD
Biogeochemical Transformation/Maintain Faunal Habitat	Upland Buffers	Buffer Width and % Perimeter

Table 2. Selected Function-Based Parameters for the GA SQT

Functional Category	Function-Based Parameters	Measurement Method
Hydraulics	Floodplain Connectivity	Bank Height Ratio
		Entrenchment Ratio
Geomorphology	Riparian Vegetation	Left Buffer Width (ft.)
		Right Buffer Width (ft.)
	Bed Form Characterization	Pool Spacing Ratio
		Percent Riffle
		LWD Index
Biology	Macros	Varies dependent upon the Level III and IV Eco-Region of the reach. Measurement methods can range from four to five total metrics. These metrics can include the assessment of EPT, burrowers, clingers, filterers-collectors, shredders, swimmers, and general taxa richness.

8.2. <u>Preservation</u>: If wetlands and/or streams are proposed for preservation, those resources must meet the preservation criteria outlined in the Rule. All proposed wetland and stream preservation must be supported with a Quantitative Mitigation Assessment to establish the existing functional capacity score. If the Savannah District determines the proposed preservation resource to be appropriate as mitigation, the mitigation credit for that resource will be limited to no more than 20 percent of the total potential functional capacity score. The Savannah District reserves discretion to limit the amount of preservation credit that is generated on any mitigation site.

9.0. SUPPORTING DOCUMENTATION

Each respective Adverse Impact and Mitigation Action worksheet must also be supported with the following information: 1) appropriate identification of the project location (vicinity and location maps); 2) a scaled figure defining the full extent of the subject aquatic resource impacts and/or mitigation activities on the project site; and 3) a copy of the completed assessment form, including the associated field assessments and raw data used to calculate the functional capacity (for both impacts and mitigation) of the aquatic resource. At the discretion of the Savannah District, additional documentation and/or site investigations associated with any wetland and/or stream adverse impact and/or mitigation assessment may be requested on a case-by-case basis.

10.0. LITERATURE REFERENCES

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U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. 2008. Wetlands Compensatory Mitigation Rule Factsheet.

Appendix 11.1. Guidelines to Evaluate Proposed Mitigation Bank Credit Purchases

SAVANNAH DISTRICT, US ARMY CORPS OF ENGINEERS, REGULATORY GUIDELINES TO EVALUATE PROPOSED MITIGATION BANK CREDIT PURCHASES IN THE STATE OF GEORGIA

Photo courtesy of:
Murphy B. Winn, retired
US Army Corps of Engineers

This document was prepared by the Regulatory Division, Savannah District, US Army Corps of Engineers, and coordinated with the US Environmental Protection Agency, US Fish and Wildlife Service, and Georgia Department of Natural Resources

SAVANNAH DISTRICT, US ARMY CORPS OF ENGINEERS, REGULATORY GUIDELINES TO EVALUATE PROPOSED MITIGATION BANK CREDIT PURCHASES IN THE STATE OF GEORGIA

I. SUBJECT

Guidance for selecting a mitigation bank that would adequately compensate for aquatic resource losses, as authorized in a Department of the Army (DA) permit in accordance with section 404 of the Clean Water Act (CWA) and/or sections 9 or 10 of the Rivers and Harbors Act (RHA) of 1899.

II. PURPOSE

The purpose of this document is two fold:

- It provides recommendations to aid permittee, their agent, and other interested parties when selecting credits at a previously approved US Army Corps of Engineers, Savannah District, Regulatory Division (herein after referenced as USACE) mitigation bank(s) to compensate for aquatic resource losses associated with an approved DA permit, as in accordance with the Final Mitigation Rule (hereinafter referred to as The Rule), dated April 10, 2008.

- It provides recommendations to aid USACE regulatory project manager/specialist (PM/S) when determining if proposed bank credits are available and appropriate to compensate for aquatic resource losses permitted in a DA permit.

III. APPLICABILITY

This document should be used as a reference when selecting a mitigation bank to compensate for USACE-approved aquatic resource losses in the State of Georgia.

The provisions provided herein have been developed to provide clarity for selecting a mitigation bank in the State of Georgia:

- Potential banks that have been submitted to the USACE after the effective date of this document shall be evaluated for availability and appropriateness in accordance with the 8-digit Hydrologic Unit Code (HUC) approach outlined herein.

- USACE-approved banks that have been signed by the Chief, Regulatory Division (or designated appointee) prior to the effective date of this document shall be evaluated for availability and appropriateness in accordance with the conditions presented in the Banking Instrument (BI)[1] and the approach outlined herein. Specific examples where a BI governs is as follows:

- Where primary service areas have been established in the BI that differ from the boundaries posted at: http://www.sas.usace.army.mil/MBSA.htm, the boundaries presented in the BI shall be used for the analysis of that bank. Furthermore, where a Primary Service Area (PSA) contains more than one digit 8-digit HUC, the 8-digit HUC analysis discussed later in this document does not apply to a bank that was submitted prior to the effective date of this document. If the bank is included within the PSA of the impact area and the bank has appropriate credits available, credits may be purchased from the "grandfathered" bank to offset the permitted impacts.

- Where aquatic resources are generally classified as a stream or wetland resource category, that category may be considered appropriate in the analysis for compensation of such resources, respectively.

The provisions provided herein have been developed to be in accordance with the requirements in The Rule, dated April 10, 2008 ((33 CFR Part 332) and (40 CFR Part 230)). Of particular importance is the recognition that the purpose of mitigation bank credits is to compensate for aquatic resource functions and services lost or impacted from an USACE authorized project.

The recommendations presented herein do not:

- Alter the regulations or circumstances under which compensatory mitigation may be required;

- Address in-lieu-fee or site specific mitigation requirements; or

- Alter provisions provided in the CWA or RHA.

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[1] It is the responsibility of the applicant and potential banker to provide necessary information documenting deviations from the guidelines presented herein. Without proper documentation, banks may not be "grandfathered" under this clause.

IV. BANK AND CREDIT SOURCE SELECTION PROCESSES

1. Background

The Rule requires that a watershed approach be taken when using mitigation bank credits to fulfill compensatory mitigation requirements, and it requires the USACE to approve the bank selected as the source of such credits.

As stipulated in The Rule, a watershed approach to compensatory mitigation should take into account:

- Baseline Ecological Conditions, including, for example:
    - Historic and existing plant communities
    - Soil conditions
    - Aquatic resource delineations
    - Compensation credits[2]

- Landscape position
    - Distance between impact site and proposed mitigation bank
    - Type of aquatic resource at impact site and proposed mitigation bank
        - Stream order types/differences (e.g., ephemeral, intermittent and/or perennial)
        - Wetland type and relationship with other aquatic resources in area

- Aquatic resource functions
    - Impact site losses
    - Bank resource objectives and functions
    - Comparative site analysis: impact losses versus bank gains
        - Streams: chemical, biological, physical functions
        - Wetlands: ecological and physical functions

Where practicable, the suite of aquatic functions to be lost at the impact site should be compensated at the proposed mitigation bank(s).

To aid applicants in their selection of an appropriate credit source, a fact sheet has been solicited from all approved banks. Information includes, for example, primary/secondary service areas, HUCs, and habitat categories. It is recommended that this information be used to support the findings: does the proposed compensatory mitigation bank fulfill the compensation requirements of the DA permit in light of the watershed approach, in-kind replacement of lost functions and services, and proximity to the impacts? Fact sheets can be found at: http://www.sas.usace.army.mil/Banking.htm or information can be requested from the USACE Project Manager/Regulatory Specialist (PM/S).

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[2] Compensation credits shall be generated using the Savannah District Mitigation SOP, as amended, unless otherwise approved by the USACE. Additionally, compensation credit calculations will need to be verified by the USACE.

The applicant must include the information necessary to verify that the proposed bank credits adequately compensate for aquatic resource functional losses based on a watershed analysis. The USACE role is to evaluate the proposed mitigation strategy for its appropriateness in compensating for lost aquatic resource functions, as authorized in the subject DA permit. If the choice of a particular mitigation bank does not adequately compensate for the aquatic resources to be lost, the PM/S will provide comments to the applicant, identifying the concerns and requesting additional information to support recommendation(s).

2. Procedural Steps

As noted in The Rule, the USACE must provide a final concurrence letter/e-mail transmission stating that the submitted proposal is an acceptable approach for compensating for impacts permitted in a specific DA authorization.

We recommend that the following analysis/recommendation be provided to the USACE when the permit application is submitted. Note that the permittee should not purchase bank credits until the USACE has provided concurrence with all recommendations. If not, the credits may not be applied for use.

The process is as follows:

a. PSA[3] Analysis:

  (1) The applicant shall:

    (a) Identify PSA and 8-digit HUC of proposed impact area.

    (b) Identify functional resource losses and credits needed for compensation.[4]

    (c) Identify names and locations of banks in PSA by 8-digit HUC. In matrix format, present approximate distances to impact area and credit types (wetland and/or stream) available for sale at each bank.

    (d) Determine if appropriate (i.e., stream and/or wetland credits) credits exist in PSA, based on a watershed approach, and identify which bank(s) could fulfill compensatory mitigation requirements permitted in the DA authorization. The level of

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[3] The US Geological Survey (USGS) has established 52 watersheds based on the 8-digit Hydrologic Unit Codes (HUC) within the state boundary of Georgia. In Georgia, these HUCs were reviewed by the IRT and used, in part, to establish standardized service areas. These service areas were developed to compensate lost aquatic functions associated with permitted impacts to waters to the US within a consistent geographical area where aquatic resources are similar in kind and function. The Savannah District issued a PN, dated March 2004, informing the public of the above service area procedures.

[4] See Footnote #2 above.

information and analysis needed to support a watershed approach shall be commensurate with the scope and scale of the proposed impacts requiring a DA permit, as well as the functional losses to result.

  i. For impacts that are within the thresholds of a Nationwide Permit (NWP), any mitigation bank may be used for the replacement of credits providing the resource functional replacements are the same (i.e., freshwater for freshwater, estuarine for estuarine, and marine for marine) and the bank is located within the same PSA as is the proposed impacts. Examples are provided in the attached Supplement.

  ii. For impacts exceeding the thresholds of a NWP, a watershed analysis shall be conducted to support final applicant recommendations. Preference shall be given first where similar resources (or habitats) occur in the same 8-digit HUC versus those occurring outside the HUC, but within the same PSA. Examples are provided in the attached Supplement. Note that bank credit recommendations shall be based on functional resource replacements as well as overall landscape position.

(e) Identify if credits from above analysis are available:

  i. Verbal or written communication with the Point of Contact (POC) for each of the banks identified above via face to face or telephone communication. POC contact information is available at: http://www.sas.usace.army.mil/bankPOCs.xls.

  ii. Document (date and time) when communication was completed and with whom you spoke (include telephone number).

  iii. Ask bank's POC if type of credits required are available. If the needed credits are not available at the time of the communication, ask if there are credits expected to be available in the near future. (i.e., before work is to be initiated, as described in DA permit). Document responses.

(f) Provide final recommendations and supporting documentation on availability and appropriateness of bank credit proposal to USACE PM/S who is assigned to subject permit application.

(2) The USACE PM/S shall review and provide a final determination stating if submitted recommendations are appropriate. Notification may be in the form of a letter or an e-mail transmission.[5]

(a) If credits are determined not appropriate, the applicant must adequately address the USACE concerns, resubmit recommendations/supporting justification, and re-request USACE determination.

(b) If credits are determined appropriate, the applicant may purchase and secure said mitigation bank credits, if available.[6]

If it is determined that appropriate replacement credits are not available within the PSA of the permitted impact area, the scope of analysis may be expanded to include the Secondary Service Area (SSA). Note that it is the applicant's responsibility to investigate the availability and appropriateness of all bank credits within the applicable PSA before considering those available in a SSA.

b. 12-Digit HUC PSA Analysis (Optional):

(1) The applicant shall:

(a) Identify PSA, 8-digit HUC, and 12-digit HUC of proposed impact area.

(b) Identify functional resource losses and credits needed for compensation.[7]

(c) Identify names and locations of banks in PSA by 12-digit HUC. In matrix format, present approximate distances to

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[5] For Individual Permits, the PM/S review period begins at the end of the 30-day Joint Public Notice Comment Period. If the PM/S has not acted (or requested additional information in writing/e-mail) on a mitigation proposal within 30-days of the close of the JPN comment period, the request should be forwarded to the Mitigation Liaison Specialist. If additional information has been requested and another 30-days has passed since the new information has been submitted to the Regulatory PM/S, the request should be forwarded to the Mitigation Liaison Specialist. If Mitigation Liaison Specialist has not acted on a request within 60-days of receipt of the request, the request should be forwarded to the Savannah District, Regulatory Chief.

[6] Recommend securing credits after the permit decision has been made. If credits are secured prior to a permit decision, securing of such credits will not influence permit decision.

[7] See Footnote #1 above.

impact area and credit types (wetland and/or stream) available for sale at each bank.

(d) Determine if appropriate (i.e., stream and/or wetland credits) credits exist in PSA, based on a watershed approach, and identify which bank(s) could fulfill compensatory mitigation requirements permitted in the DA authorization.

(e) Identify if credits from above analysis are available (see process step a(1)(e) above.

(f) Provide final recommendations and supporting documentation on availability and appropriateness of bank credit proposal to USACE PM/S who is assigned to subject permit application.

(2) The USACE PM/S shall review and provide a final determination stating if submitted recommendations are appropriate. Notification may be in the form of a letter or an e-mail transmission.[8]

(a) If credits are determined not appropriate, the applicant must adequately address the USACE concerns, resubmit recommendations/supporting justification, and re-request USACE determination.

(b) If credits are determined appropriate, the applicant may purchase and secure said mitigation bank credits, if available.[9]

As the Rule indicates that a Watershed Approach should be used to support the decision-making process and distance between the impact site and the proposed bank site is recognized as a factor in the overall equation, the USACE will reduce the credit needs by 10% when the applicant purchases credits deemed appropriate from the 12-digit impact HUC.

c. SSA Analysis: After the USACE concurs that appropriate replacement credits are not available within the PSA of the permitted impact area; the following steps <u>must</u> be completed to determine if potential credits exist in the SSA:

(1) This applicant shall:

(a) Provide documentation from above analysis demonstrating that credits are not available and/or appropriate to replace subject impacts from banks within PSA.

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[8] See Footnote # 4 above

[9] See Footnote #5 above.

(b) Provide SSA analysis similar to that conducted above for a PSA (see Section 2.a.1).

(c) Provide final recommendations and supporting documentation on availability and appropriateness of bank credit proposal to USACE PM/S who is assigned to subject permit application.

(2) The USACE PM/S shall review and provide final determination stating if submitted recommendations are appropriate. Notification may be in the form of a letter or an e-mail transmission.[10]

(a) If credits are determined not appropriate, the applicant must adequately address the USACE concerns, resubmit recommendations/supporting justification and re-request USACE determination.

(b) If credits are determined appropriate, the applicant may purchase and secure said mitigation bank credits, if available.[11]

Note that if credits are available and determined appropriate in the PSA, those credits must be used before considering potential credits in a SSA. **It is the applicant's responsibility to investigate the availability of bank credits from the applicable service areas.** The SSA is restricted to use for projects where it has been clearly <u>demonstrated</u> that appropriate credits are not currently available and are not reasonably anticipated to be available in the near future in the PSA of the permitted impact area. Each USACE decision shall be based on a case-by-case review of the facts presented by the applicant when making the final determination. **Compensation at a mitigation bank for impacts at a site that is not within either the primary or secondary service area is not acceptable, unless approved by the entire IRT.**

3. Process Summary

The applicant must provide the information necessary for the USACE to verify that proposed bank credits adequately compensate for aquatic resource functional losses based on a watershed analysis, as authorized in a DA permit. In summary:

- Replacement credits should be obtained from a mitigation bank whose Primary Service Area (PSA) encompasses the impact area, if available and appropriate.
    - If appropriate credits are obtained from a bank whose PSA includes the impact area, and is also located within the 12-digit impact HUC in which the impact area is located, the USACE will reduce the overall credit need to mitigate for the impact by 10%.

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[10] See Footnote #4 above.

[11] See Footnote #5 above.

  - For banks that were not submitted to the USACE prior to the effective date of the guidance document, and if there are multiple 8-digit HUCs within the PSA, credits should be obtained from a mitigation bank within the 8-digit HUC in which the impact occurred, if available and appropriate. If appropriate credits are not available from a mitigation bank within the impact HUC, replacement credits may be obtained elsewhere in the approved PSA, if appropriate and available.

  - For grandfathered banks, the analysis may be fulfilled by assessing those banks that have available and appropriate credits within the PSA, as approved in the signed Banking Instrument.

- If appropriate credits are not available in the PSA, replacement credits may be obtained from the Secondary Service Area (SSA).

- Compensation for impacts at a site that is not within either the PSA or SSA of an approved mitigation bank is not acceptable, unless approved by the Interagency Review Team.

If the choice of a particular mitigation bank does not adequately compensate for the aquatic resources to be lost, the PM/S will provide comments to the applicant, identifying the concerns and requesting additional information to support recommendation(s).

If for any reason a modification to the originally approved source or amount of the required mitigation credits is proposed, another credit source approval review will need to be requested by the applicant.

All pertinent documentation and analyses for a given determination shall be adequately reflected in the record and clearly demonstrate the basis for the findings. Although the level of documentation may vary among projects, each USACE decision shall be based on a case-by-case review of the facts presented by the applicant when making the final determination.

Prior to the purchase of credits, the USACE must provide a final concurrence letter/e-mail transmission stating that the submitted proposal is an acceptable approach for compensating for aquatic resource impacts permitted in a specific DA authorization.

If you have comments or questions concerning this document, please contact Justin Hammonds, Mitigation Liaison Specialist, of the Regulatory Division, at (770) 904-2365.

V. DURATION

This guidance is effective immediately and remains in effect unless revised or rescinded.

SUPPLEMENT TO EVALUATE PROPOSED MITIGATION BANK CREDIT PURCHASES IN THE STATE OF GEORGIA

Example 1.

Case Facts: As authorized in a Nationwide Permit (NWP) and in accordance with the Savannah District's Mitigation Standard Operating Procedures (SOP), the project (*USACE File Number*) would need to obtain 1.5 wetland credits and 50 stream credits. This project is located in the Upper Blue River Basin Primary Service Area (PSA) and in the 30267001 8-digit Hydrologic Unit Code (HUC). There are 5 banks located in the PSA. Additional information and analyses are provided in the following matrix:

RESOURCE ANALYSIS				
IMPACT SITE DATA				
Resource Category	**Service Area; HUC**	**Distance to Impact Site**	**Credits Needed**	
Freshwater Wetland	PSA; 30267001	- -	1.5	
Stream	PSA; 30267001	- -	50	
			Sufficient Credits Available	**Recommended for Use**
MITIGATION BANK DATA				
Alpha Mitigation Bank				
Stream	PSA; 30267001	4 miles	Yes	
Bravo Mitigation Bank				
Stream	PSA; 30267001	2 miles	Yes	X
Freshwater Wetland	PSA; 30267001	2 miles	Yes	X
Charlie Mitigation Bank				
Stream	PSA; 30267002	10 miles	Unknown	
Freshwater Wetland	PSA; 30267002	10 miles	Unknown	
Delta Mitigation Bank				
Freshwater Wetland	PSA; 30267002	15 miles	Unknown	
Echo Mitigation Bank				
Freshwater Wetland	PSA; 30267002	50 miles	Unknown	
Stream	PSA; 30267002	50 miles	Unknown	

Applicant Recommendations: Proposes to purchase all credits from the Bravo Mitigation Bank. Banker POC indicated on 30 Sep 09 that sufficient credits were available to cover project needs.

USACE Determination: Concur with Applicant proposal.

Example 2.

Case Facts: As authorized in a NWP and in accordance with the SOP, the project (*USACE File Number*) would need to obtain 1.4 marine wetland credits. This project is located in the Lower Purple River Basin PSA and in the 80200456 8-digit HUC. There are 2 banks located in the PSA. Additional information and analyses are provided in the following matrix:

RESOURCE ANALYSIS				
IMPACT SITE DATA				
Resource Category	**Service Area; HUC**	**Distance to Impact Site**	**Credits Needed**	
Marine Wetland	PSA; 80200456	- -	1.4	
			Sufficient Credits Available	**Recommended for Use**
MITIGATION BANK DATA				
X-Ray Mitigation Bank				
Freshwater Wetland	PSA; 30267005	4 miles	Yes	X
Holiday Mitigation Bank				
Estuarine Wetland	PSA; 30267005	20 miles	Yes	

Applicant Recommendations: Proposes to purchase all credits from the X-Ray Mitigation Bank. Banker POC indicated on 13 Sep 09 that sufficient credits were available to cover applicant needs. These credits are available and closest to the impact site.

USACE Determination: Do not concur with Applicant proposal. The applicant is not allowed to purchase freshwater or estuarine wetland credits to replace marine wetland impacts. Determination needs to consider resource category/functional changes and location considerations. In this case, mitigation may include use of permittee responsible compensation. The applicant will need to provide a revised analysis.

Example 3.

Case Facts: As authorized in a NWP and in accordance with the SOP, the project (*USACE File Number*) would need to obtain 7.5 wetland credits and 5000 stream credits. This project is located in the Blue River Basin PSA and in the 30267010 8-digit HUC. There are no banks located in the PSA. However, there are 4 banks located in the SSA. Additional information and analyses are provided in the following matrix:

RESOURCE ANALYSIS				
IMPACT SITE DATA				
Resource Category	**Service Area; HUC**	**Distance to Impact Site**	**Credits Needed**	
Freshwater Wetland	PSA; 30267010	- -	7.5	
Stream	PSA; 30267010	- -	5000	
			Sufficient Credits Available	**Recommended for Use**
MITIGATION BANK DATA				
Alpha Mitigation Bank				
Stream	SSA; 30267001	4 miles	Unknown	
Bravo Mitigation Bank				
Stream	SSA; 30267001	24 miles	Unknown	
Freshwater Wetland	SSA; 30267001	24 miles	Unknown	
Charlie Mitigation Bank				
Stream	SSA; 30267002	50 miles	Unknown	
Freshwater Wetland	SSA; 30267002	50 miles	Unknown	
Delta Mitigation Bank				
Freshwater Wetland	SSA; 30267002	15 miles	Unknown	

Applicant Recommendations: Proposes to purchase all credits from SSA bank(s), as there are no credits available in the PSA. Determination of credits would assess the following factors: availability and appropriateness (i.e., functional credits available at the different banks and location of the banks).

USACE Determination: Concur with Applicant proposal. In this case, it is appropriate to assess banks in the SSA.

Example 4.

Case Facts: As authorized in a NWP and in accordance with the SOP, the project (*USACE File Number*) would need to obtain 1.4 freshwater wetland credits. This project is located within the Blue River Basin (BRB) PSA and in the 33333333 8-digit HUC. There are no banks located in the PSA or SSA. However, there is 1 bank located in the adjacent PSA (i.e., Red River Basin (RRB). Additional information and analyses are provided in the following matrix:

RESOURCE ANALYSIS				
IMPACT SITE DATA				
Resource Category	**Service Area; HUC**	**Distance to Impact Site**	**Credits Needed**	
Freshwater Wetland	BRB PSA; 33333333	- -	1.4	
			Sufficient Credits Available	**Recommended for Use**
MITIGATION BANK DATA				
Zulu Mitigation Bank				
Freshwater Wetland	RRB PSA; 22222222	14 miles	Yes	X

Applicant Recommendations: Proposes to purchase all credits from Zulu Mitigation Bank, as there are no credits available in the BRB PSA and/or SSA.

USACE Determination: Coordinate Applicant's proposal with the full IRT to determine appropriateness. If determined appropriate by the IRT, concur with Applicant proposal. If determined inappropriate by the IRT, do not concur with Applicant proposal. In the even that USACE/IRT does not concur, the applicant would not be allowed to purchase freshwater wetland credits in the adjacent PSA; rather, mitigation may include use of In-Lieu Fee or permittee responsible compensation. The applicant would need to provide a revised analysis.

Example 5.

Case Facts: As authorized in accordance with the SOP, the project (*USACE File Number*) would need to obtain 25 wetland credits. This project is located in the Upper Red River Basin PSA and in the 30267005 8-digit HUC. There are 2 banks located in the PSA. Additional information and analyses are provided in the following matrix:

RESOURCE ANALYSIS				
IMPACT SITE DATA				
Resource Category	**Service Area; HUC**	**Distance to Impact Site**	**Credits Needed**	
Freshwater Wetland	PSA; 30267005	- -	25	
			Sufficient Credits Available	**Recommended for Use**
MITIGATION BANK DATA				
Alpha Mitigation Bank				
Freshwater Wetland	PSA; 30267005	1 mile	Yes	
Stream	PSA 30267005	1 mile	Yes	
Bravo Mitigation Bank				
Stream	PSA; 30267006	15 miles	Yes	X
Freshwater Wetland	PSA; 30267006	15 miles	Yes	X
Note that Bravo Bank BI was submitted for USACE review in Dec 2005.				

Applicant Recommendations: Proposes to purchase all credits from the Bravo Mitigation Bank. Banker POC indicated on 30 Sep 09 that sufficient credits were available to cover applicant needs. POC indicated that original BI was submitted for review prior to the effective date of this document and that the PSA for this bank although larger than those identified on the USACE web page also services the Upper Red River Basin. POC also indicated that BI for this restoration effort would serve for all freshwater wetland impacts. Documentation demonstrating bank was proposed in Dec 2005 and credits are appropriate were provided to USACE.

USACE Determination: Concur with Applicant proposal.

Example 6.

Case Facts: Using the Savannah District's Mitigation SOP, the project (*USACE File Number*) would need to obtain 60 wetland credits. The project is located within the Middle Red River Basin PSA and in the 30200066 8-digit HUC. There are 2 banks located in the PSA. Additional resource information and analyses are provided in the following matrix:

RESOURCE ANALYSIS				
IMPACT SITE DATA				
Resource Category	**Service Area; HUC**	**Distance to Impact Site**	**Credits Needed**	
Freshwater Wetland	PSA; 30200066	- -	60	
			Sufficient Credits Available	**Recommended for Use**
MITIGATION BANK DATA				
Charlie Mitigation Bank				
Stream	PSA; 30200066	4 miles	Yes	X
Delta Mitigation Bank				
Freshwater Wetland	PSA; 30200065	10 miles	Yes	

Applicant Recommendations: Proposes to purchase all credits from the Charlie Mitigation Bank. Banker POC indicated on 05 Oct 09 that sufficient credits were available to cover applicant needs. These credits are of greatest value, because they are the least expensive to purchase and the nearest to the project impact site.

USACE Determination: Do not concur with Applicant proposal. The applicant is not allowed to purchase stream credits to replace freshwater wetland impacts. Determination needs to consider resource category/functional changes and location factors; cost is not a consideration in this analysis. It is likely that the Delta Mitigation Bank may be an appropriate bank, depending on the type of wetlands and functions existing at the bank site and those projected for loss at the development site. The applicant will need to provide a revised analysis.

Example 7:

Case Facts: Using the SOP, the project (*USACE File Number*) would need to obtain 250 freshwater wetland credits to replace proposed impacts to a cypress swamp. This project is located in the Black River Basin PSA and in the 30300221 8-digit HUC. There are 2 banks located in the PSA. Additional information and analyses are provided in the following matrix:

RESOURCE ANALYSIS						
Resource Category	**Type**	**Location**	**Landscape Position**	**Distance to Impact Site**	**Credits Needed**	
IMPACT SITE DATA						
Freshwater Wetland	Cypress swamp	PSA; 30300221	Adjacent to Stream	- -	250	
					Sufficient Credits Available	**Recommended for Use**
MITIGATION BANK DATA						
Echo Mitigation Bank						
Freshwater Wetland	Pine flatwoods	PSA; 30300221	Adjacent to Stream	4 miles	Yes	
Foxtrot Mitigation Bank						
Freshwater Wetland	Cypress swamp	PSA; 30300222	Adjacent to Stream	25 miles	Yes	X

Applicant Recommendations: Proposes to purchase all credits from the Foxtrot Mitigation Bank. Banker POC indicated on 15 Oct 09 that sufficient credits were available to cover applicant needs. In this case functional replacement of the cypress swamp with cypress swamp is considered more important than distance.

USACE Determination: Concur with Applicant proposal.

Example 8.

Case Facts: Using the SOP, the project (*USACE File Number*) would need to obtain 1,000 stream credits and 5 wetland credits. This project is located in the Middle Green River PSA and in the 30300331 8-digit HUC. There is 1 bank located in the PSA and 4 banks in the SSA. Additional information and analyses are provided in the following matrix:

RESOURCE ANALYSIS				
IMPACT SITE DATA				
Resource Category	**Service Area; HUC**	**Distance to Impact Site**	**Credits Needed**	
Freshwater Wetland	PSA; 30300331	- -	5	
Stream	PSA; 30300331	- -	1000	
			Sufficient Credits Available	**Recommended for Use**
MITIGATION BANK DATA				
Golf Mitigation Bank				
Stream	PSA; 30300331	4 miles	Yes	
Freshwater Wetland	PSA; 30300331	4 miles	Yes	
Halo Mitigation Bank				
Stream	SSA; 30300332	2 miles	Yes	X
Freshwater Wetland	SSA; 30300332	2 miles	Yes	X
India Mitigation Bank				
Stream	SSA; 30300332	10 miles	Yes	
Freshwater Wetland	SSA; 30300332	10 miles	Yes	
Lima Mitigation Bank				
Freshwater Wetland	SSA; 30300332	15 miles	Yes	
Macke Mitigation Bank				
Freshwater Wetland	SSA; 30300332	20 miles	Yes	
Stream	SSA; 30300332	20 miles	Yes	

Applicant Recommendations: Proposes to purchase all credits from banks in the SSA. Banker POC indicated on 16 Oct 09 that sufficient credits were available to cover applicant needs. These credits are of greatest value, because they are the least expensive to purchase and are closest to the impact site.

USACE Determination: Do not concur with Applicant proposal. The applicant is not allowed to purchase credits in the SSA, until they demonstrate that credits available in the PSA are not appropriate and/or not available. Note that determination needs to consider resource category/functional changes and location considerations; cost is not a consideration in this analysis. The applicant will need to provide a revised analysis, discussing the availability and appropriateness of the credits available at the Golf Mitigation Bank.

Example 9.

Case Facts: Using the SOP, the project (*USACE File Number*) would need to obtain 1,000 stream credits and 35 wetland credits. This project is located in the Middle Purple River PSA and in the 33300022 8-digit HUC. Additional information and analyses are provided in the following matrix:

RESOURCE ANALYSIS					
IMPACT SITE DATA					
Resource Category	**Type**	**Location**	**Landscape Position**	**Distance to Impact Site**	**Credits Needed**
Freshwater Wetland	Bottomland Hardwood	PSA 33300022	Adjacent to Stream	- -	35
Stream	Intermittent	PSA 33300022	2nd Order	- -	1000
					Sufficient Credits Available
MITIGATION BANK DATA					
Romeo Mitigation Bank					
Stream	Intermittent	PSA 33300022	2nd Order	2 miles	No
Freshwater Wetland	Bottomland Hardwood	PSA 33300022	Adjacent to Stream	2 miles	No
Sierra Mitigation Bank					
Stream	Perennial	SSA 33300021	2nd Order	10 miles	Yes
Freshwater Wetland	Emergent	SSA 33300021	Adjacent to Stream	10 miles	Yes
Tango Mitigation Bank					
Freshwater Wetland	Bottomland Hardwood	SSA 33300021	Adjacent to Stream	20 miles	Yes
Stream	Intermittent	SSA 33300021	2nd Order	20 miles	Yes

Applicant Recommendations: Proposes to purchase all credits from the Tango Mitigation Bank. Romeo Banker POC indicated on 15 Sep 09 that sufficient credits were not available to cover applicant needs: there were no stream credits available and wetland credits may be available in 5 months. As all permits have been obtained and site construction may initiate once mitigation credits are secured, this site was dismissed. Sierra and Tango Banker POCs indicated on 17 Sep 09 that sufficient credits were available to cover applicant needs. In talking with the Tango Mitigation POC, POC indicated that wetland restoration efforts were similar to impacts to occur at project site.

USACE Determination: Concur with Applicant proposal.

Example 10.

Case Facts: Using the SOP, the project (*USACE File Number*) would need to obtain 3,000 stream credits and 150 wetland credits. This project is located in the Oso River PSA and in the 33300033 8-digit HUC. Additional information and analyses are provided in the following matrix:

RESOURCE ANALYSIS					
IMPACT SITE DATA					
Resource Category	**Type**	**Location**	**Landscape Position**	**Distance to Impact Site**	**Credits Needed**
Freshwater Wetland	Bottomland Hardwood	PSA 33300022	Adjacent to Stream	- -	150
Stream	Intermittent	PSA 33300022	2nd Order	- -	3000
					Sufficient Credits Available
MITIGATION BANK DATA					
Long Beach Mitigation Bank					
Stream	Intermittent	PSA 33300022	2nd Order	2 miles	1000
Freshwater Wetland	Bottomland Hardwood	PSA 33300022	Adjacent to Stream	2 miles	No
Vienna Mitigation Bank					
Stream	Intermittent	PSA 33300021	2nd Order	10 miles	500
Freshwater Wetland	Bottomland Hardwood	PSA 33300021	Adjacent to Stream	10 miles	100
Wilmington Mitigation Bank					
Freshwater Wetland	Emergent	SSA 33300020	Adjacent to Stream	20 miles	Yes
Stream	Intermittent	SSA 33300020	2nd Order	20 miles	Yes
Newport Mitigation Bank					
Freshwater Wetland	Bottomland Hardwood	PSA 33300021	Adjacent to Stream	30 miles	50
Marshfield Mitigation Bank					
Stream	Intermittent	PSA 33300021	2nd Order	25 miles	1500
Tybee Mitigation Bank					
Marine Wetland	Salt Marsh	SSA 33300020	Adjacent to River	100 miles	Yes
River	Perennial	SSA 33300020	4th Order	100 miles	Yes
Falls Church Mitigation Bank					
Stream	Intermittent	SSA 33300020	2nd Order	45 miles	150

Applicant Recommendations: Proposes to purchase the credits as follows:

- Long Beach: 1,000 stream credits
- Vienna:
    - 500 stream credits
    - 100 freshwater wetland credits
- Newport: 50 freshwater wetland credits
- Marshfield: 1,500 stream credits

Banker POCs indicated on 15 Sep 09 that sufficient credits were available to cover applicant needs.

USACE Determination: Concur with Applicant proposal.

Example 11.

Case Facts: Using the SOP, the project (*USACE File Number*) would need to obtain 100 stream credits. The project is located within the Middle Red River Basin PSA and in the 30200066 8-digit HUC. Project construction and operation is likely to affect listed fish habitat or passage. There are 2 banks located in the PSA and 1 in the SSA. Additional information and analyses are provided in the following matrix:

RESOURCE ANALYSIS					
IMPACT SITE DATA					
Resource Category	**Service Area; HUC**	**Distance to Impact Site**	**Listed Species Impacts**	**Credits Needed**	
Stream	PSA; 30200066	- -	Yes	100	
			Bank Benefits Listed Species	**Sufficient Credits Available**	**Recommended for Use**
MITIGATION BANK DATA					
Charlie Mitigation Bank					
Stream	PSA; 30200066	4 miles	No	No	
Delta Mitigation Bank					
Freshwater Wetland	PSA; 30200065	10 miles	Yes	Yes	
Mensing Mitigation Bank					
Stream	SSA 30200067	20 miles	Yes	Yes	X

Applicant Recommendations: Proposes to purchase all credits from the Mensing Mitigation Bank. Banker POC indicated on 05 Oct 09 that sufficient credits were available to cover applicant needs. These credits would fulfill stream impact and Threatened and Endangered (T&E) species requirements.

USACE Determination: Concur with Applicant proposal. Projects that impact listed species habitat must mitigate for that loss at a bank that benefits listed species (unless the applicant proposes to purchase credits at an appropriate T&E conservation bank).

Example 12.

Case Facts: Using the SOP, the project (*USACE File Number*) would need to obtain 500 stream credits. The project is located within the Silver River Basin PSA and in the 30200333 8-digit HUC. Project construction and operation is likely to affect listed fish habitat or passage. There are 2 banks located in the PSA. Additional information and analyses are provided in the following matrix:

RESOURCE ANALYSIS					
IMPACT SITE DATA					
Resource Category	**Service Area; HUC**	**Distance to Impact Site**	**Listed Species Impacts**	**Credits Needed**	
Stream (Perennial)	PSA; 3020033	- -	Cherokee Darter Habitat	500	
			Bank Benefits Listed Species	**Sufficient Credits Available**	**Recommended for Use**
MITIGATION BANK DATA					
November Mitigation Bank					
Stream (Perennial)	PSA; 30200333	4 miles	No	Yes	
Oscar Mitigation Bank					
Stream (Perennial)	PSA; 30200333	20 miles	Yes	Yes	X

Applicant Recommendations: Proposes to purchase all credits from the Oscar Mitigation Bank. These credits would fulfill stream impact and T&E species requirements.

USACE Determination: Concur with Applicant proposal. Projects that impact listed species habitat must mitigate for that loss at a bank that benefits listed species (unless the applicant proposes to purchase credits at an appropriate T&E conservation bank).

Appendix 11.2. Template Statement of Credit Availability

STATEMENT OF CREDIT AVAILABILITY

APPLICATION INFORMATION

Permit Type: Select from picklist
USACE Permit Number: SAS- -
Project Name:
Applicant:
County:
Impacted HUC:

CREDIT NEED

Stream Credit Type: Select from picklist
Stream Credits Needed:

Wetland Credit Type: Select from picklist
Wetland Credits Needed:

MITIGATION BANK NAMED

Bank/In-Lieu Fee (ILF) Program Name:
Bank/ILF Program Number: SAS- -
Primary Service Area HUC(s):
Secondary Service Area HUC(s):
Stream Credit Type Utilized: Select from picklist
Stream Credits Utilized:
Wetland Credit Type Utilized: Select from picklist
Wetland Credits Utilized:

The Bank Representative hereby authorizes the Applicant to provide this statement of credit availability for the mitigation bank listed above as a potential source of compensatory mitigation in its U.S. Army Corps of Engineers (Corps) permit application for the above referenced project. The Bank Representative shall indicate the current status of credit availability (see check boxes below) for all inquiries of credit availability for Corps permit applications within the geographic service area(s) of the respective mitigation bank. Failure of the Bank Sponsor to provide a statement of credit availability for a Corps permit application will result in the Corps' determination that the mitigation credits are **NOT AVAILBLE** for purchase from the respective mitigation bank.

☐ By signing below, I certify that the mitigation credits specified above are currently **AVAILABLE** for purchase from the named Mitigation Bank. This certification does not create an obligation to sell the specified credits.

☐ By signing below, I certify that the mitigation credits are currently **NOT AVAILABLE** for purchase from the named Mitigation Bank. This certification does not preclude the Bank Sponsor from offering the specified credits for sale if they should later become available. However, the Applicant will be under no obligation to purchase the later-offered credits if the Applicant secures acceptable credits from another source.

Bank/ILF Representative:

By:____
Name:
Date:

As the Applicant, I understand that failure to purchase mitigation credits as required by the Corps may result in a suspension or revocation of the permit and/or civil or criminal enforcement actions by the Corps or the U.S. Environmental Protection Agency.

Applicant:

By:____
Name:
Date:

Note 1: Potential mitigation credits that have not been released for sale will only be considered “available” at the discretion of the Corps.

Note 2: If the purchase of available credits identified in this statement of credit availability cannot be finalized by either party (Banker or Applicant), the Applicant will need to immediately coordinate with the Corps to ensure that an alternative compensatory mitigation plan is proposed to offset project impacts.

Note 3: If credits are being purchased from multiple mitigation banks, then a Statement of Credit Availability is required from each mitigation bank.

Appendix 11.3. Mitigation Service Areas

(In Development)

Appendix 11.4. Mitigation Plan Guidelines
(In Development)

Appendix 11.5. Monitoring Metrics and Performance Standards (In Development)

Appendix 11.6. Banking Instrument Template

(In Development)

Appendix 11.7. Freshwater Wetland Qualitative Assessment Worksheets

RIVERINE - LACUSTRINE FRINGE - FRESHWATER TIDAL WETLAND QUALITATIVE ASSESSMENT

Project Name:	
Impact Wetland Name:	
Wetland Type:	Choose Wetland Type
WAA Center Coordinates:	
Date:	

Water Storage -1

Answer		**Questions**
Value		Are there above grade fills or structures obstructing hydrologic flows into or out of the wetland, or are there drainage structures, ditches, or man-made impoundments within 100 feet of the assessment area that are hydrologically affecting the wetland? (Y/N)
Value		Is the contributing drainage basin at least 50 percent forested? (Y/N)
FUNCTION SCORE	Index Value	

BioGeoChemical Cycling - 2

Answer		**Questions**
Value		Is there large woody debris (LWD) in the wetland? (Y/N)
Value		Has the vegetative community been adversely altered within the last 20 years? (Y/N)
Value		Is the wetland hydrologically connected to the adjacent tributary at bankfull events? If the wetland is <u>Lacustrine Fringe</u> and is associated with a man-made impoundment, then the response to this assessment question should be "No". (Y/N)
FUNCTION SCORE	Index Value	

Maintain Characteristic Wetland Community - 3

Answer		**Questions**
Value		Has the vegetative community been adversely altered within the last 20 years? (Y/N)
Value		Is there greater than 10 percent invasive cover (i.e., cumulative absolute cover across all strata)? (Y/N)
FUNCTION SCORE	Index Value	

Maintain Faunal Habitat - 4

Answer		**Questions**
Value		Has the vegetative community been adversely altered within the last 20 years? (Y/N)
Value		Is there woody debris in the wetland? (Y/N)
Value		Is the contributing drainage basin at least 50 percent forested? (Y/N)
FUNCTION SCORE	Index Value	

WETLAND QUALITATIVE FUNCTIONAL CAPACITY SCORE	**Index Value**

<u>Legend</u>
Green Cell = User must manually input information.
Orange Cells = User must select the answer from the drop-down list.
Grey Cells = The calculation of these cells is automated.
Dark Grey Cells = These cells do not require input. The corresponding value is populated from the user input to a previous question.

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NON-RIVERINE WETLAND QUALITATIVE ASSESSMENT

Project Name:	
Impact Wetland Name:	
Wetland Type:	Choose Wetland Type
WAA Center Coordinates:	
Date:	

Water Storage -1

Answer		Questions
Value		Are there above grade fills or structures obstructing hydrologic flows into or out of the wetland, or are there drainage structures, ditches, or man-made impoundments within 100 feet of the assessment area and within the catchment that are hydrologically affecting the wetland? (Y/N)
Value		Is the contributing drainage basin at least 50 percent forested? (Y/N)
FUNCTION SCORE	Index Value	

BioGeoChemical Cycling - 2

Answer		Questions
Value		Is there large woody debris (LWD) in the wetland? (Y/N)
Value		Has the vegetative community been adversely altered within the last 20 years? (Y/N)
FUNCTION SCORE	Index Value	

Maintain Characteristic Wetland Community - 3

Answer		Questions
Value		Has the vegetative community been adversely altered within the last 20 years? (Y/N)
Value		Is there greater than 10 percent invasive cover (i.e., cummulative absolute cover across all strata)? (Y/N)
FUNCTION SCORE	Index Value	

Maintain Faunal Habitat - 4

Answer		Questions
Value		Has the vegetative community been adversely altered within the last 20 years? (Y/N)
Value		Is there woody debris in the wetland? (Y/N)
Value		Is the contributing drainage basin at least 50 percent forested? (Y/N)
FUNCTION SCORE	Index Value	

WETLAND QUALITATIVE FUNCTIONAL CAPACITY SCORE	**Index Value**

Legend
Green Cell = User must manually input information.
Orange Cells = User must select the choice from the drop-down list.
Grey Cells = The calculation of these cells is automated.
Dark Grey Cells = These cells do not require input. The corresponding value is populated from the user input to a previous question.

Appendix 11.8. Saltwater Wetland Qualitative Assessment Worksheets

SALTWATER TIDAL WETLAND QUALITATIVE ASSESSMENT

Project Name:	
Impact Wetland Name:	
Wetland Type:	
WAA Center Coordinates:	
Date:	

Wave Energy Attenuation – 1

Answer		**Questions**
Yes		Is the Wetland Assessment Area (WAA) mean marsh width greater than 100 meters? (Y/N)
Yes		Are one or more shorelines located adjacent to a tidal creek or river used by recreational or commercial boats? (Y/N)
Yes		Is the WAA mean percent cover of emergent marsh vegetation greater than 70 percent? (Y/N)
FUNCTION SCORE	Moderate	

BioGeoChemical Cycling – 2

Answer		**Questions**
Yes		Are there above grade fills or structures obstructing hydrologic flows into or out of the wetland, or are there drainage structures or ditches within 100 feet of the WAA that are hydrologically affecting the wetland? (Y/N)
Yes		Is the WAA mean percent cover of emergent marsh vegetation greater than 70 percent? (Y/N)
No		Is greater than 95 percent of the adjacent land use perimeter bounded by undeveloped naturally vegetated areas or open water? (Y/N)
FUNCTION SCORE	Low	

Nekton Habitat Utilization – 3

Answer		**Questions**
No		Is the ratio of shoreline to wetlands greater than 100 meters per hectare? (Y/N)
Yes		Are there above grade fills or structures obstructing hydrologic flows into or out of the wetland, or are there drainage structures or ditches within 100 feet of the WAA that are hydrologically affecting the wetland? (Y/N)
Yes		Does the WAA have 5 or more of the following habitats located onsite or within 30 meters of the project boundary: (1) Low marsh (i.e. daily tidal flooding); (2) High marsh (i.e. irregular tidal flooding); (3) Intertidal creeks/channels (exposed at low tide); (4) Subtidal creeks/channels; (5) Ponds or depressions (temporary or permanent); (6) Shallow (less than 1 meter) sand or mudflats; (7) Submerged aquatic vegetation; and (8) Oyster reefs? (Y/N)
FUNCTION SCORE	Low	

Marsh Dependent Wildlife Habitat - 4

Answer		**Questions**
No		Is the ratio of shoreline to wetlands greater than 100 meters per hectare? (Y/N)
Yes		Is the WAA mean percent cover of emergent marsh vegetation greater than 70 percent? (Y/N)
Yes		Is at least 50 percent of the WAA dominated by tall, robust, native herbaceous vegetation and have at least 2 of the following habitat types: (1) Tall, robust herbaceous vegetation that is at least irregularly flooded (i.e., S. alterniflora, S. cynosuroides, J. roemerianus, Typha spp., Schoenoplectus spp.); (2) Short herbaceous vegetation that is infrequently flooded (i.e., S. patens, S. spartinae, Distichlis spicata, Borrichia frutescens, Batis maritima); (3) Intertidal creek banks and mudflats that are exposed at low tide; and, (4) Naturally vegetated upland (forested, shrub-scrub, or dense herbaceous) with a minimum width of 30 meters adjacent to the WAA perimeter? (Y/N)
No		Is the WAA patch size (contiguous tidal fringe wetland within which the WAA is located) greater than 2 hectares? (Y/N)
No		Is 50 percent of the wetland vegetation greater than 1 meter in height? (Y/N)
FUNCTION SCORE	Low	

Plant Community Structure and Composition – 5

Answer		**Questions**
Yes		Is the wetlands mean percent cover of emergent marsh vegetation greater than 70 percent? (Y/N)
No		Is the WAA invasive cover less than 5 percent? (Y/N)
No		Is less than 1 percent vegetative cover of the WAA comprised of non-wetland species?
Yes		Is the WAA comprised of less than 5 percent woody cover? (Y/N)
FUNCTION SCORE	Moderate	

WETLAND QUALITATIVE FUNCTIONAL CAPACITY SCORE	**Low**

<u>Legend</u>
Green Cell = User must manually input information.
Orange Cells = User must select the index choice from the drop-down list.
Grey Cells = The calculation of these cells is automated.
Dark Grey Cells = These cells do not require input. The corresponding index value is populated from the user input to a previous question.

Appendix 11.9. Stream Qualitative Assessment Worksheets

PIEDMONT / RIDGE & VALLEY / BLUE RIDGE QUALITATIVE STREAM ASSESSMENT

Project Name:			
Impact Reach Name:			
Stream Type:			
Catchment Size (in Acres):		Sq. Mi.:	
SAR Center Coordinates:			
Date:			

Hydrology - 1

Value		**Questions**
Yes		The surface and groundwater hydrology of the assessment reach are free of upstream catchment impairments (e.g., diversions, stormwater management structures, wastewater facilities, agricultural ditches)? (Y/N)
No		Is the contributing drainage basin of the assessment reach at least 50 percent forested? (Y/N)
FUNCTION SCORE	**Moderate**	

Hydraulics - 2

Value		**Questions**
Value		Is the assessment reach connected to it's floodplain at bankfull event? (Y/N)
Value		Are there headcuts in the assessment reach? (Y/N)
Value		Has the assessment reach been previously straightened? (Y/N)
FUNCTION SCORE	**Index Value**	

Geomorphology - 3

Value		**Questions**
Value		Does the assessment reach have bedform diversity (i.e., the presence of riffle/pool or step/pool complexes)? (Y/N)
Value		Is there high bank erosion present throughout the assessment reach? (Y/N)
Value		Is there large woody debris (LWD) in the assessment reach? (Y/N)
Value		Are riffles/runs in the assessment reach comprised of coarse material (i.e., gravel or larger)? (Y/N)
Value		Is there a woody riparian buffer (i.e., 25 feet in width) adjacent to both sides of the assessment reach? (Y/N)
FUNCTION SCORE	**Index Value**	

Chemistry - 4

Value		**Questions**
No		Is the contributing drainage basin of the assessment reach at least 50 percent of the forested? (Y/N)
Value		Is the assessment reach designated as an impaired water on the most recent 303(D)/305(b) list?
FUNCTION SCORE	**Index Value**	

Biology - 5

Value		**Questions**
Value		Is there habitat diversity in the assessment reach (i.e., at least 3 of the following habitats: riffles, pools, steps, overhangs, leaf packs, woody debris)?
No		Is the contributing drainage basin of the assessment reach at least 50 percent of the forested? (Y/N)
SUM	**Index Value**	

STREAM QUALITATIVE FUNCTIONAL CAPACITY SCORE	**Index Value**

Legend
Green Cell = User must manually input information.
Orange Cells = User must select the index choice from the drop-down list.
Grey Cells = The calculation of these cells is automated.
Dark Grey Cells = These cells do not require input. The corresponding index value is populated from the user input to a previous question.

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COASTAL PLAIN QUALITATIVE STREAM ASSESSMENT

Project Name:			
Impact Reach Name:			
Stream Type:			
Catchment Size (in Acres):		Sq. Mi.:	
SAR Center Coordinates:			
Date:			

Hydrology - 1

Value		**Questions**
Value		The surface and groundwater hydrology of the assessment reach are free of upstream catchment impairments (e.g., diversions, stormwater management structures, wastewater facilities, agricultural ditches)? (Y/N)
Value		Is the contributing drainage basin of the assessment reach at least 50 percent forested? (Y/N)
FUNCTION SCORE	**Index Value**	

Hydraulics - 2

Value		**Questions**
Value		Is the assessment reach connected to it's floodplain at bankfull event? (Y/N)
Value		Are there headcuts in the assessment reach? (Y/N)
Value		Has the assessment reach been previously straightened? (Y/N)
FUNCTION SCORE	**Index Value**	

Geomorphology - 3

Value		**Questions**
Value		Does the assessment reach have bedform diversity (i.e., the presence of riffle/pool or step/pool complexes)? (Y/N)
Value		Is there high bank erosion present throughout the assessment reach? (Y/N)
Value		Is there large woody debris (LWD) in the assessment reach? (Y/N)
Value		Is there a woody riparian buffer (i.e., 25 feet in width) adjacent to both sides of the assessment reach? (Y/N)
FUNCTION SCORE	**Index Value**	

Chemistry - 4

Value		**Questions**
Value		Is the contributing drainage basin of the assessment reach at least 50 percent of the forested? (Y/N)
Value		Is the assessment reach designated as an impaired water on the most recent 303(D)/305(b) list?
FUNCTION SCORE	**Index Value**	

Biology - 5

Value		**Questions**
Value		Is there habitat diversity in the assessment reach (i.e., at least 3 of the following: riffles, pools, steps, overhangs, leaf packs, woody debris)?
Value		Is the contributing drainage basin of the assessment reach at least 50 percent of the forested? (Y/N)
SUM	**Index Value**	

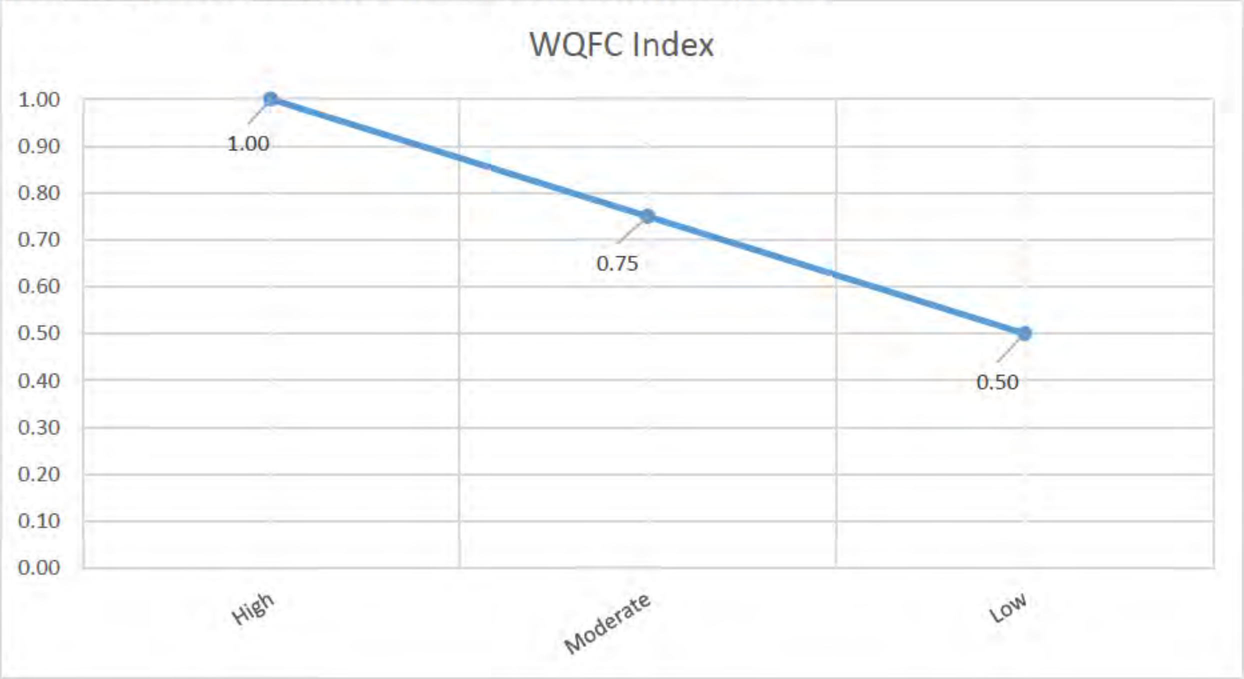
STREAM QUALITATIVE FUNCTIONAL CAPACITY SCORE	**Index Value**

Legend
Green Cell = User must manually input information.
Orange Cells = User must select the index choice from the drop-down list.
Grey Cells = The calculation of these cells is automated.
Dark Grey Cells = These cells do not require input. The corresponding index value is populated from the user input to a previous question.

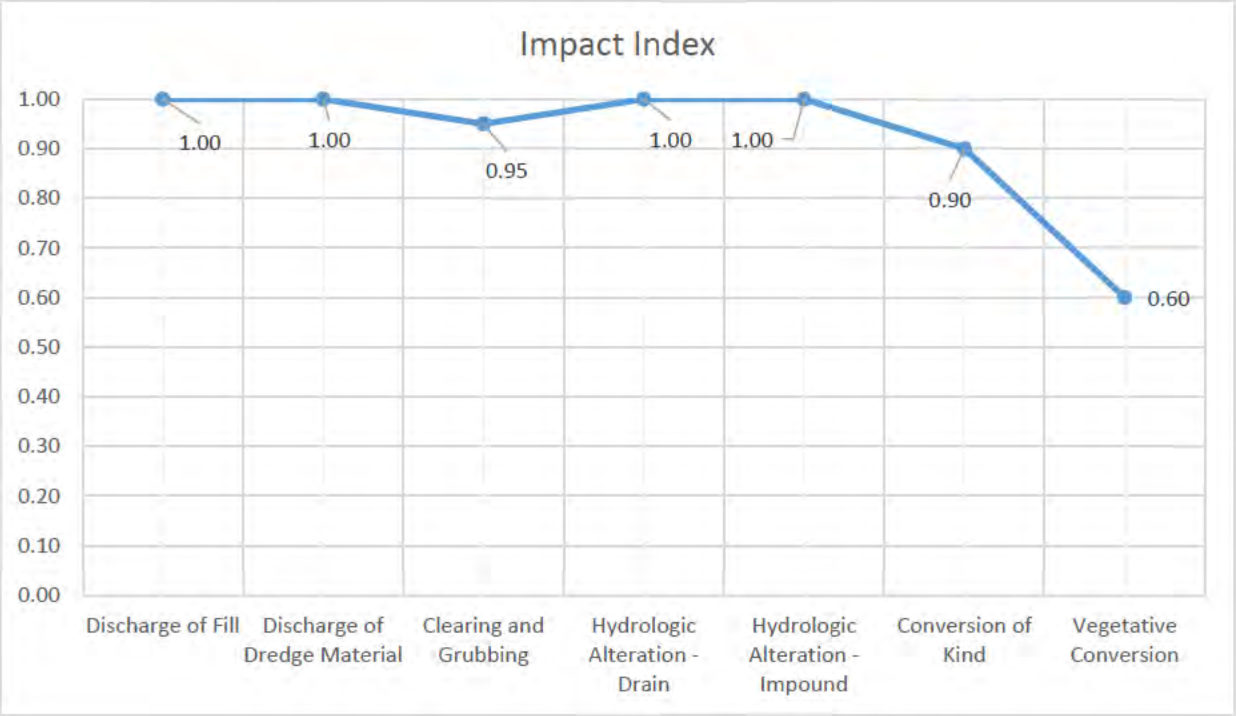
Version 2.0 (October 15, 2021)

Appendix 11.10. Indices of the Worksheets for Wetland Adverse Impacts

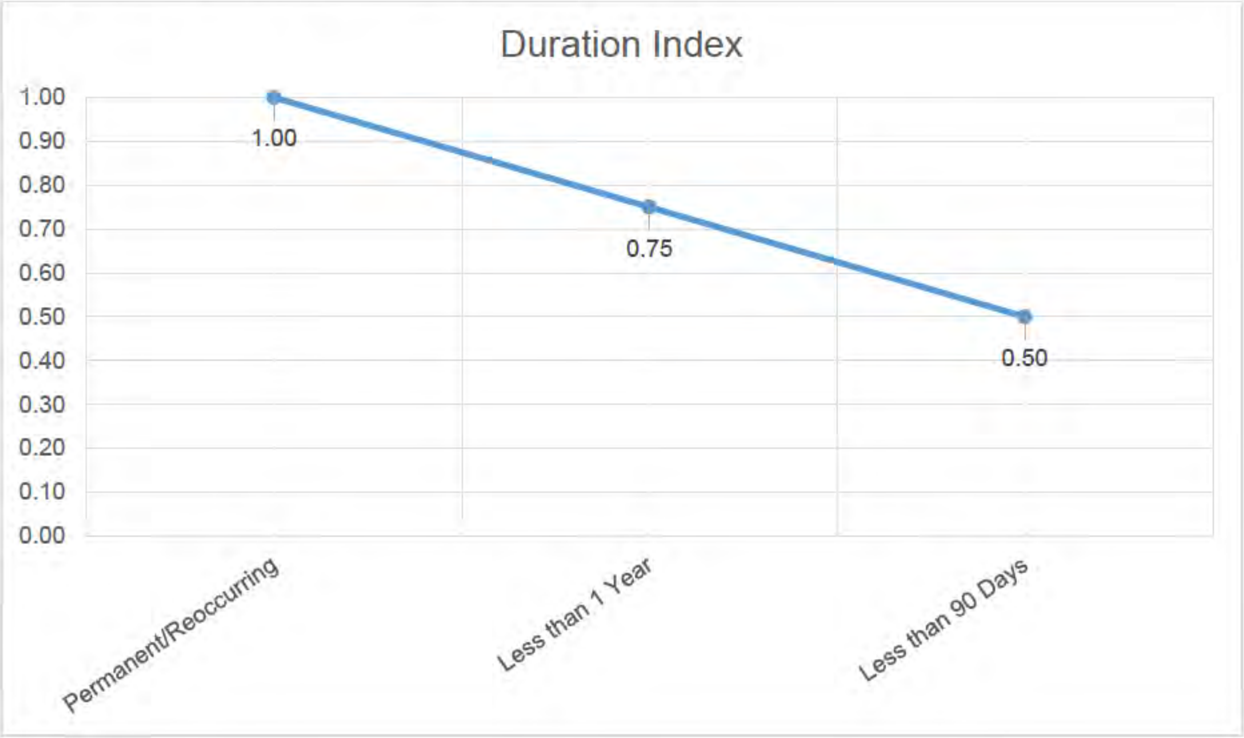
Index 1. Wetland Qualitative Function/Condition (WQFC) Index



Index 2. Wetland Impact Index



Index 3. Wetland Impact Duration Index

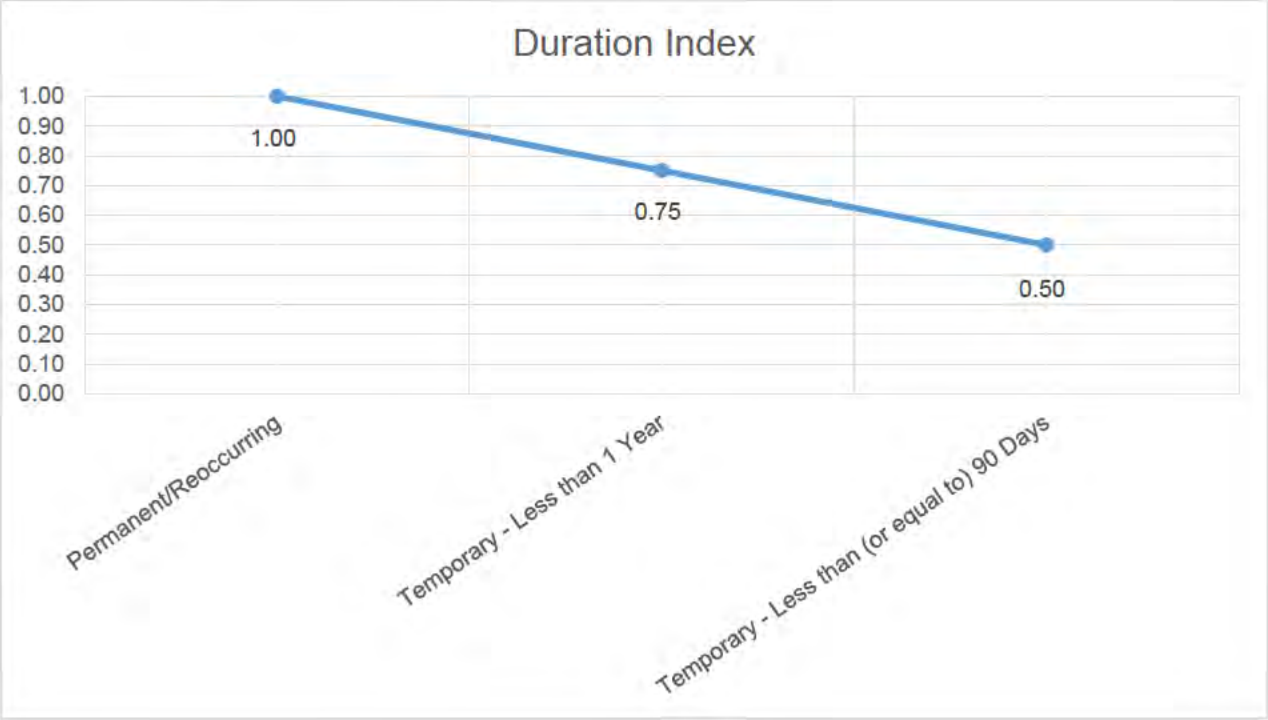


Appendix 11.11. Indices of the Worksheets for Stream Adverse Impacts

Index 1. Stream Qualitative Function/Condition (SQFC) Index

Index 2. Stream Impact Index

Index 3. Stream Impact Duration Index



Appendix 11.12. Qualitative Worksheets for Wetland Adverse Impacts

Worksheet 1: Qualitative Worksheet for Wetland Adverse Impacts

Project Name:	
Impact Wetland Name:	
Acres of Impact (Acres):	
Wetland Type:	
Date:	

Impact Factors	**Index Description**	**Index Value**
1. Wetland Qualitative Functional Capacity Score (*WQFC*)	Choose WQFC	WQFC Index
2. Impact Category Description (*Impact Category*)	Choose Primary Impact	Impact Index
3. Product of WQFC and Impact (*WQFC Impact*) =		WQFC Impact
4. Duration of Impact (*Duration*)	Choose Duration	Duration Index
5. Product of WQFC Impact and Duration (*Total WQFC Impact*) =		Total WQFC Impact
6. Product of Total WQFC Impact and Acres (***Total 2018 Wetland Credits Owed***) =		**Credits Owed**
7. Conversion of Total 2018 Wetland Credits to Legacy Credits (***Legacy Wetland Credits Owed***) =		**Legacy Credits Owed**

Legend

Green Cells = User must manually input information.
Orange Cells = User must select the index choice from the drop-down list.
Grey Cells = The calculation of these cells is automated.

Version 2.0 (October 15, 2021)

Appendix 11.13. Qualitative Worksheets for Stream Adverse Impacts

Worksheet 1: Qualitative Worksheet for Stream Adverse Impacts

Project Name:	
Impact Reach Name:	
Linear Feet of Impact (*Feet*):	
Stream Type:	
Non-Perennial Flow Regime:	
Date:	

Impact Factors	**Index Description**	**Index Value**
1. Stream Qualitative Functional Capacity Score (*SQFC*)	Choose SQFC	SQFC Index
2. Type of Impact (*Impact*)	Choose Primary Adverse Impact	Impact Index
3. Product of SQFC and Impact (*SQFC Impact*) =		SQFC Impact
4. Duration of Impact (*Duration*)	Choose Duration	Duration Index
5. Product of SQFC Impact and Duration (*Total SQFC Impact*) =		Total SQFC Impact
6. Product of Total SQFC Impact and Linear Feet **(*Total 2018 Stream Credits Owed*)**[1] =		**Credits Owed**
7. Conversion of Total 2018 Stream Credits to Legacy Credits **(*Legacy Stream Credits Owed*)**[2,3] =		**Legacy Credits Owed**

Green Cells = User must manually input information.

Orange Cells = User must select the index choice from the drop-down list.

Grey Cells = The calculation of these cells is automated.

[1] Total 2018 Stream Credits Owed are prorated to 50% for Non-Perennial Streams with Ephemeral Flow.

[2] Legacy Stream Credits Owed are prorated to 60% for Non-Perennial Streams with Intermittent Flow.

[3] Legacy Stream Credits Owed are prorated to 60% for Non-Perennial Streams with Ephemeral Flow.

Appendix 11.14. Georgia Interim Wetland Hydrogeomorphic Workbook

Existing Conditions Worksheet for Forested Wetland Mitigation Actions

Project Information and Existing Conditions Summary

Project Name:	
Mitigation Wetland Name:	
Acres of Mitigation (*Acres*):	
Wetland Type:	
WAA Center Coordinates:	
Closest Weather Station:	
Date of Assessment:	

Summary of Existing Wetland Function

Existing Condition - V_{HYDRO} Index Score	0.00
Existing Condition - V_{COMP} Index Score	0.00
Existing Condition - V_{STRUCT} Index Score	0.00
Existing Condition - V_{WD} Index Score	0.00
Existing Condition - V_{UP} Index Score	0.00
Existing Condition Functional Score	0.00

Continuous Saturation (V_{HYDRO}) Calculator

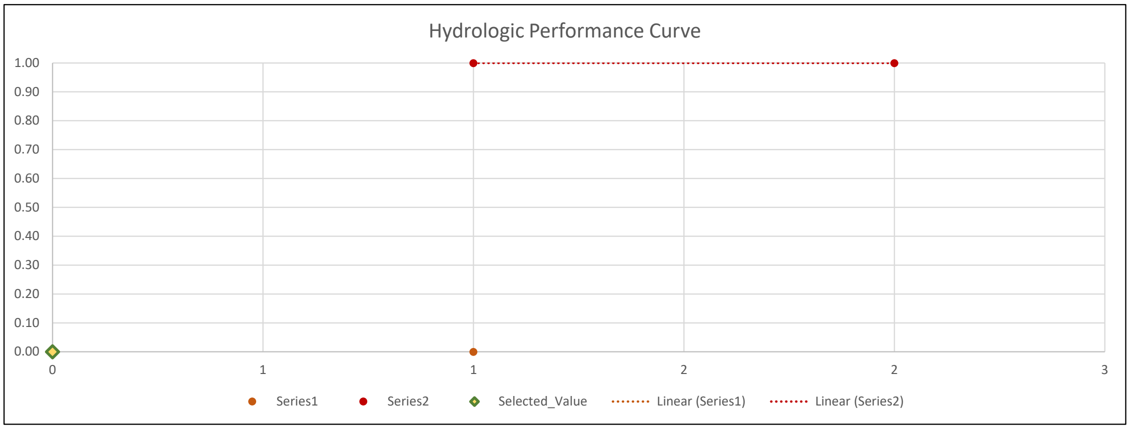
Physiographic Region:	
Confirmed Soil Series:	
Functioning Saturation Range:	
Length of Growing Season - # days (WETS, 28 degrees F - 50%):	

Functioning Saturation of Confirmed Soil Series - Lower Threshold

Ponding Duration Class of Confirmed Soil Series

	% Growing Season	Consecutive Days	Duration Class
Saturation Range (%, days): 14 days			
Consecutive Days			

Choose Days of Continuous Saturation:	
Choose Days of Continuous Ponding Duration:	



0.00	**V_{HYDRO} Index Score**

Forested Wetland Vegetation Composition (V_{COMP}) Calculator

Choose Region:

Wetland Type:

Select Wetland Type

☐	*Select Subclass*	☐	*Select Subclass*
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0 Species in Group 1

Select Wetland Type

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0 Species in Group 2

Select Wetland Type

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0 Species in Group 3

Initial Quality Index

Adjusted Quality Index

0.00 **V_{COMP} Index Score**

Forested Wetland Vegetation Structure (V_{STRUCT}) Calculator

List the species and dbh measurements of the fifteen largest canopy trees (at least 2.54 cm) within the 0.10 acre vegetation monitoring plot:

	Tree Species	DBH (in cm)	On approved planting list (Y/N):
Tree 1:			
Tree 2:			
Tree 3:			
Tree 4:			
Tree 5:			
Tree 6:			
Tree 7:			
Tree 8:			
Tree 9:			
Tree 10:			
Tree 11:			
Tree 12:			
Tree 13:			
Tree 14:			
Tree 15:			

Median Tree dbh: 0.00

0.00 **V_{STRUCT} Index Score**

Large Woody Debris (V_{LWD}) Calculator

Wetland Type:

Enter diameters (cm) of each fallen woody stem 7.6 cm (3 inches) or greater in diameter in each 50-foot transect. Leaning dead stems that intersect the sampling plane are sampled. Dead trees and shrubs still supported by their roots are not sampled. Rooted stumps are not sampled, but uprooted stumps are sampled. Down stems that are decomposed to the point where they no longer maintain their shape but spread out on the ground are not sampled.

Transect 1	Transect 2

☐ Check box if no logs were encountered within the transects.

Volume of non-living large woody stems (m3/ha)

0.00 V_{LWD} **Index Score**

Upland Buffer (V_{UP}) Calculator

Total Length of Wetland Perimeter:

Buffer Segment	**Length of Segment (L.F.)**	**Width of Buffer (L.F.)**	**Segment Index Score**	**Weighted Segment Score**
Buffer Segment 1				
Buffer Segment 2				
Buffer Segment 3				
Buffer Segment 4				
Buffer Segment 5				
Buffer Segment 6				
Buffer Segment 7				
Buffer Segment 8				
Buffer Segment 9				
Buffer Segment 10				
Total Length of Buffer Segments	0			

0.00 V_{UP} **Index Score**

Legend
Green Cells = User must manually input information.
Orange Cells = User must select the index choice from the drop-down list.
Grey Cells = The calculation of these cells is automated.
Yellow Cells = These automated cells summarize the functional index scores.

Proposed Conditions Worksheet for Forested Wetland Mitigation Actions

Project Information and Proposed Conditions Summary

Project Name:	
Mitigation Wetland Name:	
Acres of Mitigation (*Acres*):	
Wetland Type:	
Mitigation Potential:	
WAA Center Coordinates:	
Closest Weather Station:	
Date of Wetland Credit Assessment:	

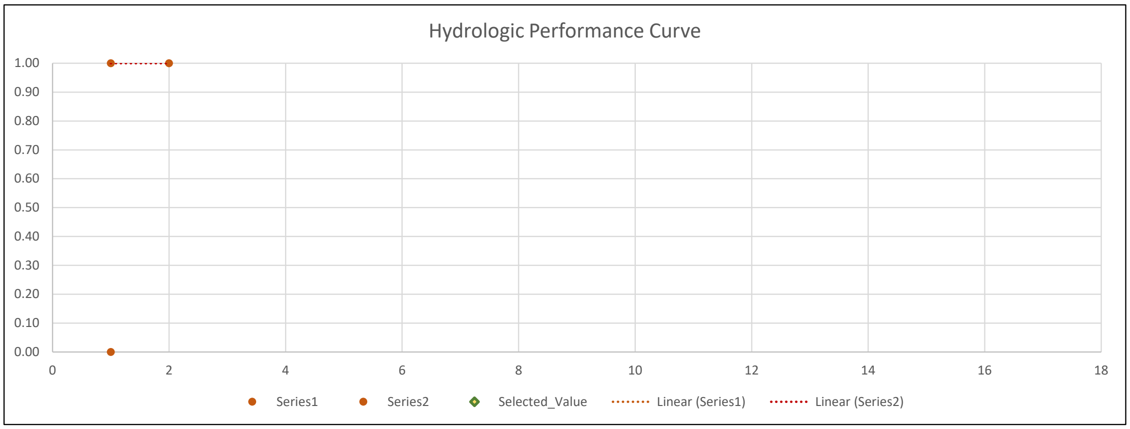
Summary of Proposed Wetland Function

Proposed Condition - V_{HYDRO} Index Score	0.00
Proposed Condition - V_{COMP} Index Score	0.00
Proposed Condition - V_{STRUCT} Index Score	0.00
Proposed Condition - V_{WD} Index Score	0.00
Proposed Condition - V_{UP} Index Score	0.00
Proposed Condition Functional Score	0.00
Net Functional Lift (Δ)	0.00
Total Wetland Credits Generated	**0.00**

Continuous Saturation (V_{HYDRO}) Calculator

Physiographic Region:	
Confirmed Soil Series:	
Functioning Saturation Range:	
Length of Growing Season - # days (WETS, 28 degrees F - 50%):	

		Functioning Saturation of Confirmed Soil Series - Lower Threshold		**Ponding Duration Class of Confirmed Soil Series**
	% Growing Season	**Consecutive Days**		**Duration Class**
Saturation Range (%, days): 14 days				
			Consecutive Days	
Choose Days of Continuous Saturation:	**16**			
Choose Days of Continuous Ponding Duration:	**3**			



0.00	**V_{HYDRO} Index Score**

Forested Wetland Vegetation Composition (V_{COMP}) Calculator

Choose Region:

Wetland Type:

Select Wetland Type

☐	*Select Subclass*	☐	*Select Subclass*
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0 Species in Group 1

Select Wetland Type

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0 Species in Group 2

Select Wetland Type

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0 Species in Group 3

Initial Quality Index

Adjusted Quality Index

0.00 **V_{COMP} Index Score**

Forested Wetland Vegetation Structure (V_{STRUCT}) Calculator

List the species and dbh measurements of the fifteen largest canopy trees (at least 2.54 cm) within the 0.10 acre vegetation monitoring plot:

	Tree Species	DBH (in cm)	On approved planting list (Y/N):
Tree 1:			
Tree 2:			
Tree 3:			
Tree 4:			
Tree 5:			
Tree 6:			
Tree 7:			
Tree 8:			
Tree 9:			
Tree 10:			
Tree 11:			
Tree 12:			
Tree 13:			
Tree 14:			
Tree 15:			

Median Tree dbh: 0.00

0.00 **V_{STRUCT} Index Score**

Large Woody Debris (V_{LWD}) Calculator

Wetland Type:

Enter diameters (cm) of each fallen woody stem 7.6 cm (3 inches) or greater in diameter in each 50-foot transect. Leaning dead stems that intersect the sampling plane are sampled. Dead trees and shrubs still supported by their roots are not sampled. Rooted stumps are not sampled, but uprooted stumps are sampled. Down stems that are decomposed to the point where they no longer maintain their shape but spread out on the ground are not sampled.

Transect 1	Transect 2

☐ Check box if no logs were encountered within the transects.

Volume of non-living large woody stems (m3/ha)

0.00 V_{LWD} **Index Score**

Upland Buffer (V_{UP}) Calculator

Total Length of Wetland Perimeter:

Buffer Segment	**Length of Segment (L.F.)**	**Width of Buffer (L.F.)**	**Segment Index Score**	**Weighted Segment Score**
Buffer Segment 1				
Buffer Segment 2				
Buffer Segment 3				
Buffer Segment 4				
Buffer Segment 5				
Buffer Segment 6				
Buffer Segment 7				
Buffer Segment 8				
Buffer Segment 9				
Buffer Segment 10				
Total Length of Buffer Segments	0			

0.00 V_{UP} **Index Score**

Legend
Green Cells = User must manually input information.
Orange Cells = User must select the index choice from the drop-down list.
Grey Cells = The calculation of these cells is automated.
Yellow Cells = These automated cells summarize the functional index scores.

Appendix 11.15. Georgia Interim Wetland Hydrogeomorphic Worksheet User Manual

U.S. Army Corps of Engineers, Savannah District's

Georgia Freshwater Forested Wetland Hydrogeomorphic Methodology – User Manual

Version 2.0 (October 2021)

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Glossary of Terms

Assessment Model – An empirically based model that defines the relationship between ecosystem and landscape scale variables and functional capacity of a wetland. The model is developed and calibrated using reference wetlands from a characteristic regional wetland subclass.

Continuous Saturation – A condition in which all easily drained voids (pores) between soil particles in the root zone (i.e., within 12 inches from the soil surface) are filled with water (at conditions that are greater than atmospheric pressure) for a period of consecutive days.

Credit – A unit of measure (e.g., a functional or areal measure or other suitable metric) representing the accrual or attainment of aquatic functions at a compensatory mitigation site. The measure of aquatic functions is based on the resources restored, established, enhanced, or preserved (33 CFR 332.2; 40 CFR 230.922).

Creation – Creation (Establishment) means the manipulation of the physical, chemical, or biological characteristics present to develop a wetland at a site at which it did not previously exist (33 CFR 332.2; 40 CFR 230.92)

Debit – A unit of measure (e.g., a functional or areal measure or other suitable metric) representing the loss of aquatic functions at an impact or project site. The measure of aquatic functions is based on the resources impacted by the authorized activity (33 CFR 332.2; 40 CFR 230.92).

Diameter at Breast Height (DBH) – Tree diameter measured at 1.4 meters (55 inches) above the ground.

Enhancement – Enhancement means the manipulation of the physical, chemical, or biological characteristics of a wetland to increase or improve a specific aquatic resource function (33 CFR 332.2; 40 CFR 230.92).

Existing Condition – The functional capacity of an associated function-based parameter, or overall wetland area, prior to mitigation actions which is expressed as an index score between 0.00 and 1.00.

Function-Based Parameter – A metric that represents and supports the functional statement of each functional category (e.g. hydrologic processes, maintain plant and animal communities, and biogeochemical processes).

Functional Capacity – The degree to which an area of wetland performs a specific function (33 CFR 332.2; 40 CFR 230.92). Functional capacity is dictated by characteristics of the wetland and the surrounding landscape, and interaction between the two.

Functions – The physical, chemical, and biological processes that occur in ecosystems (33 CFR 332.2; 40 CFR 230.92).

Index Score – A value that expresses whether the associated function-based parameter, or overall wetland area is functioning compared to a reference condition. An index score of 0.00 represents that there is no function present for the parameter/wetland, while an index score of 1.00 represents that the parameter/wetland is fully functional.

Invasive species – Generally, exotic species without natural controls that out-compete native species.

Large Woody Debris – Large Woody Debris is defined as down and dead woody stems that are greater than 7.62 centimeters (approximately 3 inches) in diameter that are no longer attached to living plants, and minimum of 1 meter in length.

Measurement Method – Specific tools, equations, assessment methods, etc. that are utilized to quantify a function-based parameter.

Net Functional Lift – The difference between the Proposed Condition and Existing Condition for an overall wetland area, which represents a change in functional capacity. The change in functional capacity is expressed as an index score of between 0.00 and 1.00.

Performance Standard – Observable or measurable physical (including hydrological), chemical and/or biological criteria that are used to determine if a compensatory mitigation project meets its objectives (33 CFR 332.2; 40 CFR 230.92). The GA HGM uses performance standards that convert measured field data values (i.e. measurement methods) to an index value of between 0.00 and 1.00.

Ponding – Standing water above ground surface.

Preservation – Preservation means the removal of a threat to or preventing the decline of a wetland by an action in or near the wetland. This term includes activities commonly associated with the protection and maintenance of wetlands through the implementation of appropriate legal and physical mechanisms (33 CFR 332.2; 40 CFR 230.92).

Proposed Condition – The functional capacity of an associated function-based parameter, or overall wetland area following the implementation of a mitigation action, which is expressed as an index score of between 0.00 and 1.00.

Reference Standard – Sites that represent conditions exhibited by the subset of reference wetlands that correspond to the highest level of functioning of the ecosystem across a suite of functions (Brinson and Rheinhardt (1996)).

Restoration – Restoration means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded wetland (33 CFR 332.2; 40 CFR 230.92).

Soil Surface – The soil surface is the top of the mineral soil; or, for soils with an O horizon, the soil surface is the top of the part of the O horizon that is at least slightly decomposed. Fresh leaf or needle fall that has not undergone observable decomposition is excluded from soil and may be described separately.

Tree Stratum – The vegetation layer consisting of self-supporting woody plants greater than or equal to 2.54 centimeters (1 inch) in diameter at breast height.

Upland Buffer – Zone or area of uplands extending outwards from the wetland boundary that is comprised of natural vegetation. In the Southeastern U.S., upland buffer vegetation should typically include a mixed assemblage of native trees, saplings, shrubs, vines, and ground cover vegetation. For the purposes of this model, the assessment of upland buffer will extend perpendicularly to a width of 100 linear feet from the wetland mitigation treatment boundary.

Wetland Type – A hydrogeomorphic wetland class or combination of classes that can be identified based on landscape and ecosystem scale factors.

1. Purpose and Background

The purpose of this User Manual is to introduce the Georgia Freshwater Forested Wetland Hydrogeomorphic Workbook (GA HGM) and provide both background and instruction on its use to calculate functional lift and inform crediting for wetland mitigation projects undertaken in accordance with the Clean Water Act 404 Regulatory Program in Georgia, as administered by the U.S. Army Corp of Engineers, Savannah District. This manual includes descriptions of how to collect data and calculate field values for each measurement method in the wetland condition assessments and describes how those field values are converted to index values in the GA HGM. Few measurements are unique to the GA HGM, and procedures are often detailed in other instruction manuals or literature. Where appropriate, this document will reference other data collection manuals and make clear any differences in data collection or calculation methods needed for the GA HGM. This manual will refer to wetland restoration in accordance with the definition used in the Compensatory Mitigation for Losses of Aquatic Resources; Final Rule (33 CFR 332; 40 CFR 230).

This definition encompasses all activities aimed to improve wetland functions undertaken for compensatory mitigation or other purposes. Smith (1995) described ten (10) important wetland functions aggregated into three categories including: hydrologic processes, maintenance of plant and animal communities, and biogeochemical processes. This research in turn informed the development of, “A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Forested Wetlands in Alluvial Valleys of the Coastal Plain of the Southeastern United States” (Wilder et al., 2013), which jointly provide the structural underpinnings of the GA HGM. This User Manual and the GA HGM Worksheets assume the reader has a firm knowledge of wetland processes and HGM (Smith, 1995, and Wilder, 2013); therefore, it does not provide extensive definitions of wetland terms including those related to hydrologic and biogeochemical processes.

Collection and analysis of the watershed-scale and wetland assessment area-scale data necessary to evaluate before selecting a potential wetland restoration site, is not limited to only those variables and methods included in the GA HGM. The GA HGM incorporates only some of the necessary assessment metrics that all wetland mitigation projects will be expected to assess and document for the U.S. Army Corp of Engineers, Savannah District and the Georgia Interagency Review Team. Thus, the GA HGM should not serve as the sole method or protocol for designing a wetland mitigation project.

The GA HGM and supporting documents, including this User Manual, can be downloaded from the RIBITS website at: https://ribits.ops.usace.army.mil/ords/f?p=107:27:9415532409189::NO::P27_BUTTON_KEY:10

The following documents are available at the above website:

- Georgia Freshwater Forested Wetland Hydrogeomorphic Workbook (GA HGM) – Microsoft Excel Workbook.
- User Manual – This manual, describing the GA HGM and how to collect data and calculate inputs to use the GA HGM.

The GA HGM and accompanying documents will be updated periodically as additional data are gathered and reference standards and measurement methods are refined. The latest version of the GA HGM manuals and tool can be downloaded from the RIBITS website.

2. Getting Started with the GA HGM

The GA HGM is used to inform mitigation credit allocations for wetland mitigation projects undertaken pursuant to the Clean Water Act 404 Regulatory Program. The measurement methods and associated performance standards utilized in the GA HGM will not necessarily be the only field variables for which monitoring will be required, nor will they be the only field variables for which performance standards will be assigned.

The GA HGM uses three modified function-based parameters provided by Wilder (2013), along with two additional function-based parameters, which were developed by the Georgia Inter-agency Review Team (GA IRT): Continuous Saturation[1], Wetland Vegetation Composition[2], Wetland Vegetation Structure[2], Large Woody Debris[2], and Upland Buffer[1]. All GA HGM function-based parameters and measurement methods used to assess baseline conditions must also be used to assess post-implementation conditions throughout the monitoring period. The maximum possible Net Functional Lift for the GA HGM (i.e. 1.00) is based on all five function-based parameters, but these parameters are not equally weighted in the calculation of the Existing and Proposed Condition Scores.

The Existing Conditions and Proposed Conditions Worksheets in the GA HGM Microsoft Excel workbook provide the only interface for users to input data to support the calculation of credit generation for each wetland treatment area(as outlined in Savannah District's most current version of the Monitoring Guidelines and Performance Standards that can be downloaded from RIBITS). Users enter data describing the existing and proposed (or monitored) conditions of the project wetland, and the worksheets quantify functional lift or loss. The worksheets contain six areas for data entry: Project Information and Existing (and Proposed) Conditions Summary, Continuous Saturation (V_{HYDRO}) Calculator, Forested Wetland Vegetative Composition (V_{COMP}) Calculator,

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[1] These function-based parameters were developed by the Georgia IRT for use in mitigation assessment of freshwater forested wetlands throughout Georgia.

[2] These function-based parameters were originally provided by Wilder (2013) and have been modified for use in mitigation assessment of freshwater forested wetlands throughout Georgia.

Forested Wetland Vegetative Structure (V_{STRUCT}) Calculator, Large Woody Debris (V_{LWD}) Calculator, and Upland Buffer (V_{UP}) Calculator. Cells that allow user input are shaded green and orange, and all other cells are locked.

2.1 Project Information and Existing Conditions Summary

The Project Information and Existing Conditions Summary section of the Existing Condition Worksheet consists of general site information and other project-specific information necessary to determine which performance standards are applied in the GA HGM for calculating index values. Some fields in this section include drop-down menus (orange cells) from which the user will select the appropriate value, while others require information to be manually entered (green cells). The values selected or entered into these fields establish links between the worksheet and the applicable performance standards. It is therefore important for the user to input accurate site information. All of the values entered within the Project Information and Existing Conditions Summary are transferred to the Project Information and Proposed Conditions Summary of the Proposed Conditions Worksheet, with the exception of the Mitigation Potential and the Date of Wetland Credit Assessment fields which require user input.

In addition to providing general site information and other project-specific information, this section also provides the Summary of Existing/Proposed Wetland Function. Further details regarding these summaries are provided in the Scoring Functional Lift section below (Section 2.3).

2.2 Existing and Proposed Condition Worksheet Field Values

Once the Project Information and Existing/Proposed Conditions Summary section has been completed, the user can input data into the field value cells (i.e., green and orange cells, and checkboxes) of the function-based parameter calculators (e.g, Continuous Saturation (V_{HYDRO}) Calculator).

The Existing Condition Worksheet field values are derived from measurements collected in the field during baseline condition assessment of each wetland treatment area on the project site before any mitigation work is undertaken. The Proposed Condition Worksheet field values are representative of estimated, but logical, field values informed by design studies/calculations, reports, and best available science. Proposed condition scores are estimated during the development of the mitigation plan, but then measured in the field during the post-implementation monitoring phase to validate the proposed condition scores.

2.3 Scoring Functional Lift

Scoring occurs automatically as field values are entered into the Existing Conditions or Proposed Conditions Worksheets. The functional parameter index score (yellow cell at the bottom of each calculator) will correspond to an index value ranging from 0.00 to 1.00 for that parameter, based on the performance curves. Parameter scores have been weighted to calculate Existing Condition Functional Score (ECFS) and Proposed Condition Functional Score (PCFS), as follows:

$$ECFS\ and\ PCFS = \frac{\left(V_{HYDRO} + \left(\frac{\left(\frac{V_{COMP} + V_{STRUCT}}{2}\right) + \left(\frac{V_{LWD} + V_{UP}}{2}\right)}{2}\right)\right)}{2}$$

The Existing Conditions and Proposed Conditions Worksheets summarize the functional parameter index scoring at the top of the sheet, next to Project Information table in each respective worksheet. The summary tables for each of the respective worksheets are entitled “Summary of Existing Wetland Function” and “Summary of Proposed Wetland Function”.

The Summary of Existing Wetland Function table illustrates the index scores for each of the function-based parameters from the existing condition assessment along with a summarized ECFS for the wetland. The Summary of Proposed Wetland Function table provides index scores for each of the function-based parameters from the proposed condition assessment along with a summarized PCFS, the Net Functional Lift Score (Δ) occurring within the wetland, and incorporates the area (Acres) of the wetland to calculate the Total Wetland Credits Generated. The change in functional condition of the project wetland is the difference between the PCFS and ECFS.

$$\Delta = (\mathrm{PCFS} - \mathrm{ECFS}) * \mathrm{Acres}$$

If the Net Functional Lift Score is a positive number, then functional lift is occurring within the wetland. If the Net Function Lift Score is a negative number, then functional loss is occurring within the wetland. If a negative Net Functional Lift Score occurs, replacement compensatory mitigation will be required to compensate for the loss of functional capacity to the wetland.

3. Measurement Method Field Values

Data collection and analysis procedures for existing condition assessments and post-implementation monitoring events should follow the procedures outlined in this section of the User Manual. During the project design and review period, the proposed condition assessment worksheet is filled out with data from the project design and best professional judgement for the anticipated project outcome. Subsequent to project implementation, actual measured field values collected during each monitoring event are entered into the same worksheet for each wetland treatment area and submitted as part all annual monitoring reports.

The field methods used to collect and calculate measured field values for each function-based parameter are summarized below. No new field sampling protocols have been developed exclusively for the GA HGM, and most parameters should be familiar to practitioners and project sponsors.

3.1 Continuous Saturation (V_{HYDRO})

The GA HGM currently contains one function-based parameter to describe hydrologic processes (e.g., water storage) in wetlands: Continuous Saturation. This parameter is documented through the direct measurement of the shallow groundwater table and aboveground inundation (“ponding”) via the installation and maintenance of groundwater monitoring wells as outlined in the *Technical Standard for Water-Table Monitoring of Potential Wetland Sites* (US Army Corps of Engineers, 2005).

Target continuous soil saturation ranges (i.e. percent of growing season) have been identified for each hydric soil series in Georgia based on soil drainage class, soil taxonomy, soil features described in the USDA NRCS Official Soil Series Descriptions, and the Water Features Tables associated with each mapped series (tables are included within the HGM Workbook). The target continuous soil saturation period for any given site will be based on the field-verified soil series, growing season length and the target soil saturation range for that verified soil series. The GA HGM includes only those soil series with a minimum continuous saturation of 10 percent of the growing season. Figure 1 illustrates how this information is utilized to inform wetland hydrologic performance standards.

Figure 1. Example performance curve for wetland hydrology based on a target soil saturation range for Roanoke series.

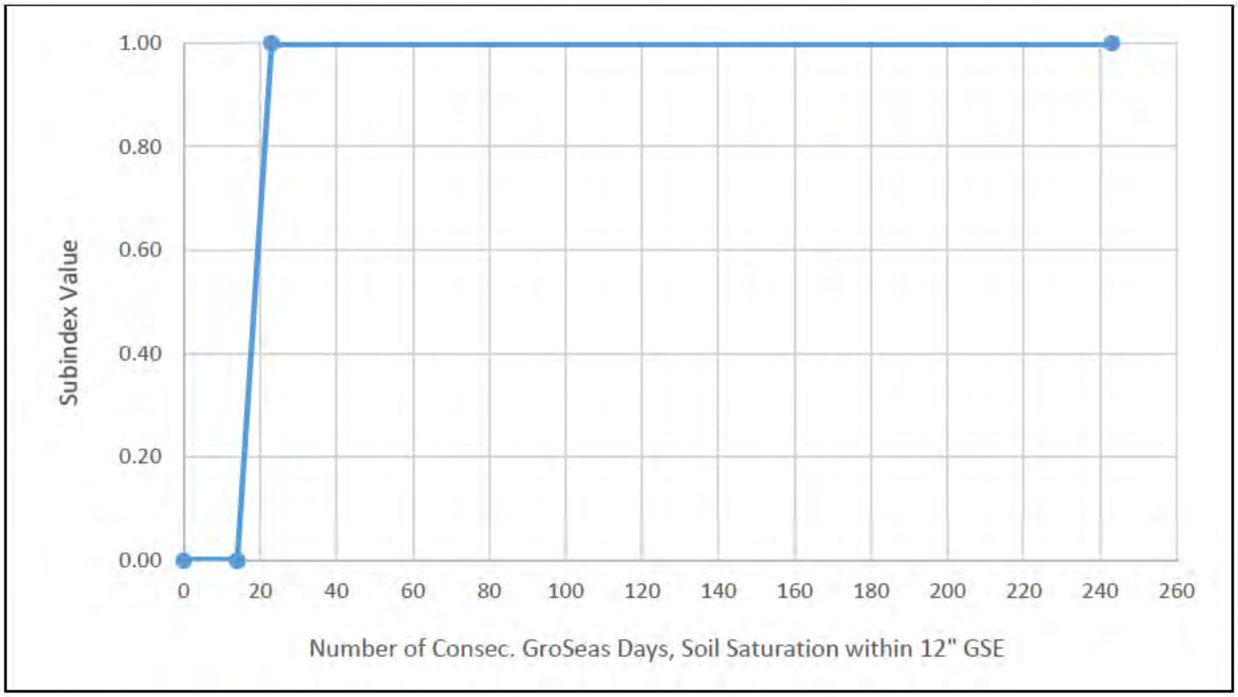

Figure 1 has been developed based on a subindex graph, in which the y-axis is a 0.00 to 1.00 index range indicative of the degree to which the variable is performing as it should. In this case, the function-based parameter is continuous saturation within 12 inches of the soil surface during the growing season.

In the example illustrated above, our mitigation wetland is located in Coweta County, Georgia and has been field verified as Roanoke soil. The closest NOAA Weather Station (Station USC00096335, Newnan 7 WNW) indicates that the mitigation site has a 233-day growing season, and the USDA NRCS official soil series description indicates that Roanoke soil is a poorly drained thermic fluvaquentic endoaquept. The target saturation range for a Roanoke soil is greater than or equal to 10% of the growing season, based on the soils worksheets in the HGM workbook, thus the target saturation range on the site is greater than or equal to 23 days during normal climatic conditions.

If water table monitoring data indicate that the number of consecutive days that soil saturation is within 12 inches of the surface is within the target saturation range during normal climatic conditions, the index score is 1.00. As duration moves towards the drier side of the scale (i.e. to the left on the x-axis), the index value declines until saturation is less than the 14-day threshold, which is the technical standard for minimum wetland hydrology. If continuous saturation during normal climatic conditions is less than 14 days, the index value defaults to zero.

The GA HGM has incorporated an additional component to this parameter based on the duration of ponding to evaluate excessive hydrology that is detrimental to the target forested wetland community type. If continuous ponding of a wetland area exceeds the USDA NRCS Ponding Duration Class for the given soil type (as provided in the soils worksheets incorporated in the HGM workbook), then the Continuous Saturation (V_{HYDRO}) Calculator will initiate an override function to reduce the continuous saturation performance curve to a V_{HYDRO} index score of no greater than 0.10. This index value does not drop to zero because the site remains a wetland, but it is a wetland with excessive hydrology. Table 1 provides the different ponding duration classes for hydric soils in Georgia.

Table 1. USDA NRCS Ponding Classes for Hydric Soils in Georgia

USDA NRCS Ponding Duration Classes	**Ponding Duration Range**	**HGM Ponding Days (Maximum Threshold)**
n/a	< 2 days	1 day
Very Brief	< 2 days	1 day
n/a to Brief	< 2 days to < 7 days	6 days
Brief	2 days to <7 days	6 days
Brief to Long	7 days to <30 days	29 days
Long	7 days to <30 days	29 days
n/a (Long)	< 2 days to <30 days	29 days
n/a to Long	< 2 days to <30 days	29 days
Brief to Very Long	2 days to $\geq$ 30 days	>=30 days
Long to Very Long	7 days to $\geq$ 30 days	>=30 days
n/a to Very Long	< 2 days to $\geq$ 30 days	>=30 days
Very Long	$\geq$ 30 days	>=30 days

In the same example as illustrated above, 23 days is the start of target continuous saturation range (i.e., greater than or equal to 23 days) for a Roanoke soil in the Newnan area. Roanoke soils are characterized as having a Ponding Duration Class of “n/a”, which corresponds to fewer than 2 days of continuous ponding. In a scenarioin which our mitigation wetland exhibits a continuous saturation of 23 days, but also has continuous ponding of 1 day, the V_{HYDRO} index score achieved is 1.00. In a second scenario, if our mitigation wetland exhibits a continuous saturation of 23 days, but also has continuous ponding of 2 days, the V_{HYDRO} index score is reduced from 1.00 to 0.10. In a third scenario, if our mitigation wetland exhibits a continuous saturation of 21 days, but also have a continuous ponding of 2 days, the V_{HYDRO} index score achieved is 0.10.

3.2 Wetland Vegetation Composition (V_{COMP})[3]

Wetland Vegetation Composition is the first of two function-based parameters describing the maintenance of plant and animal communities within the GA HGM.

The wetland vegetation composition parameter reflects the “floristic quality” of the community based on concepts in Andreas and Lichvar (1995), and Smith and Klimas (2002). The focus of this parameter is on the species that dominate the tree stratum. In reference standard freshwater forested wetlands in Georgia, the tallest stratum is composed of native canopy trees. In wetlands that have undergone recent and severe natural or anthropogenic disturbance, the tallest stratum may be dominated by herbaceous species or shrubs and tree saplings. Implicit in this approach is the assumption that the current composition of the tallest canopy layer is a reliable indicator of overall community functional capacity (i.e. dominant native tree species (≥2.54 centimeters) indicate appropriate future canopy composition). Most reference standard wetlands within the reference domain are relatively diverse with several dominant species present. Dominant species are determined using the Dominance Ratio. (Wakeley, 1997). Note that the tree stratum includes trees greater than or equal to 2.54 centimeters (1-inch) diameter at breast height.

Dominant species are classified into three groups reflecting presumed floristic quality. Group 1 consists of species that are typically canopy dominants in undisturbed forested wetlands. Group 2 consists of other native plant species that are not typical canopy dominants of mature, undisturbed forests, but are often characteristic of wetlands that have been disturbed or altered. Group 3 consists of nonnative (exotic) species or native invasive species of all strata (i.e., canopy/tree, sapling/shrub, woody vine, and herbaceous) that are usually found on low functioning sites.

In reference standard forested wetlands in the coastal plain, dominant vegetative composition includes species from Groups 1 and 2, and the number of dominants are 4 or greater in the Slope and Riverine wetland types. Two dominants are present in the reference standard Depressional wetlands in the coastal plain. If either composition or diversity diverges from those conditions, functional capacity is assumed to decline.

The procedure used to calculate an index score for V_{COMP} is described below and incorporates both quantity and quality of dominant species:

1. If total tree cover is greater than 20 percent, then V_{COMP} is determined for the tree stratum. If tree cover is less than 20 percent, then V_{COMP} cannot be calculated and the V_{COMP} Index Score will default to 0.00.

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[3] These sections have been adapted from Wilder (2013).

2. Use the “Dominance Ratio” to identify the dominant species in the tree stratum. For sites containing a tree stratum, only consider trees greater than or equal to 2.54 centimeters (1-inch) diameter at breast height.

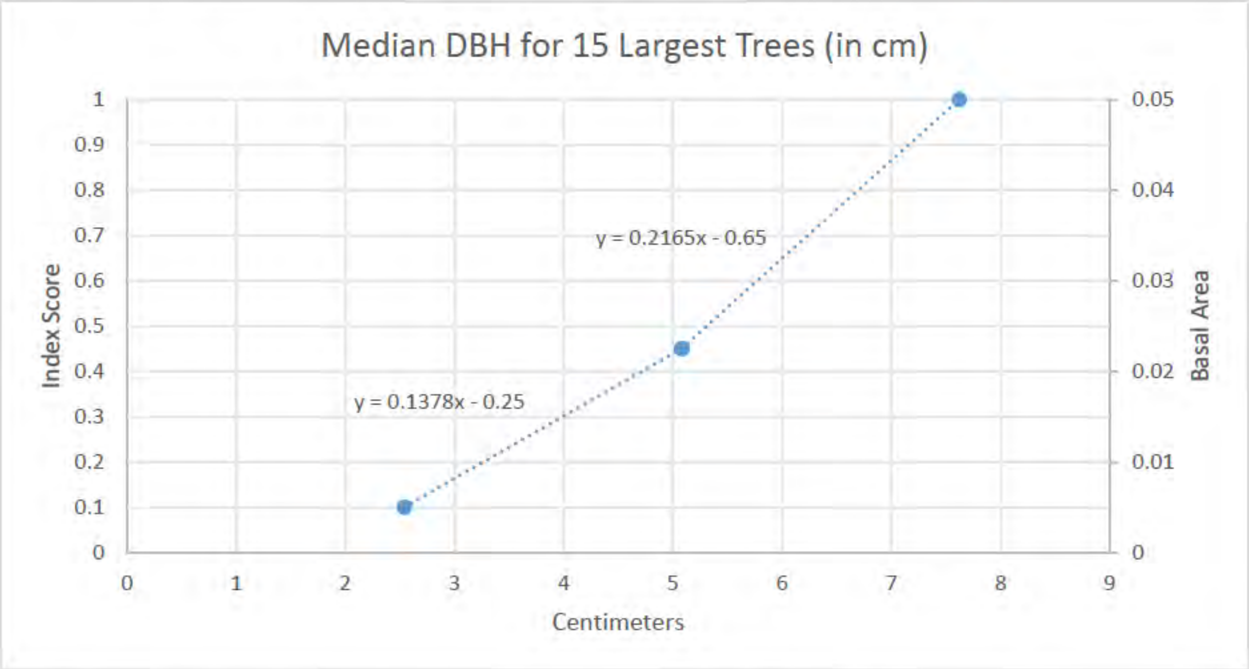
3. In the GA HGM Worksheet, place a check beside each dominant species that appears in either Group 1 or 2 for the appropriate wetland type. If a dominant species is not listed but is a species native to the reference domain, it can be added to Group 1 or 2 using the blanks provided. For any dominant species added to Group 1, data from a regionally appropriate wetland reference community must be required as supporting documentation. For exotic and invasive species in the reference domain (Group 3), check all species documented within the vegetation plot without regard to dominance or stratum. Other exotic and invasive species can be added using the blanks provided and should be assigned as Group 3 species.

3.3 Wetland Vegetation Structure (V_{STRUCT})[3]

Wetland Vegetation Structure is the second of two function-based parameters describing the maintenance of plant and animal communities within the GA HGM.

This parameter assesses the tree stratum. The tree stratum is defined as the median diameter at breast height (measured at 1.4 meters (55 inches) above the ground) for the fifteen (15) largest trees in each 0.04-hectare (0.1-acre) plot. Tree diameter is a common measure of dominance in forest ecology that expresses the relative maturity of a forest stand (Bonham, 1989; Spurr and Barnes, 1981; Tritton and Hornbeck, 1982; Whittaker, 1975; Whittaker et al., 1974). Tree basal area, measured as the cross-sectional area of tree stems per unit area (e.g., meters^2/hectare) is also a common measure of abundance, dominance, and vegetative functional capacity that has been shown to be proportional to tree biomass (Bonham, 1989; Spurr and Barnes, 1981; Tritton and Hornbeck, 1982; Whittaker, 1975; Whittaker et al., 1974. In Riverine reference wetlands in the coastal plain, the average diameter at breast height of the three largest trees of each plot in a stand ranged from 0.0 centimeters on sites where all trees had been removed to 70 centimeters (27.6 inches) in mature forest stands (Wilder, 2013). The mean diameter at breast height of the three largest trees of each plot at reference standard Slope wetlands in the coastal plain were greater than 35 centimeters (14 inches) (Wilder, 2013). Tree size was generally smaller than at the reference standard wetlands in the Riverine wetland type, where the mean was greater than 40 centimeters (15.7 inches) (Wilder, 2013). However, as vegetative development and performance of wetland mitigation sites are constrained by time (i.e., generally 10 years of annual monitoring), an index value of 1.00 is assigned for all wetland types with a minimum diameter at breast height is ≥7.62 centimeters (3-inches) for 0.04-hectare (0.1-acre) plot. The relationship between tree diameter and functional capacity is assumed to be linear; consequently, the index increases linearly from 0.10 to 1.0. Figure 2 provides the performance curve equation for the Wetland Vegetation Structure (V_{STRUCT}) Calculator.

Figure 2. Performance curve for wetland vegetative structure based on median diameter at breast height of the 15 largest trees per vegetation plot.



See the corresponding measurement methodology for tree stratum below:

1. Measure the diameter at breast height of the 15 largest trees within each 0.04-hectare (0.1 acre) plot.

2. Only record the trees that are greater than or equal to 2.54 centimeters (1-inch) diameter at breast height in the plot, even if there are fewer than 15 trees present.

3.4 Large Woody Debris (V_{LWD})[3]

The GA HGM currently contains two function-based parameters to describe biogeochemical processes, the first of which is the assessment of Large Woody Debris.

Large woody debris is defined as downed and dead woody stems that are greater than 7.62 centimeters (3-inches) in diameter that are no longer attached to living plants. Dead wood is an important component of wildlife habitat and nutrient cycling of forests. Dead wood may be present in snags, small twigs, roots, stumps, and limbs or logs. Some important dead wood habitat features, such as snags, are low in density in a healthy forest. An adequate sample design necessary to accurately estimate low density features such as snags in a forest is often outside the scope of a rapid assessment. Large woody debris as defined here matches that of “coarse woody debris” in the Forest Inventory Analysis (FIA), the volume of which may be estimated by a rapid assessment using methods based on those of the FIA (US Department of Agriculture, 2011; Waddell, 2002; Woodall and Monleon, 2008). Volume of large woody debris per hectare is used to quantify this parameter. In reference wetlands across the Coastal Plain, the volume of woody debris ranged from 0 to 700 meters^3/hectare (Wilder, 2013). The amount of woody debris in reference standard wetlands in the coastal plain varied by wetland type and were within the range of 20 to 60 meters^3/hectare (Wilder, 2013). The decrease in the parameter index is based on the assumption that lower volumes of woody debris indicate an inadequate reservoir of nutrients (and a stand at an early stage of maturity) and the inability to maintain characteristic nutrient cycling over the long term (Wilder, 2013). Above amounts characteristic of reference standard, the parameter index decreases linearly to 0.50 (Wilder, 2013). This correlation is based on the assumption that increasingly higher volumes of woody debris indicate that high levels of nutrients are stockpiled in long-term storage and are thus unavailable for primary production in the short term. This condition can occur in instances of catastrophic wind damage, such as hurricanes or following logging operations. It can also occur if a hydrologic obstruction increases inundation depth or duration to the point that trees experience dieback or death. The procedure used to calculate an index value for V_{LWD} is described below:

1. Establish two 15.24 meter (50-foot) transects perpendicular to one other, one bearing north and one bearing east, originating at the center point of the 0.04-hectare plot. The transect bearings may also be established randomly. For the first transect, note the seconds on a watch and multiply by six. The product is the first transect’s bearing. Add 90 degrees to the first transect bearing to obtain the second transect bearing. For example, if the seconds are 32, the bearing of the first transect is 192 (32 x 6) and the bearing of the second transect is 282 (192+90).

2. Measure and record the diameter of all non-living stems[4] greater than or equal to 7.62 centimeters (3 inches) in diameter that intersect the plane along the entire length of the 15.24 meter transect. Record the diameter of each stem (in centimeters) from each transect in the spaces provided on the V_{LWD} of the GA HGM Worksheet.

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[4] Log, or stem, diameter refers to the diameter at the point of intersection with the transect line. Leaning dead stems that intersect the sampling plane are sampled. Dead trees and shrubs still supported by their roots are not sampled. Rooted stumps are not sampled, but uprooted stumps are sampled. Down stems that are decomposed to the point where they no longer maintain their shape but spread out on the ground are not sampled.

3.5 Upland Buffer (V_{UP})[5]

Upland Buffer is the second of two function-based parameters describing biogeochemical processes in the GA HGM.

The functional importance of upland buffers in improving quality of surface water and groundwater has been well document in the scientific literature. Upland buffers play an important role in improving water quality, as they trap and transform pollutants such has sediments, nutrients, pathogens, and pesticides in surface water and groundwater (City of Boulder, 2007, Pearsell and Mulamoottil, 1996; Correll, 1996). Upland buffer vegetation also slows surface runoff, causing larger sediment particles and pollutants to settle out (City of Boulder, 2007; Lee et al., 2003; Correll, 1996). The filtering function of upland buffers is improved as both the density of vegetation and width of upland buffer increase. Further removal and/or transformation of pollutants can occur through groundwater filtration, uptake by vegetation, biogeochemical processes, and microbial processes in the upper soil profile (City of Boulder, 2007; Lee et al., 2003; Correll, 1996; USEPA, 2005). Also, unsaturated buffer soils are more effective at reducing bacterial concentrations than saturated wetland soils (City of Boulder, 2007; Pearsell and Mulamoottil et al., 1996). Excessive levels of nitrate can be reduced as groundwater contacts roots of upland buffer vegetation and denitrifying microbes, which can in turn reduce nuisance aquatic vegetation (City of Boulder, 2007; Lee et al., 2003). Mature vegetated upland buffers also minimize the detrimental effects of runoff, which can transport pesticides, fertilizers, and other pollutants to surface waterbodies (City of Boulder, 2007; Miltner et al., 2004; Center for Watershed Protection, 1995; Meyer et al., 2005).

The width of the upland buffer and the percent of the upland buffer protecting the wetland perimeter are assessed in this parameter. Upland buffer will only be considered present if a restrictive covenant and conservation easement are recorded on the entire buffer area. If the upland buffer is not protected by these real property protections, the upland buffer will be considered absent. The maximum upland buffer width is 100 linear feet, measured perpendicular from the treatment boundary. If a given segment of upland buffer is 100 linear feet in width, an index value of 1.00 is assigned. If the entire wetland is protected by 100 linear foot wide upland buffer, then a V_{UP} index score of 1.00 is realized. If there are multiple buffer segments of varying widths, each buffer segment receives a weighted score based on the percentage of its length compared to the total length of the wetland perimeter. Upland buffer can be comprised of both uplands and/or wetlands. Figure 3 provides the performance curve for the width of an upland buffer segment in the Upland Buffer (V_{UP}) Calculator.

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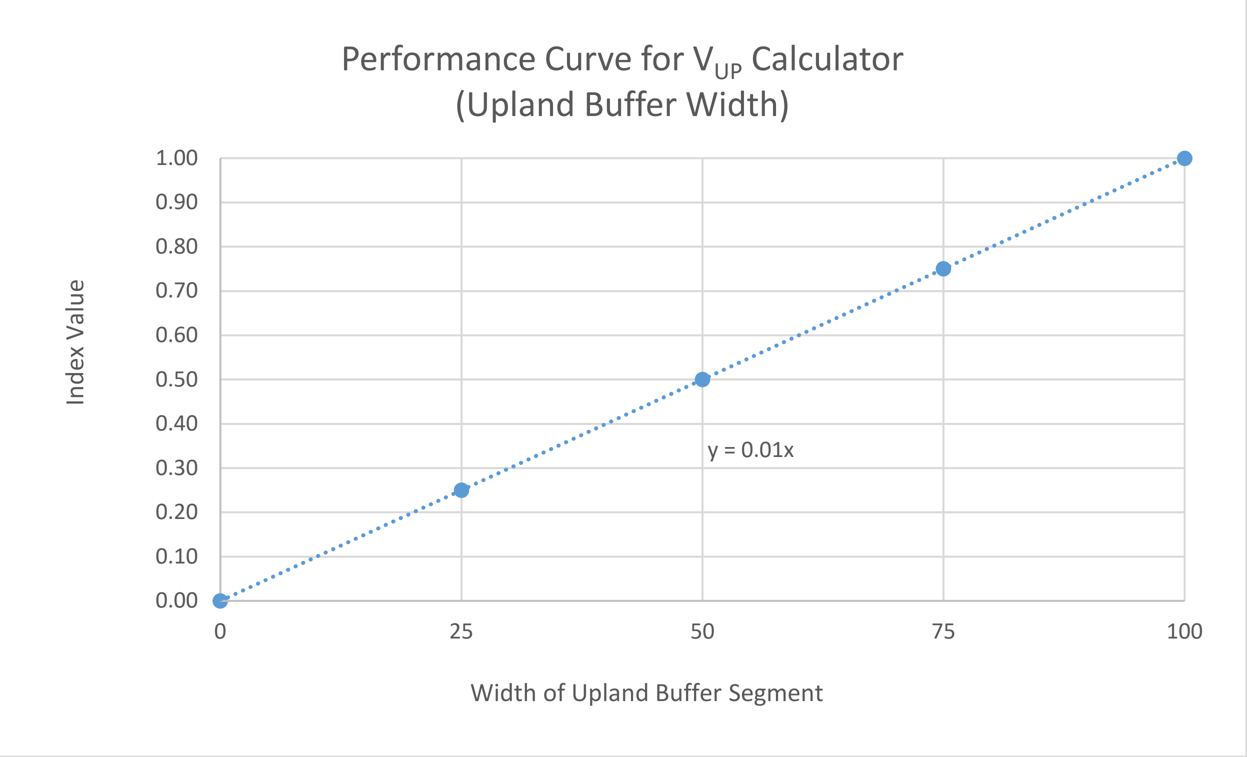
[5] The supporting documentation on the functional importance of upland buffers was adapted from "Wetland and Stream Buffers: A Review of the Science and Regulatory Approaches to Protection." (City of Boulder, 2007).

Figure 3. Performance curve for the width of an upland buffer segment.



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Appendix 11.16. Georgia Interim Saltwater Wetland Hydrogeomorphic Worksheet
(In Development)

Appendix 11.17. Georgia Interim Saltwater Wetland Hydrogeomorphic Worksheet User Manual (In Development)

Appendix 11.18. Georgia Interim Stream Quantification Tool

GEORGIA STREAM QUANTIFICATION TOOL

Site Information and Performance Standard Stratification	
Project Name:	
Reach ID:	
Mitigation Potential:	
Existing Stream Type:	
Proposed Stream Type:	
Level III Eco-region:	
Level IV Eco-region:	
County:	
Coordinates:	
Drainage Area (sqmi):	
Proposed Bed Material:	
Existing Stream Length (ft):	
Proposed Stream Length (ft):	
Stream Slope (%):	
Flow Type:	
Service Area:	
Stream Temperature:	
Date of Data Collection:	
Valley Type:	

Notes
1. Users input values that are highlighted based on restoration potential
2. Users select values from a pull-down menu
3. Leave values blank for field values that were not measured

FUNCTIONAL CHANGE SUMMARY	
Exisiting Condition Score (ECS)	
Proposed Condition Score (PCS)	
Change in Functional Condition (PCS - ECS)	
Percent Condition Change	
Existing Stream Length (ft)	0
Proposed Stream Length (ft)	0
Additional Stream Length (ft)	0
Existing Functional Foot Score (FFS)	
Proposed Functional Foot Score (FFS)	
Proposed FFS - Existing FFS	
Functional Change (%)	

WARNING: Sufficient data are not provided.

FUNCTION BASED PARAMETERS SUMMARY

Functional Category	Function-Based Parameters	Existing Parameter	Proposed Parameter
Hydraulics	Floodplain Connectivity		
Geomorphology	Riparian Vegetation		
	Bed Form Characterization		
Biology	Macros		

FUNCTIONAL CATEGORY REPORT CARD

Functional Category	ECS	PCS	Functional Change
Hydraulics			
Geomorphology			
Biology			

EXISTING CONDITION ASSESSMENT

					Roll Up Scoring				
Functional Category	Function-Based Parameters	Measurement Method	Field Value	Index Value	Parameter	Category	Category	Overall	Overall
Hydraulics	Floodplain Connectivity	Bank Height Ratio							
		Entrenchment Ratio							
Geomorphology	Riparian Vegetation	Left Buffer Width (ft)							
		Right Buffer Width (ft)							
	Bed Form Characterization	Pool Spacing Ratio							
		Percent Riffle							
		LWD Index							
Biology	Macros								

PROPOSED CONDITION ASSESSMENT

					Roll Up Scoring				
Functional Category	Function-Based Parameters	Measurement Method	Field Value	Index Value	Parameter	Category	Category	Overall	Overall
Hydraulics	Floodplain Connectivity	Bank Height Ratio							
		Entrenchment Ratio							
Geomorphology	Riparian Vegetation	Left Buffer Width (ft)							
		Right Buffer Width (ft)							
	Bed Form Characterization	Pool Spacing Ratio							
		Percent Riffle							
		LWD Index							
Biology	Macros								

Version 2.0 (October 15, 2021)

Appendix 11.19. User Manual & Scientific Support for the Georgia Stream Quantification Tool

U.S. Army Corps of Engineers, Savannah District

User Manual & Scientific Support for the Georgia Stream Quantification Tool

Version 2.0 (October 2021)

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Appendix B – Development of Percent Riffle Reference Curves for the Georgia SQT
Appendix C – Development of Large Woody Debris Reference Curves for the Georgia SQT
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Glossary of Terms

Alluvial Valley – Valley formed by the deposition of sediment from fluvial processes.

Catchment – Portion of the project watershed that drains to the uppermost extent of the assessment reach. The catchment is the total drainage area contributing to the assessment reach.

Colluvial Valley – Valley formed by the deposition of sediment from hillslope erosion processes, typically confined by terraces or hillslopes.

Condition Score – A value between 0.00 and 1.00 that expresses whether the associated parameter, functional category, or overall assessment reach is functioning, functioning-at- risk, or not functioning compared to a reference condition.

- ECS = Existing Condition Score
- PCS = Proposed Condition Score

Credit – A unit of measure (e.g., a functional or areal measure or other suitable metric) representing the accrual or attainment of aquatic functions at a compensatory mitigation site. The measure of aquatic functions is based on the resources restored, established, enhanced, or preserved (33 CFR 332.2; 40 CFR 230.922).

Debit – A unit of measure (e.g., a functional or areal measure or other suitable metric) representing the loss of aquatic functions at an impact or project site. The measure of aquatic functions is based on the resources impacted by the authorized activity (33 CFR 332.2; 40 CFR 230.92).

Functional Capacity – The degree to which an area of aquatic resource performs a specific function (33 CFR 332.2; 40 CFR 230.92).

Functional Category – The levels of the Stream Functions Pyramid Framework: Hydrology, Hydraulics, Geomorphology, Physicochemical, and Biology. Each category is defined by a functional statement.

Functional Foot Score (FFS) – The product of a condition score and stream length.

- Existing FFS = Existing Functional Foot Score. Calculated by measuring the existing stream length and multiplying it by the ECS.
- Proposed FFS = Proposed Functional Foot Score. Calculated by measuring the proposed stream length and multiplying it by the PCS.

Function-Based Parameter – A structural measure or function (e.g., expressed as a rate) that both represents and supports the ecosystem functions expressed as functional statements for each functional category.

Functions – The physical, chemical, and biological processes that occur in ecosystems (33 CFR 332.2; 40 CFR 230.92).

Performance Standard – Observable or measurable physical (including hydrological), chemical and/or biological attributes that are used to determine if a compensatory mitigation project meets its objectives (33 CFR 332.2; 40 CFR 230.92). The GA SQT uses reference curves that convert measured field data values (i.e., measurement methods) to an index value of between 0.0 and 1.0.

Reference Conditions – Conditions incorporating the whole range of variability exhibited by a regional class of aquatic resource as a result of both natural processes and anthropogenic disturbances (33 CFR 332.1; 40 CFR 230.92),

Reference Standard Condition – A stream condition that is considered fully functioning for the parameter being assessed.

Restoration - Restoration means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource (33 CFR 332.2; 40 CFR 230.92).

Riparian Buffer (a.k.a. stream buffer or buffer) – Zone or area extending outwards from top of bank on either side of the channel that is comprised of natural vegetation. In the Southeastern U.S., natural riparian buffer vegetation should typically include a mixed assemblage of trees, saplings, shrubs, vines, and ground cover vegetation.

Stream Functions Pyramid Framework (SFPF) – The Stream Functions Pyramid is comprised of five functional categories (see above) stratified based on the premise that lower-level functions support higher-level functions and that they are all influenced by local geology and climate.

1. Purpose and Background

The purpose of this User Manual is to introduce the Georgia Interim Stream Quantification Tool (GA SQT) and provide both background and instruction on its use to calculate functional lift and inform crediting for stream compensatory mitigation projects undertaken in accordance with the Clean Water Act (CWA), Section 404 regulatory program in Georgia. This manual includes descriptions of how to collect and calculate field values for each assessment metric in the stream reach condition assessments and describes how those field values are converted to index values within the GA SQT. Few measurements are unique to the GA SQT, and procedures are often detailed in other instruction manuals or literature. Where appropriate, this document will reference other data collection manuals and make clear any differences in data collection or calculation methods needed for the GA SQT. This manual will refer to stream restoration in accordance with the definition used by the Final Mitigation Rule (33 CFR 332; 40 CFR 230):

> *Restoration means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource.*

This definition encompasses all activities aimed to improve stream functions undertaken for compensatory mitigation or other purposes. Fischenich (2006) described 15 key stream and riparian zone functions aggregated into five categories including system dynamics, hydrologic balance, sediment processes and character, biological support, and chemical processes and pathways. This work informed the development of the Stream Functions Pyramid Framework (SFPF; Harman et al., 2012) and the North Carolina SQT (Harman and Jones, 2017), which collectively provide the structural underpinnings of the GA SQT. The functional pyramid provides an organizational framework around which stream restoration practitioners and project reviewers can develop and identify clear goals, inform better site selection and focus on a suite of measurements for assessing applicable functions in an objective manner. This document and the Georgia Interim Stream Quantification Tool Worksheet assume the reader has a firm knowledge of stream processes and the SFPF. Therefore, it does not provide extensive definitions of geomorphic terms such as bankfull, thalweg, riffle, etc.

Collection and analysis of the watershed-scale and stream reach-scale data necessary to evaluate a stream restoration project, or even selecting a potential stream restoration site, is not limited to the assessment metrics and methods included in the GA SQT. The GA SQT incorporates only some of the necessary assessment metrics that all stream restoration project Sponsors are expected to assess and document as part of project siting and planning. Thus, the GA SQT is not a stand-alone method or protocol for designing a stream restoration project.

The Georgia Stream Quantification Tool (GA SQT) – Microsoft Excel Workbook and this User Manual can be downloaded from the RIBITS website at: https://ribits.ops.usace.army.mil/ords/f?p=107:27:12853458931130::NO::P27_BUTTON_KEY:10.

In addition, the above referenced RIBITS web site also includes a Macroinvertebrate Traits table that lists trophic and habit traits per macroinvertebrate genus used in the assessment metrics for the Biology functional category (see Section 3.3). The GA SQT and accompanying documents will be updated periodically as additional data are gathered and reference standards and assessment metrics are refined. Users are encouraged to periodically review the documents posted to this directory in case updates have been made since their last use of the GA SQT.

2. Getting Started with the GA SQT

The GA SQT is used to inform mitigation credit allocations for stream mitigation projects undertaken pursuant to the CWA 404 regulatory program. The assessment metrics, measurement methods and associated performance standards utilized in the GA SQT will not necessarily be the only field variables necessary to be monitored, nor will they be the only field variables for which performance standards will be assigned.

The GA SQT uses three functional categories from the SFPF: Hydraulics, Geomorphology and Biology. Except for the benthic macroinvertebrate parameter of the Biology functional category, all GA SQT functional categories, parameters and assessment metrics used to assess existing (baseline) conditions must also be used to assess post-construction conditions throughout the monitoring period. By contrast, post-construction monitoring of benthic macroinvertebrates may cease once interim performance standards are satisfied. Note however, that the maximum possible overall index score of the GA SQT (i.e., 1.0) is based upon all three functional categories weighted equally. Consequently, by excluding the Biology category from assessment of final performance standards, the practitioner also limits the potential overall scoring to 0.67 (instead of 1.0).

The quantification tool worksheet in the GA SQT Microsoft Excel workbook is the main spreadsheet for the GA SQT. Users enter field data describing the existing and proposed (or monitored) conditions of the mitigation project assessment reach, and the calculator quantifies functional lift or loss. The quantification tool worksheet contains three areas for data entry: Site Information and Performance Standard Stratification, Existing Condition Assessment field values, and Proposed Condition Assessment field values. Cells that allow user input are shaded grey. All other cells are locked.

2.1 Site Information and Performance Standard Stratification

The Site Information and Performance Standard Stratification section of the quantification tool worksheet includes general site information and other project-specific information necessary to determine which reference curves are applied in the GA SQT for calculating index values. Some fields in this section include drop-down menus from which the user selects the appropriate value, while others require information to be entered manually. The values selected or entered into these fields establish links between the quantification tool worksheet and the applicable reference curves. It is therefore important for the user to input accurate site information.

2.2 Existing and Proposed Condition Assessment Field Values

Once the Site Information and Performance Standard Stratification section has been completed, the user may input data into the field value column of the Existing and Proposed Condition Assessment tables.

The Existing Condition Assessment field values are derived from measurements collected in the field during baseline condition assessment of the project site before any mitigation work is undertaken. The Proposed Condition Assessment field values are estimated during the development of the mitigation plan, and informed by design studies/ calculations, reports, and best available science. Proposed condition field values are subsequently validated or refined by measurements in the field during the post-construction monitoring phase.

2.3 Scoring Functional Lift

Scoring occurs automatically as field values for each assessment metric are entered into the Existing Condition Assessment or Proposed Condition Assessment tables. A field value will reflect an index value ranging from 0.0 to 1.0 for that assessment metric, based on the reference curves provided in the Reference Curves worksheet. Parameter scores within each functional category are equally weighted and averaged to calculate functional category scores. Similarly, functional category scores are equally weighted and averaged to calculate an overall condition score.

The quantification tool worksheet summarizes the scoring at the top of the sheet, next to and beneath the Site Information and Performance Standard Stratification table. There are three summary tables: Functional Change Summary, Function Based Parameters Summary and Functional Category Report Card.

The Functional Change Summary table provides the overall scores from the Existing Condition Assessment and Proposed Condition Assessment sections. This table illustrates the overall condition scores, functional change occurring at the project site, and incorporates the length of stream in the project to calculate the overall Functional Foot Score (FFS). The change in functional condition of the project stream is the difference between the proposed condition score (PCS) and the existing condition score (ECS). A FFS is the product of a condition score and the stream length. The table includes the existing and proposed stream lengths in order to calculate and communicate both existing and proposed FFS. Since the condition score must be 1.0 or less, a FFS is always less than or equal to the actual stream length.

$$Existing\ FFS = ECS * Existing\ Stream\ Length$$

$$Proposed\ FFS = PCS * Proposed\ Stream\ Length$$

The difference between the Proposed FFS and the Existing FFS is the amount of functional lift (or loss) resulting from the project related activities and will inform the calculation of mitigation credits. The functional lift is also shown as the percent lift in functional feet for an assessment reach.

$$Functional\ Change = \frac{Proposed\ FFS - Existing\ FFS}{Existing\ FFS} * 100$$

The Proposed FFS – Existing FFS score is also reported in the Mitigation Summary table. If this value is a positive number, functional lift is occurring at the project site. A negative number represents a functional loss. To evaluate projects that consist of multiple reaches, the Proposed FFS – Existing FFS score for each assessment reach is summed to create an overall project functional foot value.

The Functional Based Parameters Summary table provides a summary of the existing and proposed scores for each assessed parameter (e.g., floodplain connectivity, riparian vegetation, bed form characterization, and macroinvertebrates). Each of these parameter scores is calculated through the assessment of specific sets of equally weighted measurement methods (e.g., bank height ratio, entrenchment ratio, etc.). The parameter scores also play an important role in the roll up scoring of the Existing and Proposed Condition Assessments sections, as they support the calculation of functional change between the PCS and ECS.

The Functional Category Report Card table summarizes the functional change between PCS and ECS at the individual functional category level (e.g., Hydraulics, Geomorphology, Biology). The mean functional change of these functional categories is the Change in Functional Condition score outlined in the Functional Change Summary table.

3. Assessment Metric Field Values

The GA SQT includes Condition Assessments on the quantification tool worksheet, as well as the monitoring data worksheets. Data collection and analysis procedures for existing condition assessments and post-construction monitoring events should follow the procedures outlined in this section of the User Manual. During the project design and review period, the proposed condition assessment table is filled out with data collected to inform the project design and the anticipated project outcome. Following project construction, actual measured field values collected during each monitoring event are entered in the monitoring data worksheets.

The field methods used to collect and/or calculate measured field values for each assessment metric are summarized below. No new field sampling protocols have been developed exclusively for the GA SQT, and most parameters will be familiar to practitioners and project sponsors. The only assessment metric with which practitioners may be unfamiliar is the large woody debris index. In addition, the protocol for sampling and evaluating benthic macroinvertebrates is not the same as that utilized by the Georgia Environmental Protection Division as part of its monitoring and assessment program.

3.1 Hydraulics

The GA SQT currently contains one function-based parameter to describe the transport of water in the channel, on the floodplain, and through sediments: floodplain connectivity. Two assessment metrics are used to quantify floodplain connectivity: bank height ratio (BHR) and entrenchment ratio (ER). This parameter and both assessment metrics should be used for all stream mitigation projects. Note that the reference curves are stratified by Rosgen (1996) stream type to account for differences between streams within alluvial valleys relative to colluvial valleys. Both BHR and ER should be assessed for a stream length that is 20x the bankfull width or the entire assessment reach length, using whichever is shorter (Harrelson et al., 1994). Note however that the minimum assessment reach length for the GA SQT is 100 meters (328 feet).

3.1.1 Bank Height Ratio (BHR)

Bank height ratio (BHR) is a measure of channel incision and therefore representative of the potential for a stream to inundate its floodplain; the lower the ratio, the greater the likelihood for stormflow in undammed streams to inundate the floodplain. The most common calculation for BHR is the low bank height divided by the maximum bankfull riffle depth (D_{max}). The low bank height is the lower of the left and right streambanks (measured at a riffle), indicating the minimum water depth necessary to inundate the floodplain:

$$BHR = Low\ Bank\ Height/D_{max} \qquad \text{Equation (1)}$$

To improve consistency, the GA SQT requires BHR to be measured at every riffle within the assessment reach. The BHR should be measured at the midpoint of the riffle, halfway between the head of the riffle and the head of the run, or pool if there is not a run. Using this dataset, a weighted BHR is calculated using Equation (2) and illustrated in Table 1.

$$BHR_{weighted} = \Sigma^{n}_{i=1}(BHR_i{*}RL_i)/\Sigma^{n}_{i=1}\ RL_i \qquad \text{Equation (2)}$$

where, RL_i is the length of the
riffle where BHR_i was measured.

Table 1. Example calculation of weighted bank height ratio (BHR).

Riffle ID	Length (RL)	BHR	BHR * RL
R1	25	1.0	25
R2	50	1.5	75
R3	5	1.1	5.5
R4	30	1.7	51
Total	**110 ft.**	**Total**	**156.5**
Weighted BHR = 156.5/110 = 1.4			

The reference curve for BHR is based on categories of risk provided by Rosgen (2014), where very low and low risk banks are functioning (i.e., BHR ≤1.2); high, very high, and extreme risk banks are not functioning (i.e., BHR ≥1.6); and moderate risk banks are functioning-at-risk (i.e., 1.2 <BHR<1.6). For the GA SQT, BHR can be calculated for each riffle within the assessment reach using either detailed or rapid field methods. While rapid field methods may be suitable for preliminary site assessments, detailed methods must be used for more formal assessment of baseline conditions, design, and post-construction monitoring.

Detailed Method:
For the GA SQT, the BHR is measured at riffle features from the longitudinal profile. Harrelson et al. (1994) provides field instructions for surveying a longitudinal profile, and examples of BHR calculations made at riffles along the longitudinal profile are provided in Rosgen (2014). This method is objective and reproducible, as it is measured directly from the surveyed longitudinal profile and easily verified in the office.

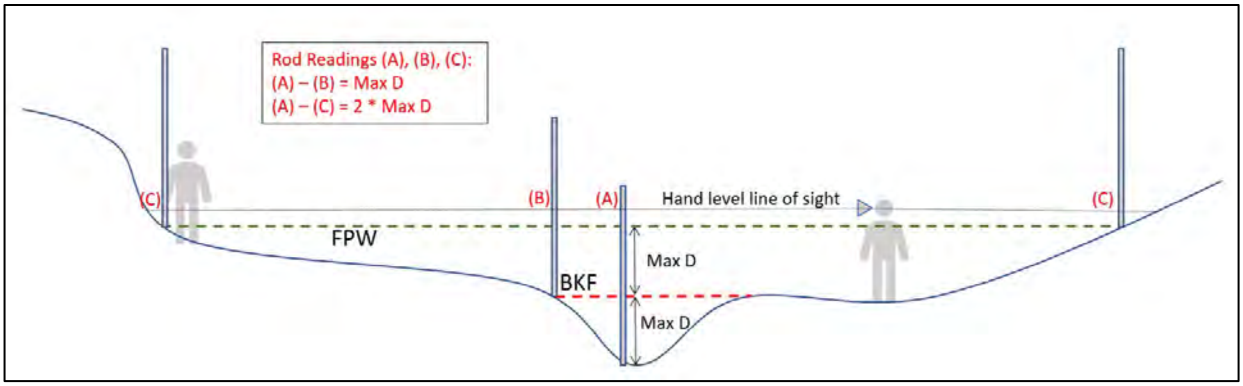
Rapid Method:
The rapid method for measuring BHR is undertaken in the field using a stadia rod and a hand level and does not require a longitudinal profile survey. A line level can be used instead of a hand level for small streams.

1. Identify the middle of the riffle feature and the lower of the two streambanks.
2. Measure the difference in stadia rod readings from the thalweg to the top of the low streambank. This result is the Low Bank Height in Equation (1).
3. Measure the difference in stadia rod readings from the thalweg to the bankfull indicator and enter this value in the denominator of Equation (1).
4. Measure the length of the riffle.
5. Repeat these measurements for every riffle to enter values into Equation (2).

3.1.2 Entrenchment Ratio (ER)

Entrenchment ratio (ER) is used to describe the vertical containment of a channel. It is a measure of approximately how far the 2-percent-annual-chance (50-year) discharge will laterally inundate the floodplain (Rosgen, 1996). ER is calculated by dividing the flood prone width by the bankfull width of a channel, measured at a riffle cross section (Equation (3)). The flood prone width (FPW on Figure 1) is measured as the cross-section width at an elevation two times the bankfull max depth.

$$ER = Flood\ Prone\ Width/Bankfull\ Width \qquad \text{Equation (3)}$$



Source: TDEC (2017).

Figure 1. Surveying entrenchment ratio using rapid methods.

Unlike the BHR, the ER does not have to be measured at every riffle if the valley width is fairly consistent. For valleys that have a variable width, or for channels that have BHR's that range from 1.8 to 2.2, it is recommended that the ER be measured at each riffle and calculate a weighted ER using Equation (4) and as illustrated in Table 2.

$$ER_{weighted} = \Sigma^n_{i=1}(ER_i * RL_i)/\Sigma^n_{i=1} RL_i \qquad \text{Equation (4)}$$

where, RL_i is the length of the riffle where ER_i was measured.

Table 2. Example calculation of weighted entrenchment ratio (ER).

Riffle ID	Length (RL)	ER	ER * RL
R1	25	1.2	30
R2	50	2.1	105
R3	5	1.6	8
R4	30	1.8	54
Total	**110 ft.**	**Total**	**197**
Weighted ER = 197/110 = 1.8			

There are two reference curves for ER, one for C and E type streams that are typically in alluvial valleys, and one for A and B type streams that typically occur in higher gradient systems with confined valleys. Note that the reference curves utilized in the GA SQT are based on the proposed stream type, not the existing stream type. For example, if the existing stream type is a Gc and the proposed stream type (which should be the appropriate stream type for the given valley morphology) is a C, the GA SQT will use reference curves for a C-type channel. The reference conditions for this assessment metric are based on the classification criteria for stream type. For the GA SQT, ER can be calculated using either detailed or rapid field methods. While rapid field methods may be suitable for preliminary site assessments, detailed methods must be used for more formal assessment of baseline conditions, design, and post-construction monitoring.

Detailed Method:
Measure ER at riffle features from surveyed cross sections. Harrelson et al. (1994) provides field instructions for surveying a cross section, and example ER calculations are provided in Rosgen (2014). This method is objective and reproducible, as it is measured directly from the surveyed cross sections and is easily verified in the office.

Rapid Method:
The rapid method for measuring ER is undertaken in the field using a stadia rod and a hand level and does not require surveyed cross sections. A line level can be used instead of a hand level for small streams. The rapid method measures the ER using bankfull and entrenchment widths measured from a riffle cross section.

1. Identify the middle of the riffle feature.
2. Measure the width between bankfull indicators on both banks and enter this value in the denominator of Equation (4).

3. Measure the difference in stadia rod readings from the thalweg to the bankfull indicator.
4. Locate and flag the point along the cross section in the floodplain where the difference in stadia rod readings between the thalweg and that point is twice that of the difference measured in the previous step.
5. Repeat step 4 on the other bank.
6. Measure the distance between the flags and enter this value as the numerator of Equation (3).
7. Measure the length of the riffle and repeat these measurements for every riffle to enter values into Equation (4), if needed.

3.2 Geomorphology

The GA SQT contains two function-based parameters to describe the transport of wood and sediment that creates diverse bed forms and maintains dynamic equilibrium: riparian vegetation and bed form characterization. One assessment metric is used to represent riparian vegetation, and three metrics are used to characterize bed forms.

3.2.1 Riparian Vegetation

Riparian vegetation is a critical component of a healthy stream ecosystem. While riparian vegetation is itself a biological component of stream environments that supports other biological components of the stream ecosystem and could therefore be included in the Biology functional category, it also directly affects channel stability (geomorphology) and supports denitrification and other water quality functions. The assessment metric used in the GA SQT is the width of the vegetated riparian buffer measured laterally on both the left and right sides of the channel. The width of the riparian buffer plays an important role in the capacity of the channel to adjust in response to long-term climatic trends and commensurate changes in sediment load and/or discharge. Therefore, riparian vegetation is placed within the Geomorphology functional category of the GA SQT.

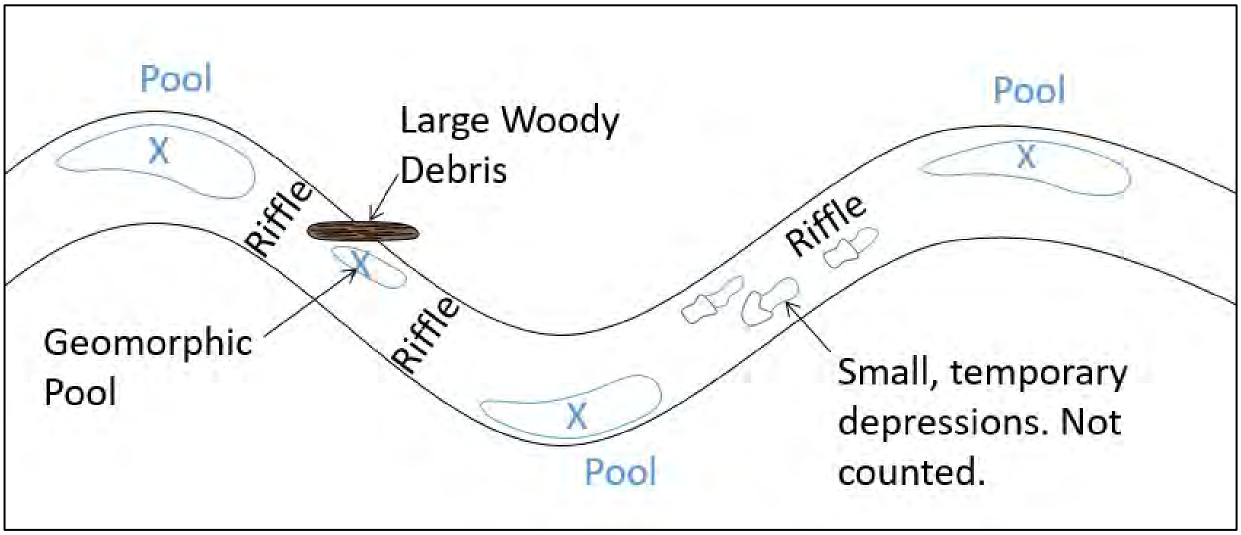
The riparian buffer width is measured horizontally from the top of the stream bank to the outer limit of the natural vegetative buffer or the proposed forested conservation easement boundary. Buffer width is measured perpendicular to the fall-line of the valley on the left and right sides of the channel. This measurement excludes the channel width itself. Measurements should be taken every 50-100 feet along the centerline of the channel (not the thalweg) and can be performed using recent ortho-imagery. However, remote sensing measurements must be verified with sufficient measurements collected in the field. An average buffer width is then calculated individually for the right and left side of the assessment reach of the channel.

3.2.2 Bed Form Characterization

Bed forms include riffles (to include steps and cascades), runs, pools and glides. Together, these bed features create important habitats for aquatic life and help dissipate the energy of flowing water. The location, stability, and depth of these bed features are indicative of sediment transport processes acting against the channel boundary conditions. Therefore, if the bed forms are representative of reference standards, it is assumed that the sediment transport processes are functioning normally and in equilibrium.

There are three assessment metrics for this parameter: pool spacing ratio, percent riffle, and large woody debris. Pool spacing ratio and percent riffle should be assessed over a channel length that is at least 20x the bankfull width (two meander wavelengths for meandering streams is preferable) or the entire assessment reach length, whichever is shorter (Harrelson et al., 1994). Large woody debris should be assessed over a channel length of 100 meters. Note that the minimum assessment reach length for the GA SQT is 100 meters.

Pools are only measured if they are geomorphically significant and relatively permanent. In reference standard alluvial systems, these include pools located along the outside of meander bends and pools downstream of large, relatively stable flow obstructions such as steps formed by large trees, boulders, or bedrock outcrops (Figure 2). Large pools providing energy dissipation are included, but small pools providing only habitat are not. For example, small, temporary depressions within riffles are not included as pools in the GA SQT. Pools should be noticeably deeper than riffle features, and the water surface slope of the pool should be lower than the riffle water surface slope at low flow.

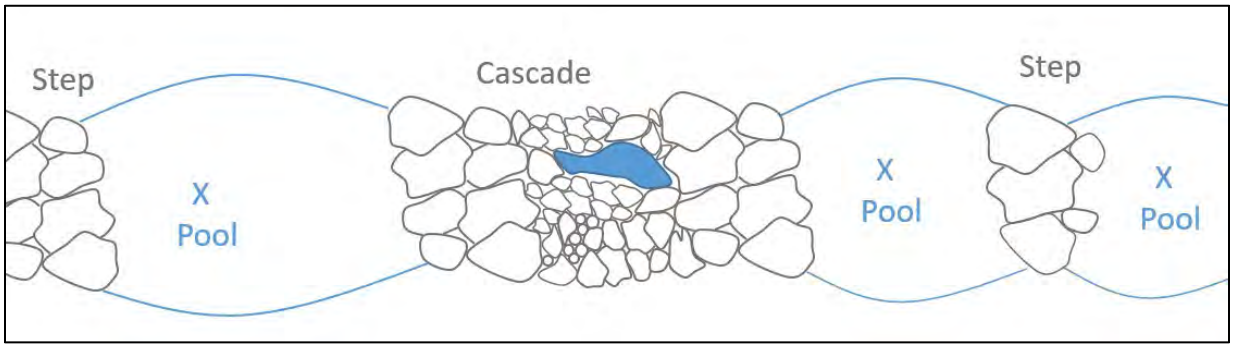


Source: TDEC (2017).

Figure 2. Pool spacing in alluvial valley streams (X marks the D_{max} location of pools counted for pool spacing).

Compound pools that are not separated by a riffle within the same meander bend are treated as a single pool. The deepest of such compound pools is used for measuring pool spacing. Compound bends with two pools separated by a riffle are treated as two pools. These scenarios are illustrated in Rosgen (2014).

Pools in colluvial valleys should only be included in measurements of pool spacing for the GA SQT if they are downstream of a riffle. Small, temporary pools within a riffle or cascade are not counted (Figure 3).



Source: TDEC (2017).

Figure 3. Pool spacing in colluvial valleys (X marks the D_{max} location of pools counted for pool spacing).

3.2.2.1 Pool Spacing Ratio

The pool spacing ratio is the calculation of the distance between successive geomorphically relevant pools divided by the mean bankfull riffle width (Equation (5)). The mean bankfull riffle width is measured from each of the riffle cross sections within the assessment reach. Dimensions from these riffles are used in this ratio in order to quantify the departure from a stable condition.

$$Pool\ Spacing\ Ratio = \frac{Distance\ between\ sequential\ pools}{Mean\ bankfull\ width} \qquad \text{Equation (5)}$$

The pool spacing ratio is calculated for each pair of sequential pools in the assessment reach. While the range of pool spacing ratios observed at a site should be assessed and reported, the field value entered in the GA SQT is the median value based on at least five, consecutive pool spacing measurements. In a meandering stream, a moderate ratio is preferred over a very low or very high ratio. In other words, having too many pools or too many riffles can be detrimental to channel stability. In steeper gradient systems, the frequency of pools often increases with slope, and concerns about channel stability increase with higher pool spacing ratios.

Reference curves for pool spacing ratio in the GA SQT are based on field data collected from 23 high quality, stable reference streams in South Carolina and Tennessee (Jennings Environmental, 2017; SCDNR, accessed 1/23/2020 and 4/6/2020). Development of reference curves for pool spacing ratio in the GA SQT is described in Appendix A.

Detailed Method:
For the detailed method, pool-to-pool spacing is measured from the longitudinal profile as the distance between the deepest points of two successive pools.

Rapid Method:
For the rapid measurement of pool spacing, a tape measure is laid along the stream centerline or bank and the stations for the deepest point of each pool within the assessment reach are recorded in the field and used to calculate the pool-to-pool spacing. A stable riffle is selected from within the assessment reach and the bankfull width of this stable riffle is measured with a tape measure and recorded to calculate the pool-to-pool spacing ratio for each pair of pools using Equation (5).

3.2.2.2 Percent Riffle

The percent riffle is the total length of riffles within the assessment reach divided by the total assessment reach length. Riffle length is measured from the head (beginning) of the riffle downstream to the head of the pool. Thus, run features are included with the riffle length. Calculating the percent pool in the assessment reach is optional, and reference conditions for percent pool are not provided. However, if practitioners choose to calculate percent pool, the glide features should be included with the pools in the percent pool calculation.

Reference curves for percent riffle in the GA SQT are based on field data collected from 33 high quality, stable reference streams in Alabama, South Carolina and Tennessee (Helms et al., 2013, 2016; Jennings Environmental, 2017; SCDNR, accessed 1/23/2020 and 4/6/2020). Development of reference curves for percent riffle in the GA SQT is described in Appendix B.

Detailed Method:
For the detailed assessment method, the percent riffle is measured from a longitudinal profile of the stream thalweg. Instructions for surveying a longitudinal profile are provided by Harrelson et al. (1994).

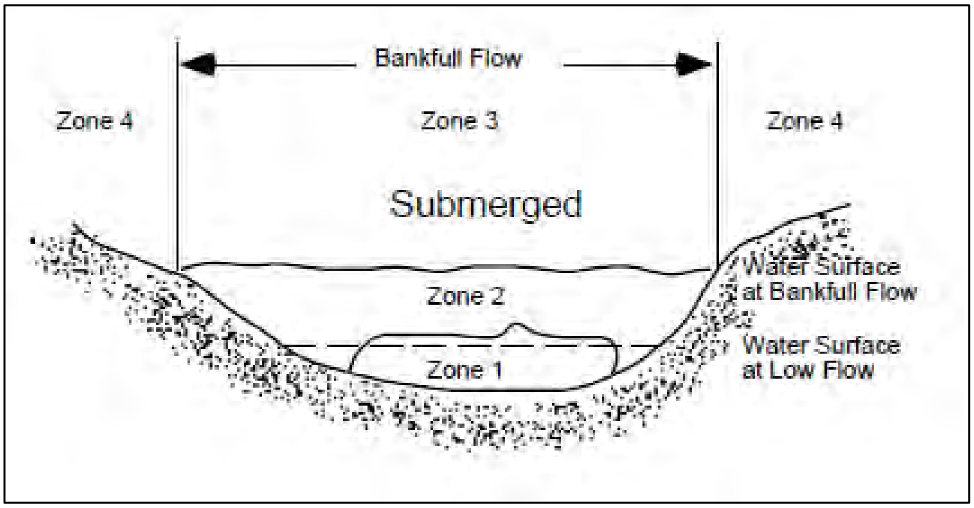
Rapid Method:
For the rapid assessment, a tape measure is laid along the stream centerline or bank and the stations at the beginning of each riffle and end of each run within the

assessment reach is recorded in the field and used to calculate the individual riffle lengths. These lengths are then summed and divided by the total assessment reach length.

3.2.2.3 Large Woody Debris

Large woody debris (LWD) is quantified in the GA SQT using the LWD Index (LWDI) developed by the U.S. Forest Service (Davis et al., 2001). LWD is defined as dead wood over 1.0 meters in length and at least 10 cm in diameter at the largest end. The LWD must be in or immediately adjacent to the active stream channel, but not solely resting atop the valley flat of an incised channel. Each of four zones or locations for the LWD contributes to the scoring of LWDI (Figure 4). As a result, it provides a better representation of the degree to which LWD may influence the physical and biological attributes of a stream. For example, simple piece counts of LWD provide no distinction between a 40 cm piece of LWD lying half submerged across the entire stream bed and forming a pool downstream (Zone 1 in Figure 4) versus a 12 cm piece of LWD that lies on the stream bank above bankfull elevation (Zone 4 in Figure 4). The latter plays a decidedly less critical role in bed form and habitat provision than the former.

A sample reach of 100 meters is required and must be within the assessment reach or sub-reach limits as the other geomorphology assessments. Additionally, the 100-meter stream reach from which the LWDI is calculated should represent the 100-meter segment of the larger assessment reach that will yield the highest LWDI score. The highest score, rather than an average score, is selected to reduce subjectivity in identifying an average condition.



Source: Davis et al. (2001), citing Robison and Beschta (1990).

Figure 4. Four stream locations or zones for inventorying large woody debris using the LWD Index (Davis et al., 2001).

Reference curves for LWDI in the GA SQT are based on surveys following methods described in Harman et al. (2017) conducted in 73 high quality, stable reference streams in South Carolina and Tennessee (Jennings Environmental, 2017; SCDNR, accessed 1/23/2020 and 4/6/2020). Development of reference curves for LWDI in the GA SQT is described in Appendix C.

3.3 Biology

The GA SQT contains one function-based parameter to evaluate the biodiversity and ecological integrity of aquatic life: macroinvertebrate community structure. This function-based parameter has been calibrated to reference conditions for streams draining ≤ 3.0 square miles in the Piedmont and Blue Ridge level III ecoregions (Ecoregions 45 and 66, respectively) and streams with pH > 5.0 that drain ≤ 7.0 square miles in three level IV ecoregions within the larger Southeastern Plains ecoregion: Dougherty Plain (ecoregion 65g), Tifton Upland (ecoregion 65h) and Atlantic Southern Loam Plains (ecoregion 65l). Stream mitigation projects undertaken on streams with characteristics other than those outlined above will be assessed for Biology on a case-by-case basis.

Detailed procedures are being finalized for collecting and analyzing stream benthic macroinvertebrate data for the GA SQT, which will be provided in a revision to Appendix E of the *“Monitoring Guidelines & Performance Standards for Freshwater Wetlands and Non-Tidal Streams”.*

The macroinvertebrate community structure reference curves for the GA SQT utilize a multi-metric Headwater Stream Restoration (HStR) index that is based on proportions of genus-level taxa richness sharing specific trophic and habit traits per applicable ecoregion (Table 3). While all taxa in the entire macroinvertebrate sample (i.e., all collections per sample reach) must be picked and identified to obtain accurate taxa richness data for the HStR index, actual enumeration of all specimens per taxon is not required.

Each taxon must be identified and assigned to its respective habit and trophic traits as described in Appendix E of the *“Monitoring Guidelines & Performance Standards for Freshwater Wetlands and Non-Tidal Streams.”* Note however that while genera within the family Chironomidae must be identified from macroinvertebrate samples collected in the Blue Ridge and Piedmont ecoregions, they do not in the Southeastern Plains.

The *“Georgia Interim Stream Quantification Tool”* Microsoft Excel workbook available on the USACE Savannah District’s RIBITS web page automates the necessary calculations to convert raw genus-level proportion macroinvertebrate data into the applicable final HStR index. Users are required only to enter the “raw” proportion-based values for each applicable metric dependent on the location of their project. Users will receive an error message unless these raw proportions are entered in the Excel workbook to the 1/100th place (i.e., two digits to the right of the decimal). Development of the HStR indices and SQT reference curves for macroinvertebrate community structure per ecoregion for the GA SQT is described in Appendix D.

Table 3. Biological metrics used in the HStR index per ecoregion for the GA SQT.

Ecoregion	Metrics
Blue Ridge (66)	Genus taxa richness Proportion genus-level EPT Proportion genus-level Burrower Proportion genus-level Clinger Proportion genus-level Shredder
Piedmont (45)	Genus taxa richness Proportion genus-level EPT Proportion genus-level Clinger Proportion genus-level Shredder
Dougherty Plain (65g)	Genus taxa richness Proportion genus-level EPT Proportion genus-level Clinger Proportion genus-level Collector-Filterer
Tifton Upland (65h)	Genus taxa richness Proportion genus-level EPT Proportion genus-level Clinger Proportion genus-level Swimmer
Southern Loam Plains (65l)	Genus taxa richness Proportion genus-level EPT Proportion genus-level Clinger Proportion genus-level Collector-Filterer Proportion genus-level Shredder

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Appendix A

Development of Pool Spacing Ratio Reference Curves for the Georgia SQT

Pool-to-Pool Spacing in Southeastern U.S. Streams: Derivation of Pool Spacing Ratio Reference Curves for Georgia

Version 2.1 – 6.10.2020

Montgomery et al. (1995) succinctly summarize the foundation of stream pool-to-pool spacing as “a fundamental aspect of channel morphology”:

> *Well-established tenets in fluvial geomorphology hold that pool-to-pool spacing averages 5-7 channel widths in free-formed pool-riffle reaches (Leopold and Wolman, 1957; Leopold et al., 1964; Keller, 1972; Keller and Melhorn, 1978) and 1-4 channel widths in steeper step-pool reaches (Whittaker, 1987; Chin, 1989; Grant et al., 1990). Pools, however, may be either freely formed by the interaction of flow and sediment transport or forced by local obstructions (e.g., bedrock, boulders, bank projections, and large woody debris (LWD) consisting of logs, root wads, or debris jams), which cause flow convergence and turbulent velocity fluctuations that scour the channel bed (e.g., Zimmerman et al., 1967; Swanson et al., 1976; Dolan et al., 1978; Keller and Swanson, 1979; Beschta, 1983; Lisle, 1986; Smith, 1990).*

Pool spacing ratio (PSR) is a function not only of the distance between successive geomorphic pools, but also bankfull width. The linear distance between successive pools in a stream varies considerably. It is therefore important to survey a longitudinal profile of sufficient length to include multiple pools. A stream’s PSR is often determined by dividing the median pool-to-pool spacing by the bankfull width.

Geomorphology data were collected from streams located in seven ecoregions across South Carolina and Tennessee during efforts to regionalize the Stream Quantification Tool (SQT) in those states (Jennings Environmental, 2017; SCDNR, accessed 1/23/2020 and 4/6/2020). Our primary interest for this exercise was pool-to-pool spacing data collected from streams in ecoregions common to Georgia. We therefore restricted our assessment to data collected from streams in the Piedmont (45), Southeastern Plains (65), Blue Ridge (66) and Ridge & Valley (67). We compiled data collected from 23 streams draining watersheds 9.0 square miles or less in the above-named ecoregions of South Carolina and Tennessee (Reference curves for percent riffle in the GA SQT are based on field data collected from 33 high quality, stable reference streams in Alabama, South Carolina and Tennessee (Jennings Environmental, 2017; SCDNR, accessed 1/23/2020). Seventy five percent of those streams drain approximately 2.0 square miles or less.

We first tested for outliers among the median PSR value for each stream using the “IQR Method.” The interquartile range (IQR) of the data represents the central 50% of the data. Upper and lower bounds (sometimes referred to as “fences”) are defined by adding 1.5 times the IQR to the third quartile of the data (Q3) and subtracting 1.5 times the IQR from the first quartile of the data (Q1). Any data value that is more than 1.5 IQR above Q3 or less than 1.5 IQR below Q1 is considered an outlier. One site in the SC Piedmont was found to be an outlier and was removed. The remaining 22 sites summarized in Appendix A-I were further assessed as described below.

We used scatter plots generated in Microsoft Excel and histograms using an Excel template developed by McDonald (2014) to visualize the entire distribution of data. We used box plots generated in PC Ord (v6.08) to visualize relationships among various *a priori* categorical groups of data (e.g., ecoregion, Rosgen stream type, etc.). Where box plots suggested potential discriminatory efficiency between groups, we conducted further statistical tests to evaluate the significance of those groups.

Our data set is limited in number (n=22), and when divided into categorical groups, each group is even fewer in number. Testing for differences among more than two groups is a task classically suited to ANOVA. However, traditional ANOVA requires that the data are normally distributed; an assumption often violated when sample numbers are small. McDonald (2014) contends that one-way ANOVA is not very sensitive to deviations from normality and further asserts that simulations with a variety of non-normal distributions, including flat, highly peaked, highly skewed, and bimodal, demonstrate that the proportion of false positives in one-way ANOVA is always around five percent or less. However, he does not explicitly state whether these simulations include small data sets. In addition to normality, ANOVA also assumes that the variance within groups being tested is equal; a condition known as homoscedasticity. The Kruskal-Wallis test, which makes no assumption of normality, is often considered a non-parametric alternative to one-way ANOVA when data are not normally distributed. However, the Kruskal-Wallis test also assumes that the data within each group has the same distribution, even if it is non-normal. Heteroscedastic data violates this assumption in Kruskal-Wallis just as it does in a one-way ANOVA.

We used both ANOVA and Kruskal-Wallis to test for differences among categorical groupings of PSR data from South Carolina and Tennessee. One-way ANOVA was used if Bartlett's test for homoscedasticity within groups was satisfied, and Welch's ANOVA was used if the data proved to be heteroscedastic. The Tukey-Kramer test identified significance at the $p<0.05$ level for variance of means between pairs of groups in the one-way ANOVA, and the Games-Howell test performed the same function in Welch's ANOVA. We also ran Kruskal-Wallis tests on the same groups to test for consistency with results of the ANOVA. Note that a Kruskal-Wallis test on only two groups is equivalent to a Mann-Whitney U test. All statistical tests were run with a five percent confidence limit using templates developed by McDonald (2014).

Results

There is a modest negative correlation between median PSR and basin area, channel gradient (slope) and bankfull width (Table A-1). Approximately equivalent correlation coefficients result whether the calculation is the product moment correlation (Pearson) summarized in Table A-1 or rank-order correlation (Spearman;not shown). Bankfull width explains approximately one-third of the variance in linearly regressed median PSR (Figure A-1), and both channel slope and basin area account for less than 25% of the variation in median PSR ($R^2 = 0.21$ and 0.22, respectively) (data not shown).

Median pool-to-pool spacing box plots with sites grouped by ecoregion suggest only moderate differentiation among groups (Figure A-2). However, median PSR indicates greater separation among groups, especially for streams in the Southeastern Plains (Figure 3). While median pool-to-pool spacing does not statistically differ among streams grouped by ecoregion (one-way ANOVA $F_{3, 18} = 0.822$; $p = 0.499$; Kruskal-Wallis adj $H_3 = 1.989$; $p = 0.575$), median PSR does (one-way ANOVA $F_{3, 18} = 4.304$; $p = 0.02$; Kruskal-Wallis adj $H_3 = 8.168$; $p = 0.043$). A Tukey-Kramer test on these ecoregion groups illustrates that the only pair of ecoregion groups that differ is the Southeastern Plains (65) and the Blue Ridge (66).

Despite that linear regression of median PSR against channel gradient indicates little predictive capacity of the latter (Figure A-4), box plots comparing multiple different categorical groupings of median PSR based on various channel gradient thresholds suggest a potential useful threshold at 3% slope (Figure A-5). When the categorical channel gradient groups illustrated in Figure A-5 are condensed to only two groups defined by channels less than 3%, versus those equal to or greater than 3%, the differentiation of median PSR at this threshold becomes even more clear (Figure A-6). These two groups are in fact statistically different (one-way ANOVA $F_{1, 20} =6.936$; $p = 0.016$; Kruskal-Wallis adj $H_1 = 5.576$; $p = 0.018$). Channels with gradients of 3% to 5% are reported by Whittaker (1987) and Chin (1989) to have naturally lower pool-to-pool spacing, and this correlation is reflected in our own data.

Grouping streams based on Rosgen stream type should theoretically account for differences in channel and valley gradient, as well as valley confinement. During its SQT regionalization effort, the State of Wyoming developed five different PSR reference curves across all ecoregions differentiated by Rosgen stream type (C, Cb, B+Ba, Bc and E). However, median PSR data from South Carolina and Tennessee do not support similar differentiation. Rosgen C streams do not differentiate from Ba streams, Bc streams, the single B stream or the single Ca stream in our data (Figure A-7). If all streams are re-grouped based primarily on the root Rosgen designation (e.g. "B streams," instead of B, Ba and Bc streams), there is a minor improvement in visual differentiation, but the discriminatory power separating B+Ba+Bc channels and C+Ca channels remains poor (Figure A-8). Further, there is only fair discriminatory power between C+Ca channels and E+Eb channels. Only the single Cb stream in our data differentiates cleanly from all other Rosgen groups illustrated in Figure A-7 and Figure A-8.

The State of Tennessee also calculated PSR reference curves for all ecoregions across the state but did so differentiated by a 2% channel threshold value. Our data includes only a single site with a channel gradient between 2% and 3%, but the median PSR of that site is greater than all median PSR values from streams greater than 3% slope in our data (Figure A-9). Although all streams with a channel gradient ≥ 3% come from the same ecoregion (i.e. the Blue Ridge), there are four additional Blue Ridge streams with a channel gradient < 3% (Table A-2). As already noted, statistical tests indicate that these two groups are in fact different.

PSR Reference Curve

Montgomery et al. (1995) cite many decades of literature indicating that pool-to-pool spacing averages 5-7 channel widths in free-formed pool-riffle reaches (e.g. low gradient alluvial reaches) and 1-4 channel widths in steeper step-pool reaches. Our reference data from four ecoregions in South Carolina and Tennessee only partially conforms to these reported norms.

The data included 51 cumulative pool spacings in longitudinal profiles surveyed in the 15 streams with less than three percent slope, and 33 cumulative pool spacings in longitudinal profiles surveyed in the seven streams with a slope equal to or greater than 3%. PSR for all 51 pool spacings of the former group ranges from a minimum of 0.7 to a maximum of 12.3, with an average of 3.6 (data not shown). Thus, the average PSR among streams with a channel gradient less than three percent is 28% less than the lower limit of the average range for “free-formed pool-riffle reaches” cited by Montgomery et al. (1995). By contrast, PSR for all 33 pool spacings of the latter group ranges from a minimum of 0.3 to a maximum of 5.6. The average PSR of 1.6 (data not shown) is within the average range for steeper streams suggested by Whittaker (1987) and Chin (1989).

We developed two PSR reference curves for Georgia distinguished by a channel gradient threshold value of three percent (Figure A-10). These curves assign an index value of 1.0 to PSR values lying within the respective IQR of the grouped reference data. Index values of 0.5 were assigned to the 5th percentile and 95th percentile of the respective reference data. The x-intercept of the falling limb for each parabolic reference curve is based on the slope of the respective curve’s rising limb from the x-intercept to an index value of 0.5 (Table A-3).

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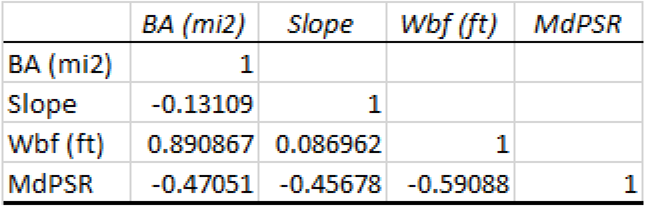
Table A-1. Pearson correlation among median PSR and basin area, channel gradient (slope) and bankfull width among 22 reference streams in four ecoregions of South Carolina and Tennessee: Piedmont, Blue Ridge, Ridge & Valley and Southeastern Plains.



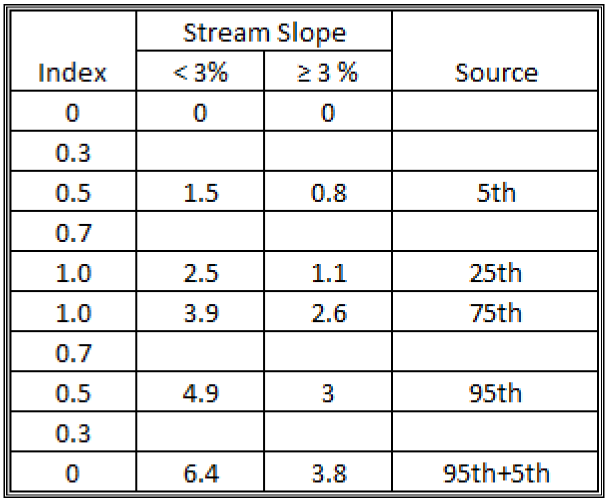
	BA (mi2)	*Slope*	*Wbf (ft)*	*MdPSR*
BA (mi2)	1			
Slope	-0.13109	1		
Wbf (ft)	0.890867	0.086962	1	
MdPSR	-0.47051	-0.45678	-0.59088	1

Table A-2. Streams in each channel gradient threshold group.

Streams < 3% Channel Gradient				Streams ≥ 3% Channel Gradient			
ID	Ecoregion	Type	MdPSR[1]	ID	Ecoregion	Type	MdPSR
5scp	45	E5	4.6	10 66g	66	C4b	0.7
6scp	45	C5	2.0	4scbr	66	B4	2.4
7scp	45	E5	2.6	9 66d	66	C3a	2.1
2scbr	66	B4c	3.3	11 66d	66	B3a	0.8
4scp	45	E5	3.0	4 66g	66	B4a	2.8
2 65e	65	E5	3.5	3scbr	66	B3a	3.2
5 65e	65	E5	4.5	7 66e	66	B3a	1.4
6 67i	67	C4	3.7				
5 67f	67	C3	4.1				
3 65e	65	E5	5.5				
12 67f	67	C4	1.5				
6scbr	66	E4	3.5				
5scbr	66	B4c	2.4				
13 66g	66	B3c	1.4				
4 67f	67	E4b	3.4				

[1] MdPSR = median pool spacing ratio.

Table A-3. PSR data used to generate reference curves for the Georgia SQT.



Index	Stream Slope		Source
	< 3%	≥ 3 %	
0	0	0	
0.3			
0.5	1.5	0.8	5th
0.7			
1.0	2.5	1.1	25th
1.0	3.9	2.6	75th
0.7			
0.5	4.9	3	95th
0.3			
0	6.4	3.8	95th+5th

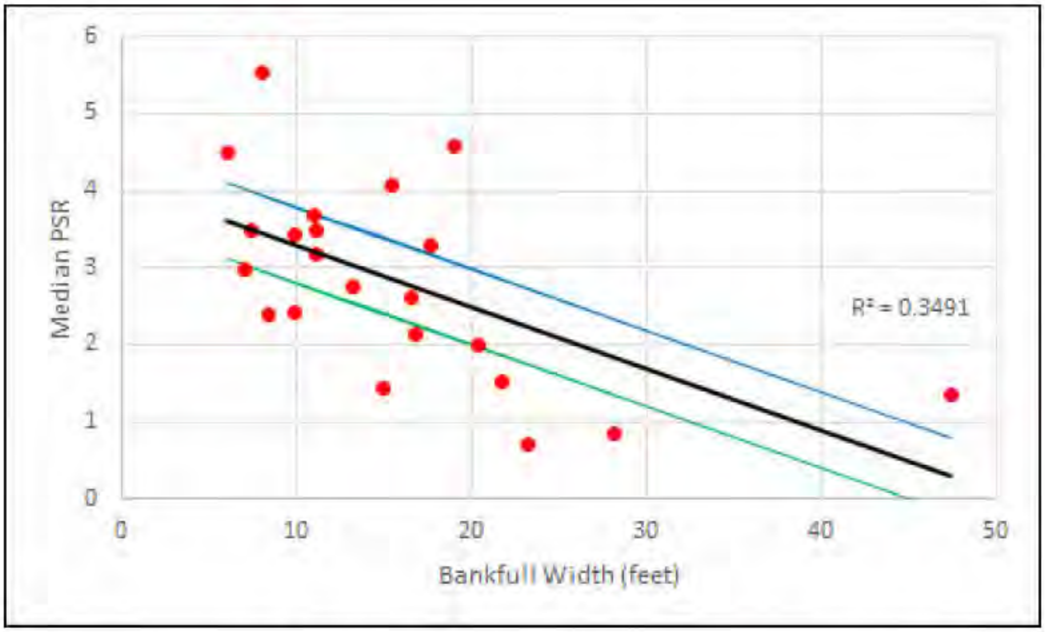


Figure A-1. Regression of median PSR with bankfull width. Blue and green lines bound the 95% confidence interval. Note that removing the stream with a bankfull width of 47.4 feet, increases the R^2 to 0.39.

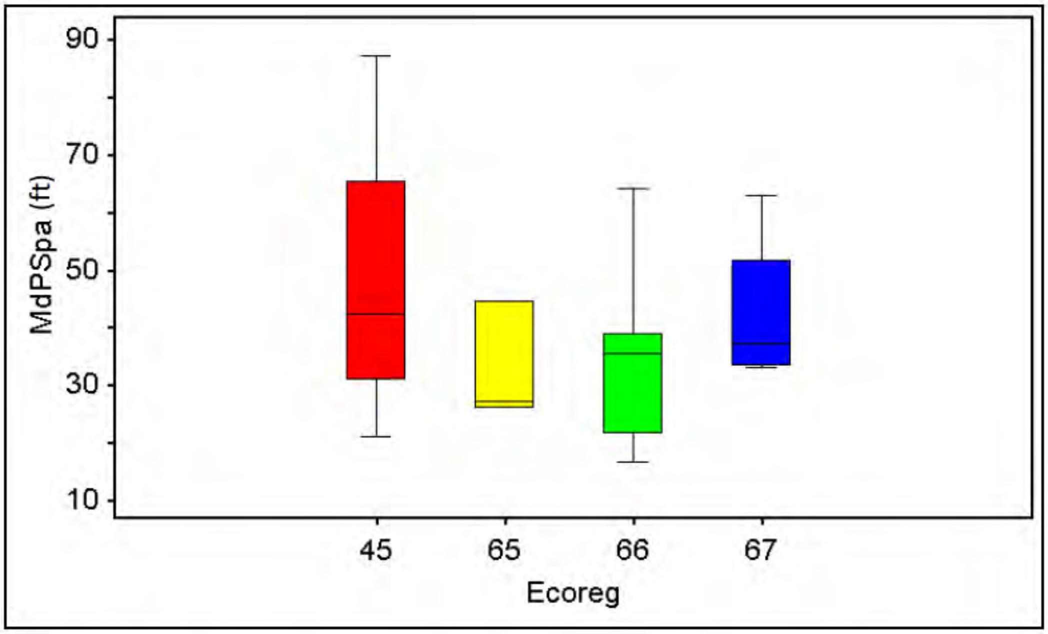


Figure A-2. Median pool-to-pool spacing per ecoregion: Piedmont (45), Blue Ridge (66), Ridge & Valley (67), Southeastern Plains (65).

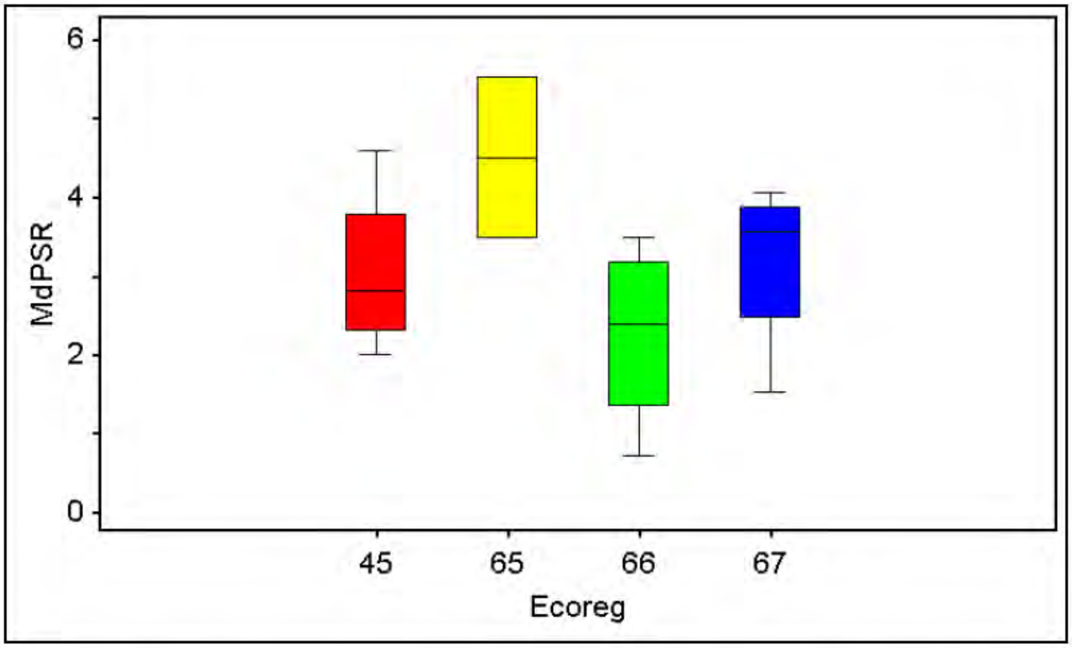


Figure A-3. Median PSR per ecoregion: Piedmont (45), Blue Ridge (66), Ridge & Valley (67), Southeastern Plains (65).

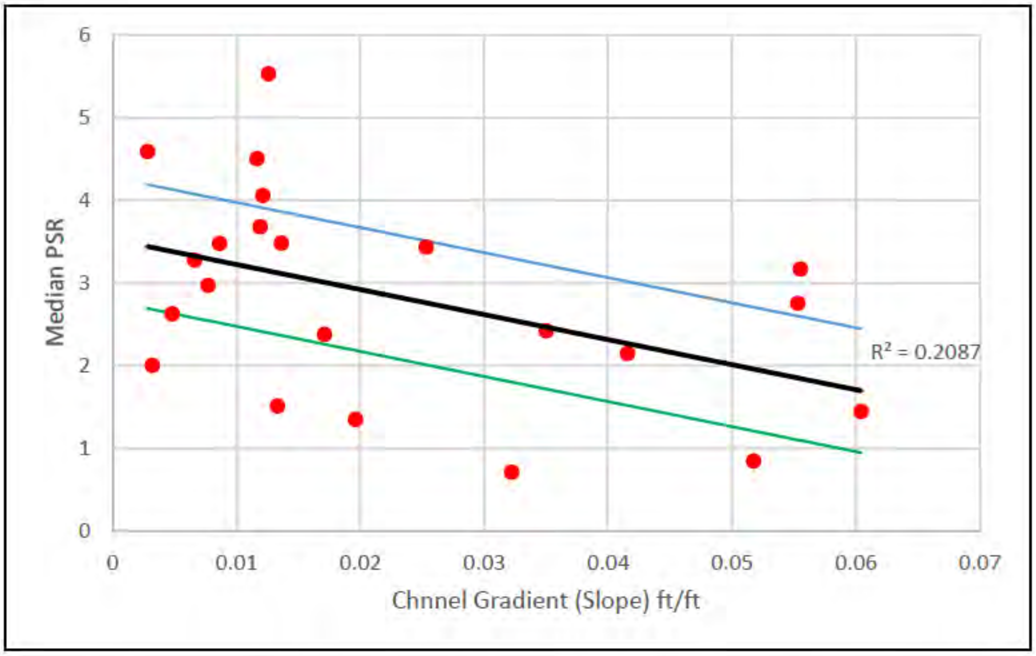


Figure A-4. Regression of median PSR with channel gradient. Blue and green lines bound the 95% confidence interval.

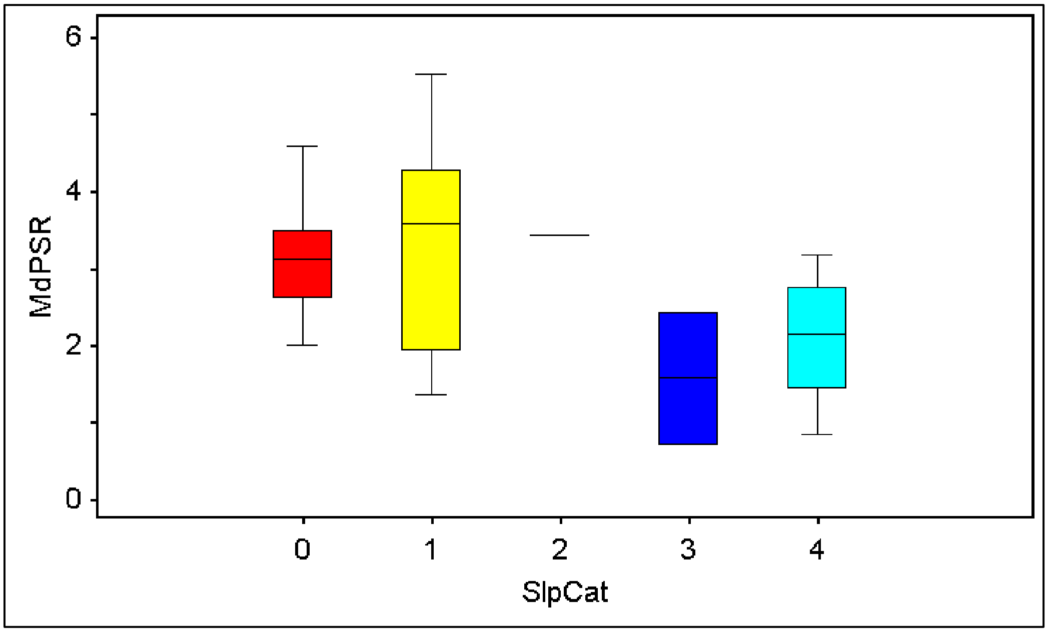


Figure A-5. Median PSR among streams grouped by various categorical channel gradient thresholds: SlpCat 0, x < 1% SlpCat 3, 3% ≥ x > 4%
SlpCat 1, 1% ≥ x > 2% SlpCat 4, x ≥ 4%
SlpCat 2, 2% ≥ x > 3%

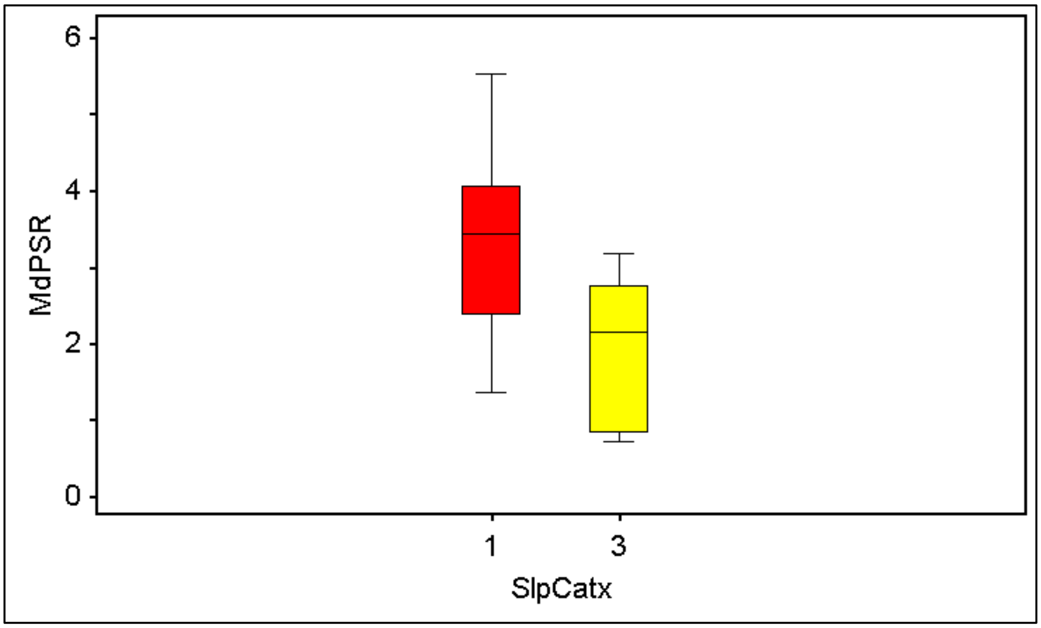


Figure A-6. Median PSR among streams grouped by a 3% channel gradient threshold:
SlpCat 1, x < 3% (n=15) SlpCat 3, x ≥ 3% (n=7).

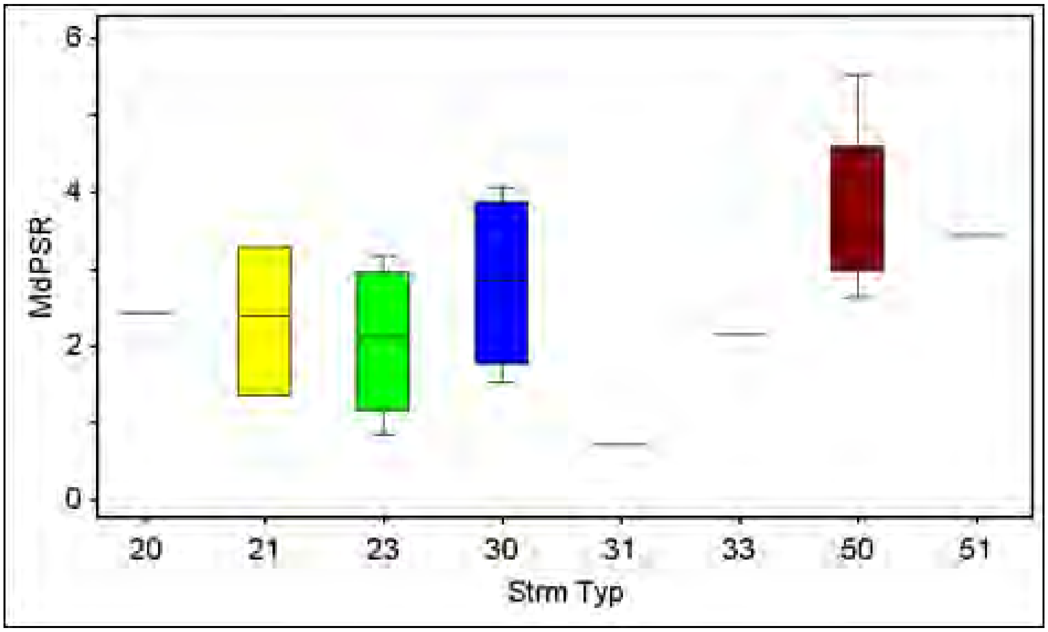


Figure A-7. Median PSR among streams grouped by Rosgen stream type:

20 – B	30 – C	50 – E
21 – Bc	31 – Cb	51 – Eb
23 – Ba	33 – Ca	

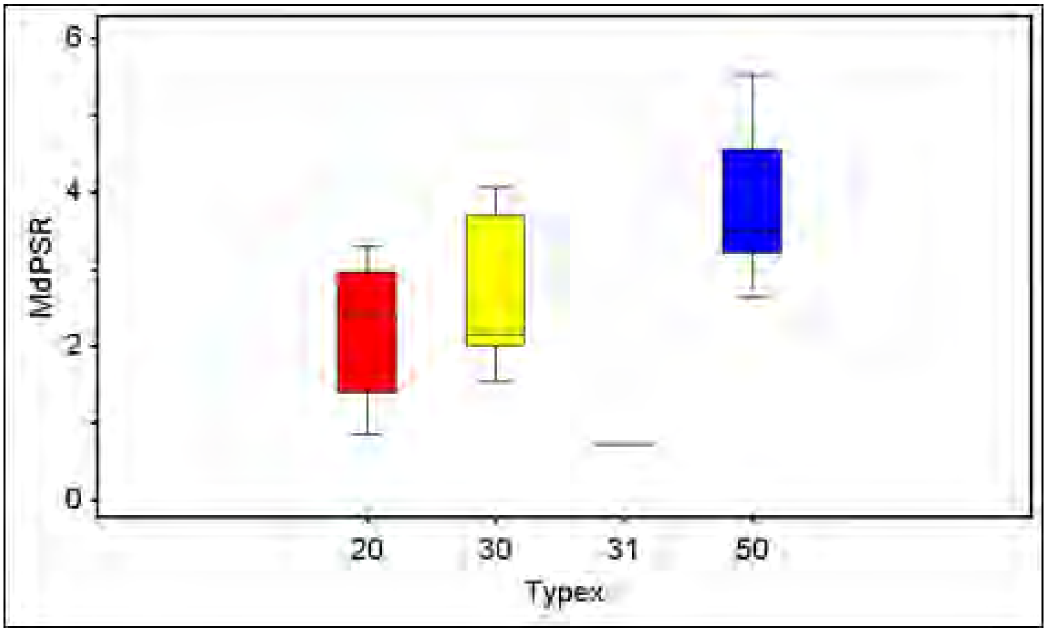


Figure A-8. Median PSR among streams grouped by consolidated Rosgen stream type: 20 – B, Bc, Ba 30 – C, Ca 50 – E, Eb 31 - Cb

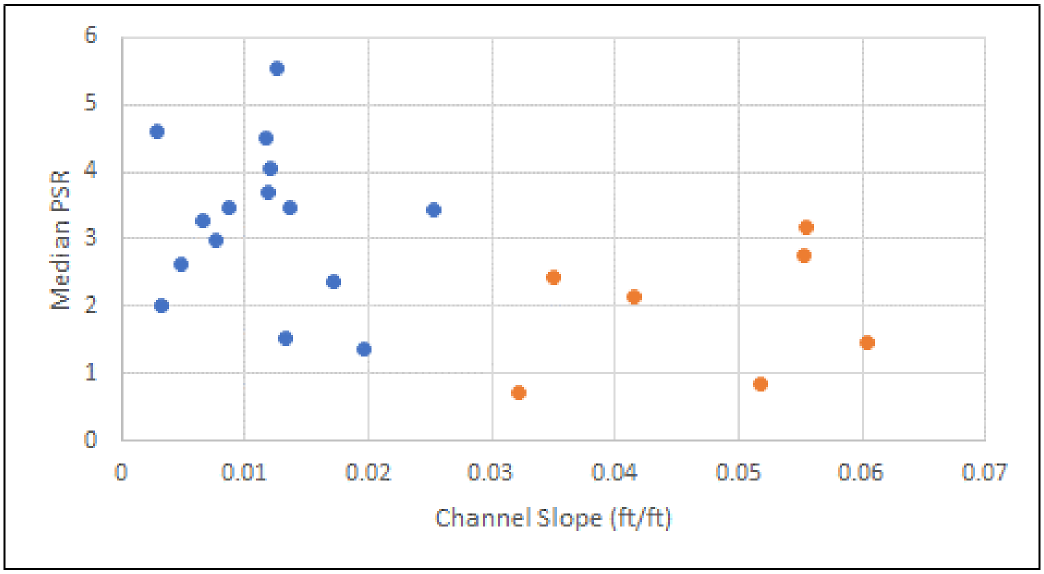


Figure A-9. Median PSR vs. channel gradient (slope) for 22 South Carolina and Tennessee reference sites, visually differentiated by a channel gradient threshold of 3%.

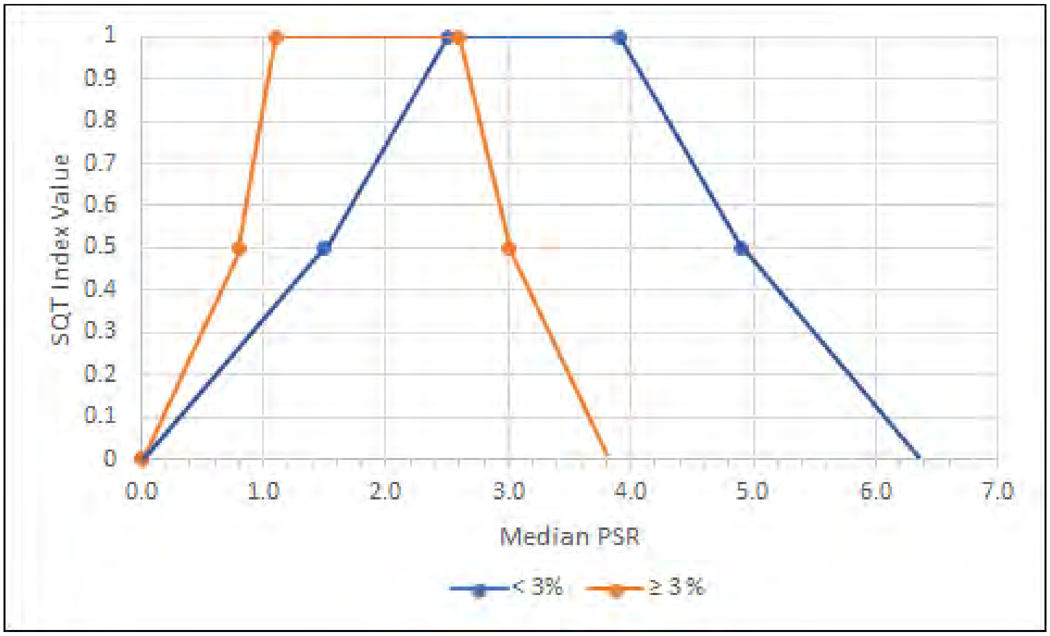
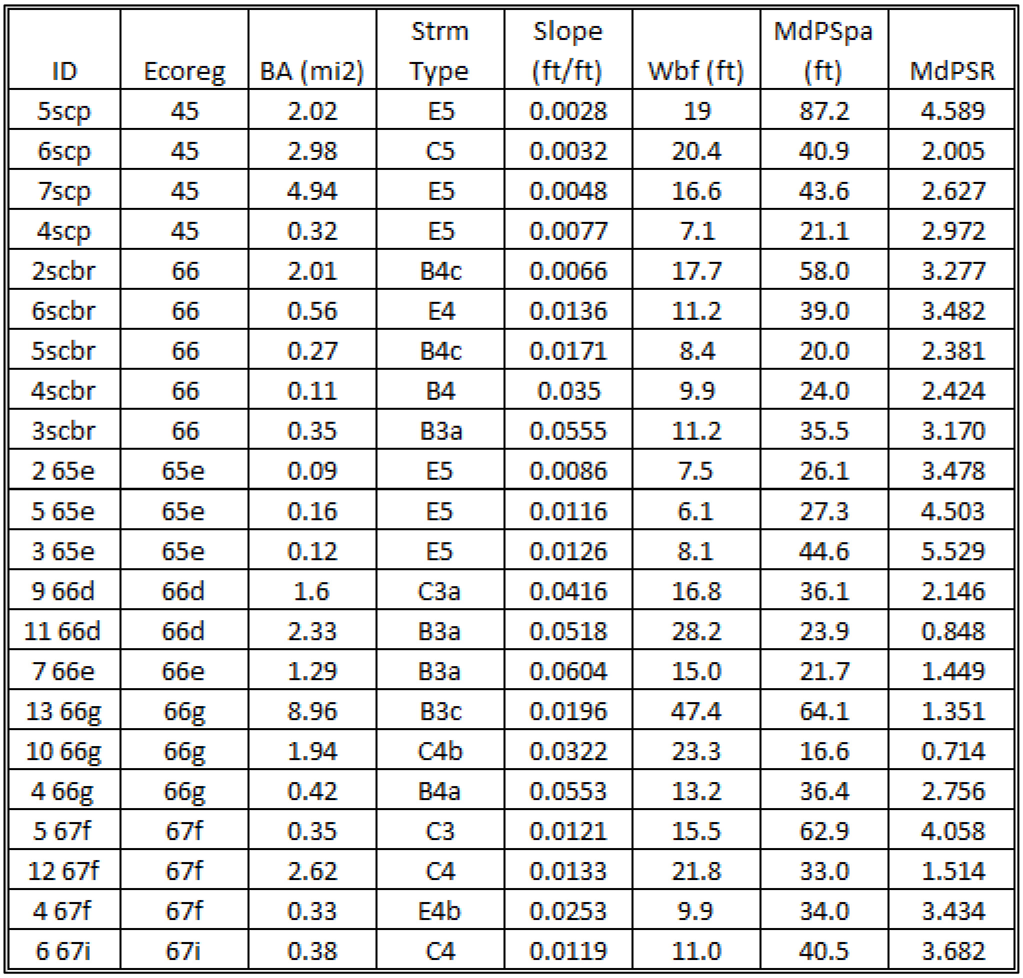


Figure A-10. PSR reference curves for the Georgia SQT.

APPENDIX A-I

Longitudinal profile reference sites in four ecoregions of South Carolina and Tennessee: Piedmont (45), Blue Ridge (66), Ridge & Valley (67), and Southeastern Plains (65)



ID	Ecoreg	BA (mi2)	Strm Type	Slope (ft/ft)	Wbf (ft)	MdPSpa (ft)	MdPSR
5scp	45	2.02	E5	0.0028	19	87.2	4.589
6scp	45	2.98	C5	0.0032	20.4	40.9	2.005
7scp	45	4.94	E5	0.0048	16.6	43.6	2.627
4scp	45	0.32	E5	0.0077	7.1	21.1	2.972
2scbr	66	2.01	B4c	0.0066	17.7	58.0	3.277
6scbr	66	0.56	E4	0.0136	11.2	39.0	3.482
5scbr	66	0.27	B4c	0.0171	8.4	20.0	2.381
4scbr	66	0.11	B4	0.035	9.9	24.0	2.424
3scbr	66	0.35	B3a	0.0555	11.2	35.5	3.170
2 65e	65e	0.09	E5	0.0086	7.5	26.1	3.478
5 65e	65e	0.16	E5	0.0116	6.1	27.3	4.503
3 65e	65e	0.12	E5	0.0126	8.1	44.6	5.529
9 66d	66d	1.6	C3a	0.0416	16.8	36.1	2.146
11 66d	66d	2.33	B3a	0.0518	28.2	23.9	0.848
7 66e	66e	1.29	B3a	0.0604	15.0	21.7	1.449
13 66g	66g	8.96	B3c	0.0196	47.4	64.1	1.351
10 66g	66g	1.94	C4b	0.0322	23.3	16.6	0.714
4 66g	66g	0.42	B4a	0.0553	13.2	36.4	2.756
5 67f	67f	0.35	C3	0.0121	15.5	62.9	4.058
12 67f	67f	2.62	C4	0.0133	21.8	33.0	1.514
4 67f	67f	0.33	E4b	0.0253	9.9	34.0	3.434
6 67i	67i	0.38	C4	0.0119	11.0	40.5	3.682

MdPSpa = median pool-to-pool spacing.
MdPSR = median pool spacing ratio.

Appendix B

Development of Percent Riffle Reference Curves for the Georgia SQT

Percent Riffle in Southeastern U.S. Streams:
Derivation of Percent Riffle Reference Curves for Georgia
(v1.1, 8/24/2020)

We assembled longitudinal channel profile data surveyed in reference stream reaches distributed across seven level III ecoregions in Alabama, South Carolina and Tennessee (Helms et al., 2013, 2016; Jennings Environmental, 2017; SCDNR, accessed 1/23/2020 and 4/6/2020). Helms et al. (2016) included these Alabama data with additional geomorphic and biological sample data from the same Alabama Piedmont streams to propose ecogeomorphological stream design and assessment tools. The Tennessee Department of Environment and Conservation developed regionalized Stream Quantification Tool (SQT) reference curves for percent riffle in 2018 using these data collected in Tennessee (TDEC, 2018).

Our primary interest for this exercise was to develop percent riffle SQT reference curves for streams in Georgia. We therefore focused on data collected from 33 streams in Alabama, South Carolina and Tennessee located in ecoregions common to Georgia: Piedmont (45), Southeastern Plains (65), Blue Ridge (66) and Ridge & Valley (67) (Table B-1). All surveyed stream reaches drained watersheds of 9.0 square miles or less. The average watershed size among these 33 sites was 1.6 square miles, and the median was 0.9 square miles. Over 95% of the sites drained 5.0 square miles or less, and over 75 percent of them drained fewer than 2.5 square miles.

We tested for outliers among all sites using the “IQR Method.” The interquartile range (IQR) of the percent riffle data across all sites represents the central 50% of the data. Upper and lower bounds (sometimes referred to as “fences”) are defined by adding 1.5 x IQR to the third quartile of the data (Q3) and subtracting 1.5 x IQR from the first quartile of the data (Q1). Any data value that lies outside of these fences (i.e. more than 1.5 x IQR above Q3 or less than 1.5 x IQR below Q1) is considered an outlier.

Q1 = 26.0%
Q3 = 46.0%
IQR = 20.0%
Upper Fence = Q3 + (1.5 x IQR) = 75.9%
Lower Fence = Q1- (1.5 x IQR) = -3.9%

None of the percent riffle values surveyed from the 33 reference stream sites fell outside these limits, thus all sites were retained for analysis.

We used scatter plots developed in Microsoft Excel and box plots from PC-Ord (v6.08) to first visualize relationships among the data. Systat (version 13.2) was used to statistically test for differences among groups, as described further below. McDonald (2014) was used to test for homoscedasticity (i.e. equal variance) of data in each group.

There is no obvious relationship between percent riffle and either watershed size, channel slope or bankfull width across all sites (Figures B-1 thru B-3, respectively), supported by the lack of Pearson correlation among these variables (Table B-2). Box plots of percent riffle suggest potential differentiation among streams grouped by ecoregion (Figure B-4), with the IQR of percent riffle from streams in the Southeastern Plains (65) lying generally lower than the IQR of percent riffle from streams in the Piedmont (45) and Ridge & Valley (67), and less than the median percent riffle in the Blue Ridge (66). However, a one-way ANOVA performed in Systat v.13.2, following a Shapiro-Wilk test for normality (test statistic = 0.951; p= 0.144) and Bartlett's test for homoscedasticity (p= 0.405), failed to reject the null hypothesis that the mean percent riffle in each of the four ecoregions is the same. Thus, the mean value for percent riffle in each group was homogeneous (one-way anova, $F_{3, 29}$ = 1.3, P= 0.293). We also used the non-parametric Kruskal-Wallis test to evaluate whether the percent riffle values in each of the four groups comes from the same cumulative distribution. It too failed to reject the null hypothesis (p= 0.241), thus indicating no significant difference in the cumulative distribution of the data.

Nonetheless, Figure B-4 illustrates clearly that the distribution of data within each ecoregion varies, and because SQT reference curves are based on these distributions (i.e., percentiles of the distributions), we wished to explore these differences further. We suspected that the lower percent riffle of streams in the Southeastern Plains (65) may be attributable to channel slope, which would be expected to generally be lower in the Southeastern Plains than the other ecoregions. However, the channel slope for streams surveyed in the Southeastern Plains (65) is not in fact appreciably lower than streams surveyed in either the Piedmont (45) or the Ridge & Valley (67) (Figure B-5). Bartlett's test on channel slope grouped by ecoregion indicates that the data are strongly heteroscedastic (p< 0.0001). Consequently, neither one-way ANOVA nor Kruskal-Wallis tests on channel slope per ecoregion data is a suitable test. Instead, we used Welch's ANOVA with a Games-Howell test to identify which pairs of groups, if any, have different means (McDonald, 2014). The result of these tests indicates that the mean channel slope does in fact differ among ecoregions (Welch's ANOVA, $F_{3, 6.9}$ = 10.59, P= 0.006). However, only streams surveyed in the Blue Ridge (66) differ from those in any other ecoregion (Table B-3).

Closer inspection of the raw data shows that six of the eight streams surveyed in the Blue Ridge (66) have a channel slope greater than three percent. We then divided all 33 streams into two *a priori* groups based on three percent channel slope to test the influence of this channel gradient threshold on percent riffle. Figure B-6 suggests fair discriminatory power of this three percent channel slope threshold, and Bartlett's test indicated no heteroscedasticity between these two groups (p= 0.917). However, a two-sample t-test performed in Systat v.13.2 following a Shapiro-Wilk test for normality (test statistic = 0.939; p= 0.118) failed to reject the null hypothesis that the mean percent riffle of the two groups is the same (95% confidence level, t= 1.204, df= 7.2, p= 0.267).

We further explored the discriminatory efficiency of various *a priori* groups first using two percent channel slope as a threshold value and then groups based on ecoregion, with the Southeastern Plains (65) in its own group and all other ecoregions in a second group (Figures B-7 and B-8, respectively). While the two percent channel slope threshold provided no greater discriminatory efficiency than the three percent channel slope threshold illustrated in Figure B-5, separating streams located in the Southeastern Plains (65) is not only an intuitively logical distinction due to differences in geology, substrate, etc., but also provides for robust differentiation of the percent riffle values in each group for generation of SQT reference curves (Figure B-8).

Derivation of Percent Riffle SQT Reference Curve Subindex Values

We recognize that there is reference percent riffle data from only three streams in the Southeastern Plains (65). While this is an unfortunately few number of sites upon which to base performance standards for stream mitigation projects in this ecoregion, we believe it would be even more unjustifiable to aggregate all of the data and thereby hold stream mitigation projects undertaken in the Southeastern Plains (65) to an implausible standard based on the other three ecoregions in our dataset. Consequently, the percent riffle SQT reference curve for the Southeastern Plains utilizes the complete range of values (minimum to maximum) to define a fully functioning subindex score of 1.0. We assigned a zero (0.0) subindex score to five percent riffle in this ecoregion and used the resulting slope of the rising limb of the reference curve to construct the falling limb (Figure B-9).

By comparison, the majority of the percent riffle reference curve for the Piedmont (45), Blue Ridge (66) and Ridge & Valley (67) is based squarely on the data distribution within that group. Percent riffle values between the median and 75th percentile of the reference data were selected to represent the range for fully functioning (subindex value of 1.0). The 25th percentile of the reference data represents the threshold value between fully functioning and functioning-at-risk (subindex value 0.7) for the rising limb, and the 95th percentile represents the same threshold and subindex value on the falling limb. The 5th percentile of the data is equivalent to a subindex value of 0.3, and we extended the rising limb from this value to intercept the x-axis at 12% riffle (0.12, 0). The same reference curve slope from 0.0 to 0.7 on the rising limb was used to construct the falling limb of the curve from 0.7 to 0.0, thus intercepting the x-axis at 75% riffle on the falling limb (Figure B-9). All applicable percent riffle SQT index values used to develop the reference curves are provided in Table B-4.

References

Helms, B., J. Zink, D. Werneke, T. Hess, Z. Price, G. Jennings and E. Brantley. 2016. Development of ecogeomorphological (EGM) stream design and assessment tools for the Piedmont of Alabama, USA. Water 8, 161, doi:10.3390/w8040161.

Helms et al. 2013. "Eco-morphological stream design and assessment tools for the Alabama Piedmont," Final Wetland Program Development Grant Report submitted to EPA Region 4, December 2013. Atlanta, GA.

Jennings Environmental, Inc. 2017. Tennessee Reference Stream Morphology and Large Woody Debris Assessment: Report and Guidebook. Prepared for the Tennessee Department of Environment and Conservation, December 2017. https://www.tn.gov/content/dam/tn/environment/water/natural-resources-unit/wr_nru_tennessee-ref-stream-morphology.pdf

McDonald, J.H. 2014. Handbook of Biological Statistics (3rd ed.). Sparky House Publishing, Baltimore, Maryland. http://www.biostathandbook.com/index.html

South Carolina Department of Natural Resources, Accessed January 23, 2020 and April 6, 2020. http://www.dnr.sc.gov/environmental/streamrestoration.html

TABLES

Table B-1. Ecoregional distribution of streams utilized for development of percent riffle reference curves in Georgia.

Ecoregion	# Sites
Piedmont (45)	18
Blue Ridge (66)	8
Ridge & Valley (67)	4
Southeastern Plains (65)	3
∑	33

Table B-2. Pearson correlation of percent riffle with basin area (watershed size), channel slope and bankfull width in reference streams located in four ecoregions of Alabama, South Carolina and Tennessee: Piedmont (45), Southeastern Plains (65), Blue Ridge (66), Ridge & Valley (67).

All sites				n=33
	BA (mi2)	*Ch Slope*	*Wbf (ft)*	*PercRiff*
BA (mi2)	1			
Ch Slope	-0.11	1		
Wbf (ft)	0.88	-0.03	1	
PercRiff	0.15	-0.12	0.07	1

Table B-3. Statistical difference of mean channel slope surveyed from streams located in four ecoregions of Alabama, South Carolina and Tennessee: Piedmont (45), Southeastern Plains (65), Blue Ridge (66), Ridge & Valley (67).

	Piedmont (45) mn= 0.0065	SE Plains (65) mn= 0.0109	Blue Ridge (66) mn= 0.0404	Ridge & Val (67) mn= 0.0157
Piedmont (45)	│			
SE Plains (65)	│	│		
Blue Ridge (66)	0	0	│	
Ridge & Val (67)	│	│	0	│

│ = No difference.
0 = Significant difference.

Table B-4. Percent riffle and corresponding SQT index values used to develop the Georgia SQT percent riffle reference curves. Italicized values are interpolated.

SQT Index Value	Percent Riffle	
	Eco 65	Eco 45, 66 & 67
0	*0.05*	*0.12*
0.3	- -	0.18
0.7	- -	0.26
1.0	0.19	0.36
1.0	0.27	0.51
0.7	- -	0.61
0	*0.41*	*0.75*

FIGURES

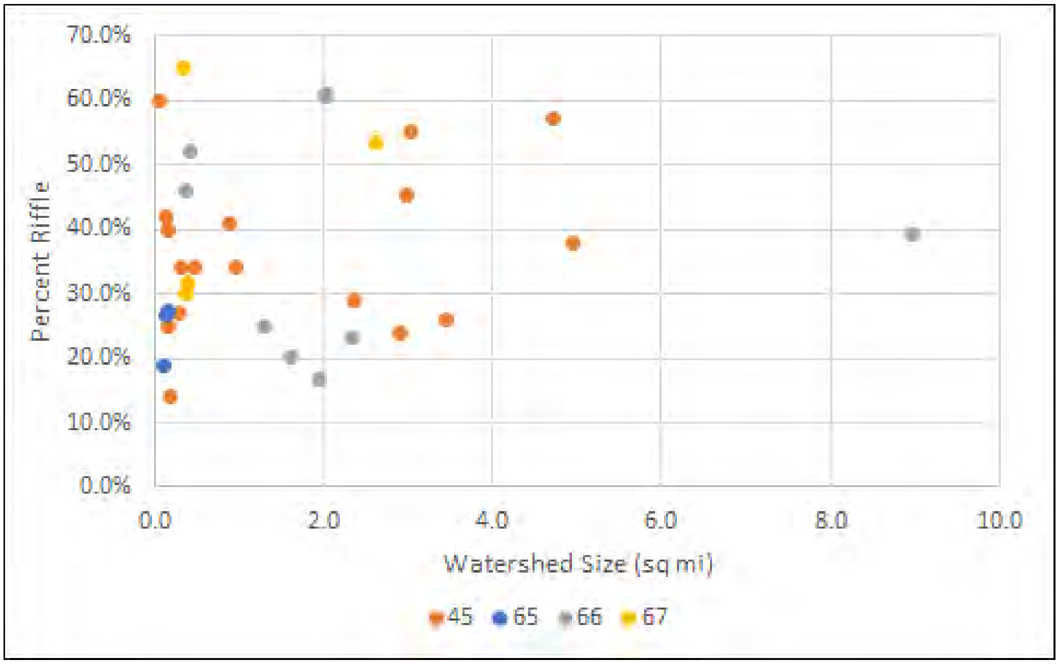


Figure B-1. Scatter plot of percent riffle to watershed size across selected ecoregions in Alabama, South Carolina and Tennessee: Piedmont (45), Southeastern Plains (65), Blue Ridge (66) and Ridge & Valley (67).

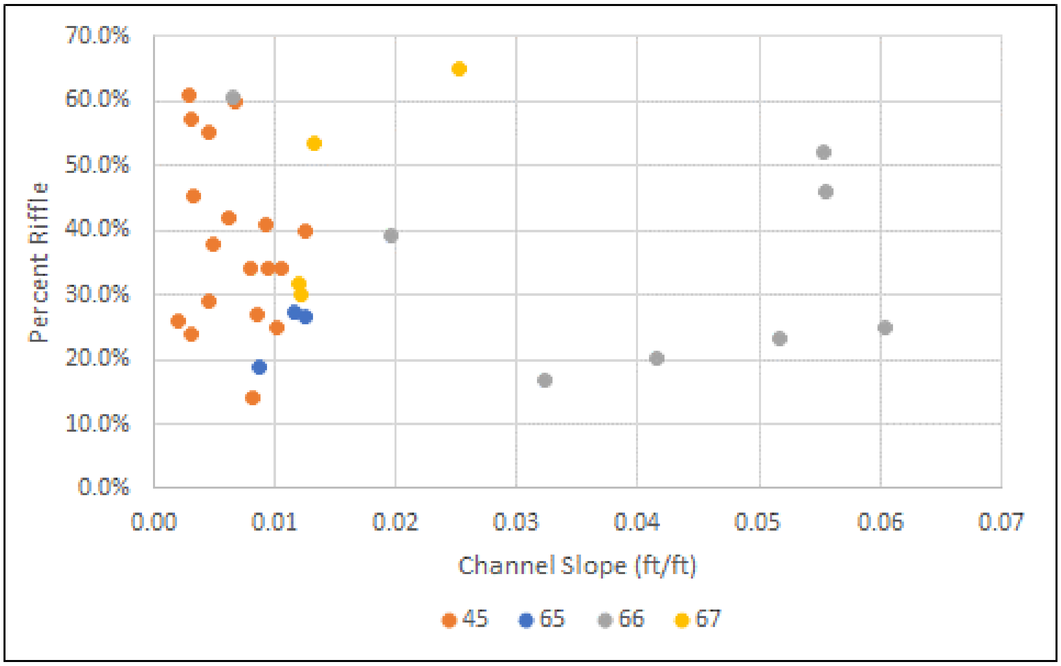


Figure B-2. Scatter plot of percent riffle to channel slope across selected ecoregions in Alabama, South Carolina and Tennessee: Piedmont (45), Southeastern Plains (65), Blue Ridge (66) and Ridge & Valley (67).

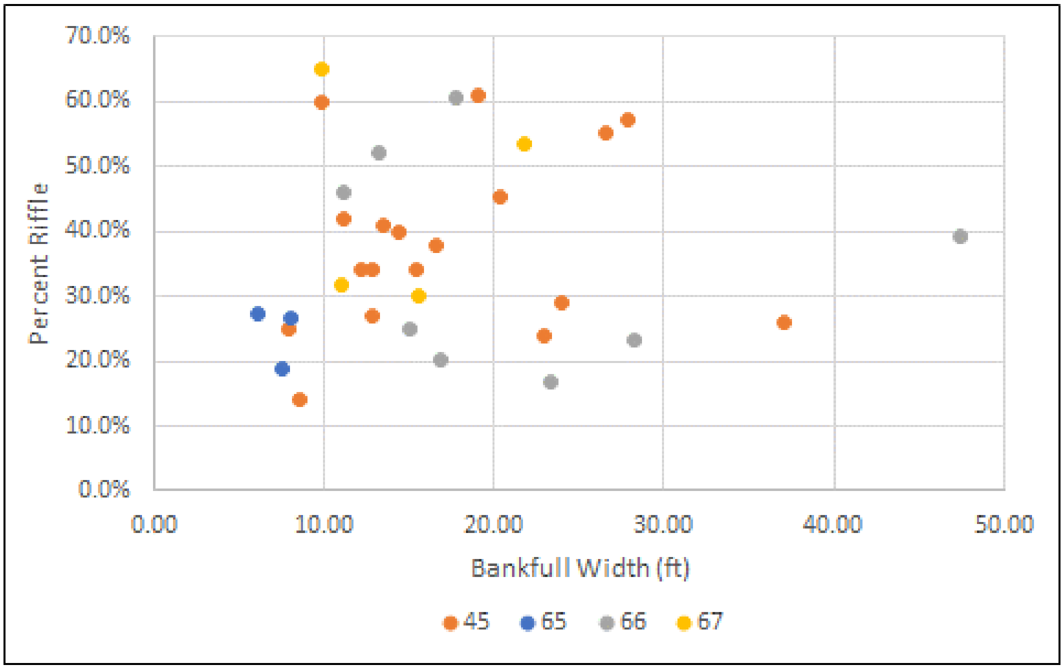


Figure B-3. Scatter plot of percent riffle to bankfull width across selected ecoregions in Alabama, South Carolina and Tennessee: Piedmont (45), Southeastern Plains (65), Blue Ridge (66) and Ridge & Valley (67).

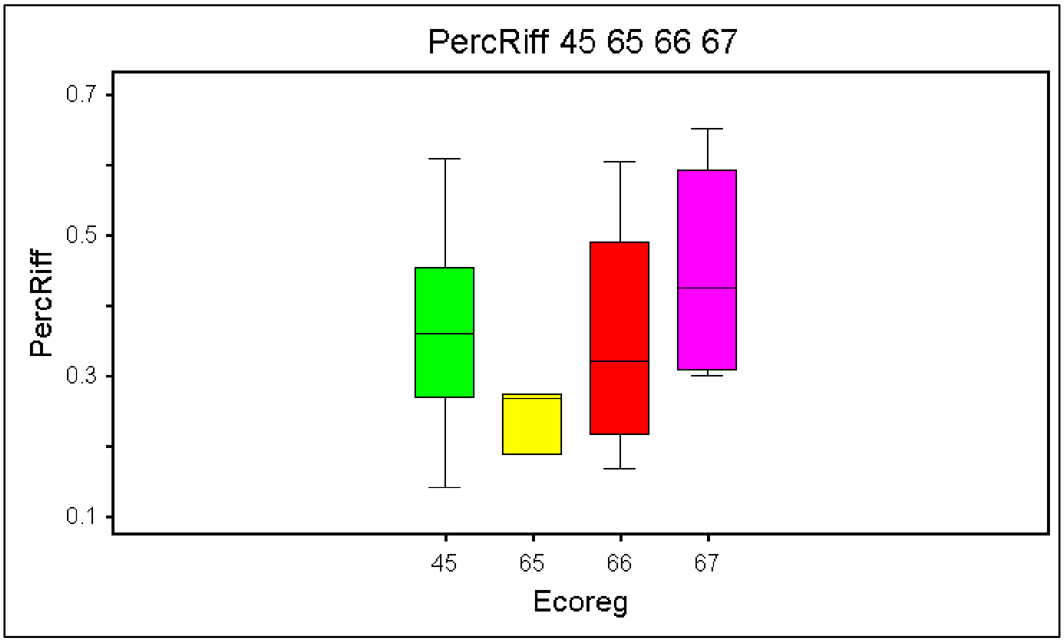


Figure B-4. Percent riffle of reference streams in the Piedmont (45), Southeastern Plains (65), Blue Ridge (66) and Ridge & Valley (67) ecoregions in Alabama, South Carolina and Tennessee [n=33].

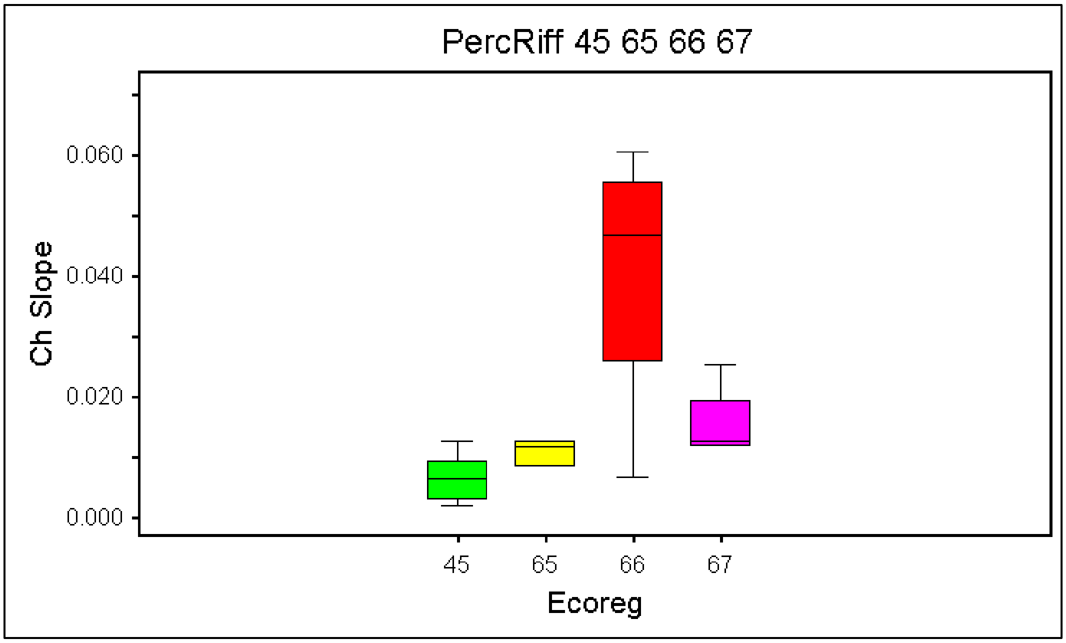


Figure B-5. Channel slope of reference streams in the Piedmont (45), Southeastern Plains (65), Blue Ridge (66) and Ridge & Valley (67) ecoregions in Alabama, South Carolina and Tennessee [n=33].

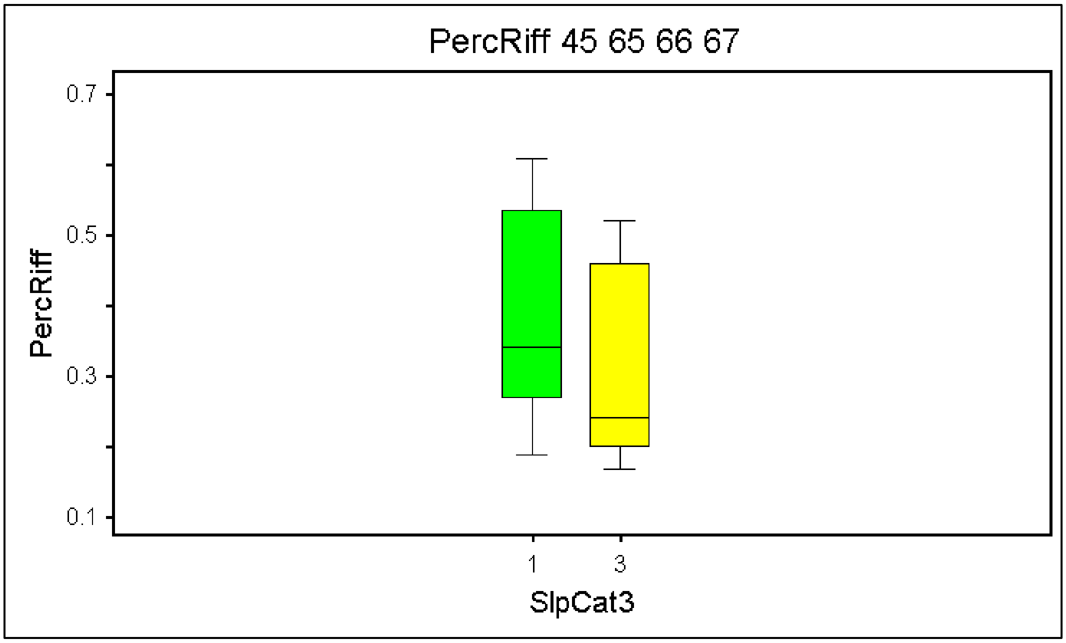


Figure B-6. Percent riffle of reference streams in the Piedmont (45), Southeastern Plains (65), Blue Ridge (66) and Ridge & Valley (67) in Alabama, South Carolina and Tennessee grouped by channel slope: Group 1 < 3%; n= 27; Group 3 ≥ 3%, n= 6.

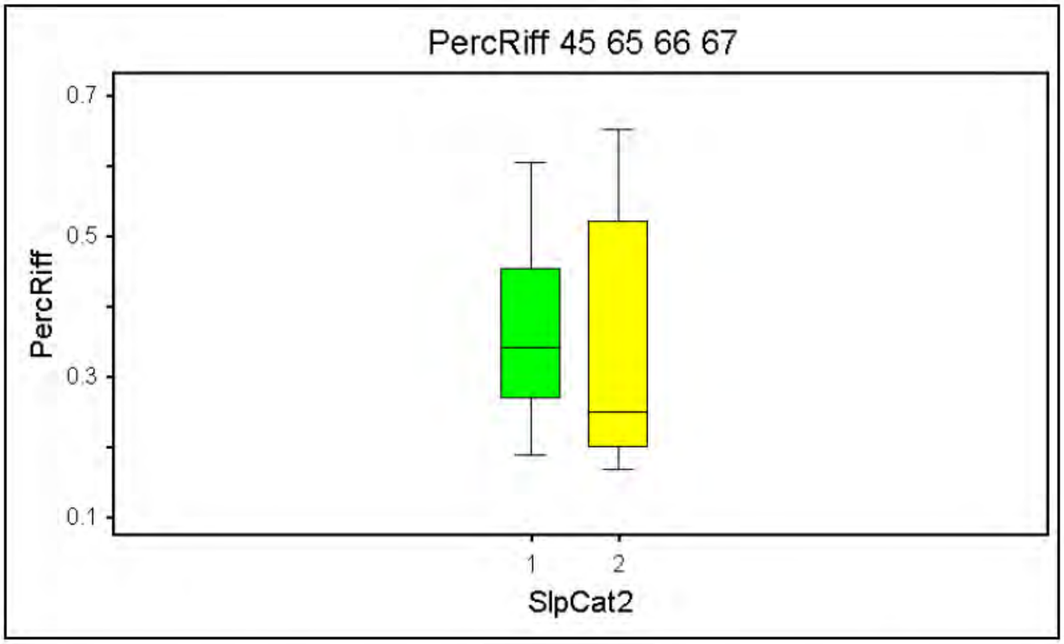


Figure B-7. Percent riffle of reference streams in the Piedmont (45), Southeastern Plains (65), Blue Ridge (66) and Ridge & Valley (67) in Alabama, South Carolina and Tennessee grouped by channel slope: Group 1 < 2%; n= 26; Group 2 ≥ 2%, n= 7.

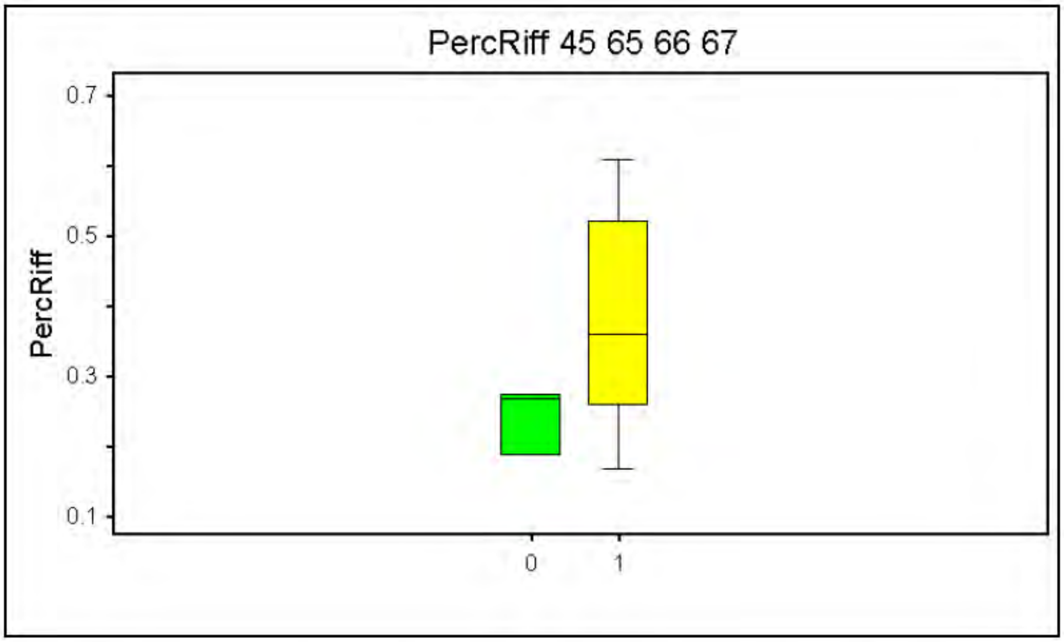


Figure B-8. Percent riffle of reference streams in Alabama, South Carolina and Tennessee grouped by ecoregion: Group 0 = Southeastern Plains (65); n= 3; Group 1= Piedmont (45), Blue Ridge (66) and Ridge & Valley (67); n= 30.

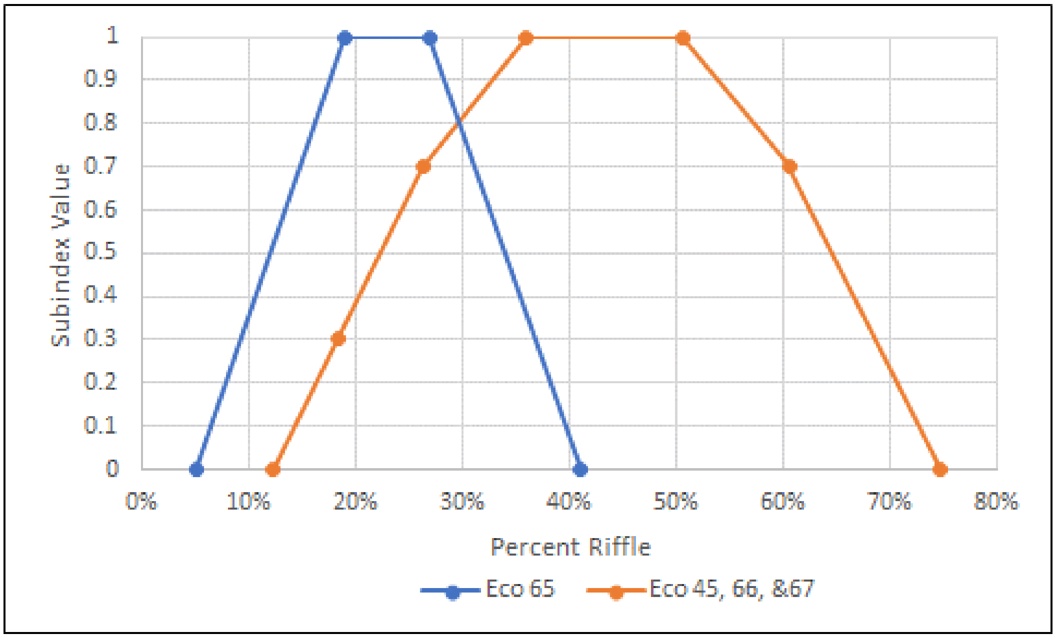


Figure B-9. Percent riffle SQT reference curves for Georgia.

Appendix C

Development of Large Woody Debris Index Reference Curves for the Georgia SQT

Large Woody Debris in Southeastern U.S. Streams:
Derivation of Large Woody Debris Index Reference Curves for Georgia
(v2.1, 6/3/2020)

Large woody debris was measured in reference streams distributed across eight ecoregions in South Carolina and Tennessee during efforts to regionalize the Stream Quantification Tool (SQT) in those states (Jennings Environmental, 2017; SCDNR, accessed 1/23/2020 and 4/6/2020). All data were converted to large woody debris index (LWDI) values following methods described in Harman et al. (2017) based on a protocol originally presented by Davis et al. (2001).

Our primary interest for this exercise was on LWDI values collected from streams located in ecoregions common to Georgia. We therefore restricted our assessment to streams in the Piedmont (45), Southeastern Plains (65), Blue Ridge (66) and Ridge & Valley (67). We compiled data collected from 80 streams draining watersheds less than 100 square miles in the above-named ecoregions of South Carolina and Tennessee.

Two sites in the South Carolina Blue Ridge were discovered to have had large woody debris manipulated by the U.S. Forest Service (J.Whalen email to L.Riggins, 1/15/2020), so these two sites were removed from further analysis. We tested for LWDI outliers among all remaining sites using the “IQR Method.” The interquartile range (IQR) of the data represents the central 50% of the data. Upper and lower bounds (sometimes referred to as “fences”) are defined by adding 1.5 times the IQR to the third quartile of the data (Q3) and subtracting 1.5 times the IQR from the first quartile of the data (Q1). Any data value that lies outside of these fences (i.e. more than 1.5 IQR above Q3 or less than 1.5 IQR below Q1) is considered an outlier.

Q1 = 133
Q3 = 273
IQR = 140
Upper Fence = Q3 + (1.5 x IQR) = 483
Lower Fence = Q1- (1.5 x IQR) = -78

Three Tennessee sites in the Blue Ridge and one in the Ridge & Valley were found to be outliers and removed from further analysis. One South Carolina site in the Southeastern Plains was also removed as an outlier. Data from the remaining 73 sites were retained for analysis (Appendix C-I). These sites drained watersheds ranging in size from 0.04 to 94.7 square miles. However, 75% of the sites drained fewer than 11 square miles and approximately one-half of them drained less than 1.5 square miles.

We used scatter plots developed in Microsoft Excel and box plots from PC-Ord (v6.08) to first visualize relationships among the data. Templates developed by McDonald

(2014) were used to test for statistical differences among various categorical groupings described below. One-way ANOVA was used if Bartlett's test for homoscedasticity within groups was satisfied, and Welch's ANOVA was used if it was not. The Tukey-Kramer test identified significance at the $p<0.05$ level for variance of means between pairs of groups in the one-way ANOVA, and the Games-Howell test performed the same function in Welch's ANOVA.

There is no obvious relationship between LWDI and basin area, channel gradient or bankfull width across all sites in all four ecoregions (Figures C-1 thru C-3, respectively), supported by the lack of Pearson correlation among these variables either as a whole (Table C-1 (a)) or per ecoregion (Table C-1 (b)-(e)). Box plots of LWDI suggest potential differentiation among streams grouped by ecoregion, with the LWDI IQR in Piedmont and Ridge & Valley streams lying generally lower than those in the Southeastern Plains and Blue Ridge (Figure C-4). A single-factor ANOVA with Tukey-Kramer confirms that both the Southeastern Plains and the Blue Ridge are significantly different from the Ridge & Valley, however the Piedmont differs from none of the other three ecoregions ($F_{3,\,69}$= 4.18, P= 0.009).

Figure C-2 suggests a clustering of LWDI values in streams with a channel gradient greater than approximately 3 percent. Previous exploratory analysis of the data revealed that all but one of the streams in our data set above that threshold channel gradient lie in a single ecoregion; the Blue Ridge. We consequently explored the utility of separating the Blue Ridge streams into two groups based on a channel gradient threshold of 3% (Figure C-5). A one-way ANOVA with Tukey-Kramer confirmed that both the Piedmont and the Ridge & Valley are significantly different from Blue Ridge streams ≥ 3% ($F_{4,\,68}$= 4.066, P= 0.005). However, despite that the respective IQR's for the two groups of Blue Ridge streams suggest good discriminatory efficiency between them (Figure C-5), they are not statistically significantly different from one another.

Nonetheless, we combined streams from the Piedmont and Ridge & Valley with streams < 3% slope from the Blue Ridge into a single group, leaving a second group composed of streams in the Southeastern Plains and streams from the Blue Ridge ≥ 3% slope (Figure C-6). Not only do the LWDI IQR's of the two groups suggest good discriminatory power, they are also statistically different ($F_{1,\,71}$= 14.14, P< 0.005). While it is true that soils, vegetative species (but not necessarily structure) and physical stream conditions are generally quite different in the ecoregions comprising the latter group, the reference LWDI data collected in the Southeastern Plains and in streams with a channel gradient ≥ 3% in South Carolina and Tennessee are very similar.

Derivation of LWDI Subindex Values

Federal regulations define *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 (33 CFR 332.2; 40 CFR 230.92). However, as previously noted, all the data used for this analysis were collected from geomorphologically stable streams in South Carolina and Tennessee judged *a priori* to be “high quality”, minimally disturbed streams based on physical habitat, riparian zone conditions and geomorphic conditions. Consequently, we do not have LWDI data spanning the entire reference stream condition gradient from poor to good.

The Wyoming Stream Technical Team (WSTT) faced a similar conundrum during regionalization of the SQT where they had LWDI data from only 22 minimally disturbed reference streams (WSTT, 2018). The WSTT selected the median of the reference dataset to demarcate the maximum LWDI index score and the 25th percentile of the data was used to define the threshold between functioning and functioning-at-risk SQT index values (WSTT, 2018). Thus, sites with the highest 75% of the reference LWDI represent the Functioning category defined by an index value ≥ 0.7, while sites with the lowest 25% of the reference LWDI data comprise primarily the Functioning-At-Risk category $0.3 < x < 0.7$.

The Georgia SQT has also adopted this approach and developed two LWDI reference curves for Georgia utilizing data from all 73 reference streams partitioned into the two groups illustrated in Figure C-6. We developed the LWDI reference curves for the Georgia SQT to be approximately parabolic in shape, in recognition that too much LWD may be indicative of channel instability and adjustment. Numerous stream and channel evolution models include phases of active channel degradation and/or widening (e.g. Stage IV in Schumm et al. (1984) and Simon and Hupp (1987); Stages 3 & 4 in Cluer and Thorne (2013)). This kind of rapid channel morphological adjustment often causes trees and shrubs growing on channel banks to fall into the channel as the banks retreat, potentially leading to an overabundance of large woody debris in the stream. We recognize that periodic natural disturbances may likewise lead to an abundance of woody debris in southeastern streams (e.g. insect infestation, hurricane, tornado, drought, fire, etc.). These pulses of wood added to streams should not automatically be considered detrimental or cause for mitigation. However, excessive wood contributions to stream channels and riparian zones already disturbed or denuded during major restoration efforts may adversely affect stream hydraulics and lead to excessive stresses on already susceptible channel banks.

LWDI values between the median and 95th percentile of the reference data for each respective group of streams were selected to represent the range for a maximum LWDI index value of 1.0. The 25th percentile of the reference data was selected to represent the threshold value between Functioning and Functioning-At-Risk (index value 0.7) for the rising limb of both reference curves. We extended the rising limb of both curves from an index value of 0.7 to intercept the x-axis at (0,0) and used the resulting slope from each rising limb to form the respective falling limb of each curve between index values

1.0 and 0.0 to form the back side of the parabola (Figure C-7). Applicable LWDI SQT index values for each reference curve are provided in Table C-3.

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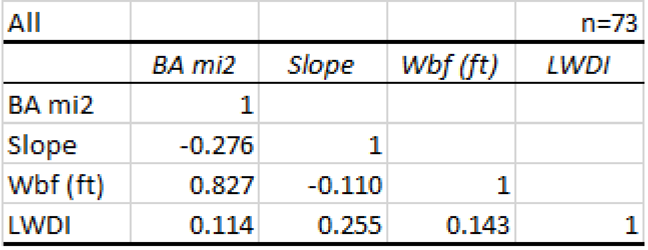
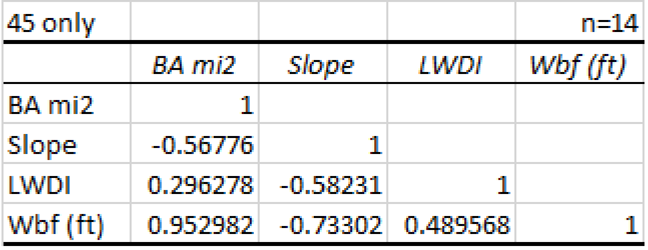
TABLES

Table C-1. Correlation among basin area, channel gradient (slope), bankfull width and large woody debris index (LWDI) for reference streams in four ecoregions of South Carolina and Tennessee: Piedmont (45), Blue Ridge (66), Ridge & Valley (67) and Southeastern Plains (65).



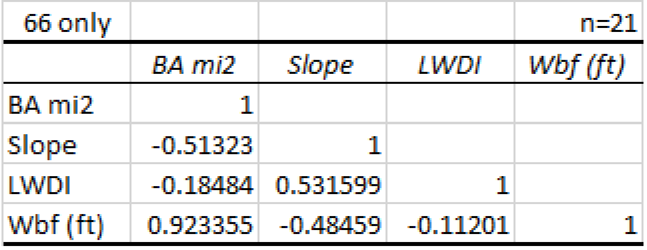
All				n=73
	BA mi2	*Slope*	*Wbf (ft)*	*LWDI*
BA mi2	1			
Slope	-0.276	1		
Wbf (ft)	0.827	-0.110	1	
LWDI	0.114	0.255	0.143	1

a)



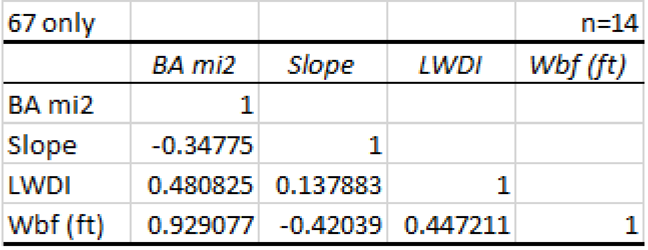
45 only				n=14
	BA mi2	*Slope*	*LWDI*	*Wbf (ft)*
BA mi2	1			
Slope	-0.56776	1		
LWDI	0.296278	-0.58231	1	
Wbf (ft)	0.952982	-0.73302	0.489568	1

b)



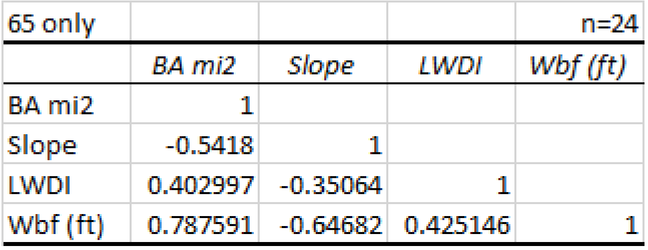
66 only				n=21
	BA mi2	*Slope*	*LWDI*	*Wbf (ft)*
BA mi2	1			
Slope	-0.51323	1		
LWDI	-0.18484	0.531599	1	
Wbf (ft)	0.923355	-0.48459	-0.11201	1

c)



67 only				n=14
	BA mi2	*Slope*	*LWDI*	*Wbf (ft)*
BA mi2	1			
Slope	-0.34775	1		
LWDI	0.480825	0.137883	1	
Wbf (ft)	0.929077	-0.42039	0.447211	1

d)



65 only				n=24
	BA mi2	*Slope*	*LWDI*	*Wbf (ft)*
BA mi2	1			
Slope	-0.5418	1		
LWDI	0.402997	-0.35064	1	
Wbf (ft)	0.787591	-0.64682	0.425146	1

e)

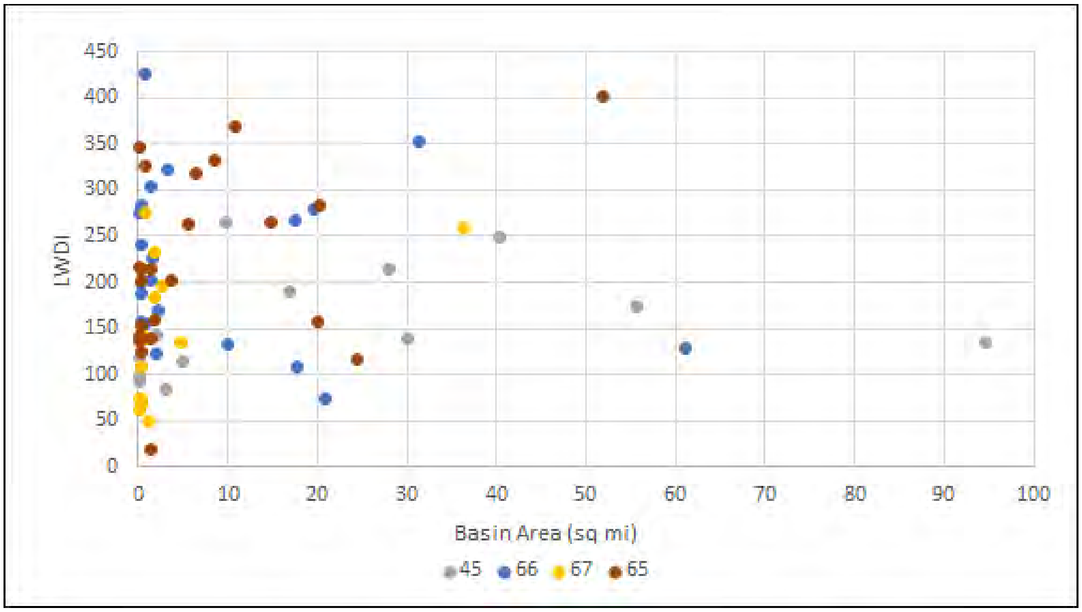
Table C-2. Summary of streams utilized for development of large woody debris index (LWDI) reference curves.

Ecoregion	# Sites
Piedmont (45)	14
Blue Ridge (66)	21
Ridge & Valley (67)	14
Southeastern Plains (65)	24
∑	73

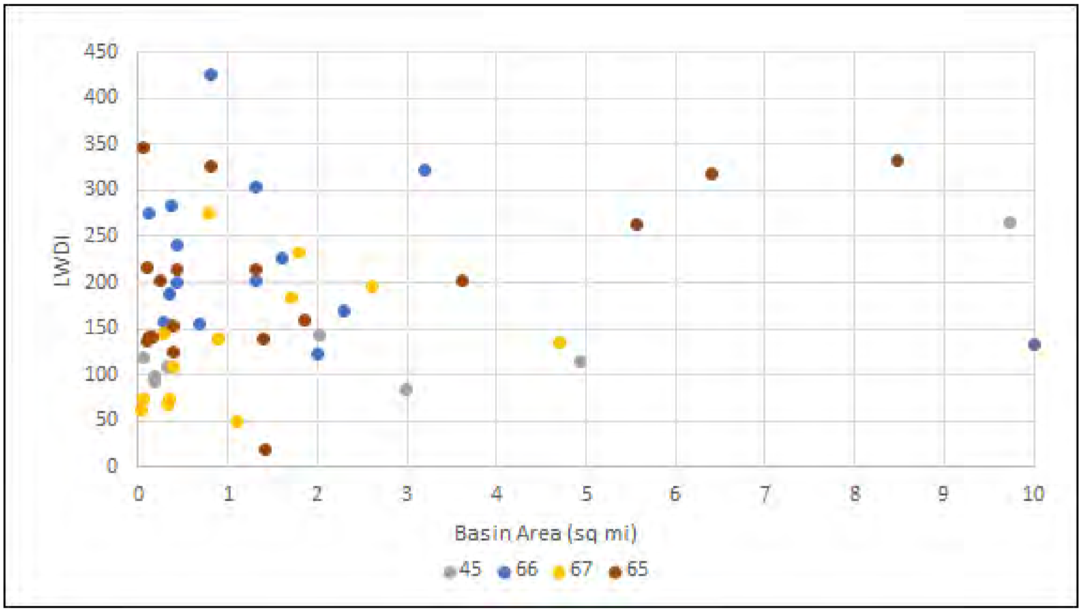
Table C-3. Large woody debris index (LWDI) values and corresponding SQT index values used to develop the Georgia SQT LWDI reference curves.

SQT Index Value	LWDI	
	Ecoregions 45, 67 & (66 < 3%)	Ecoregions 65 & (66 ≥ 3%)
0	0	0
0.3		
0.7	109	156
1.0	138	216
1.0	269	378
0.7		
0	407	593

FIGURES



a)



b)

Figure C-1. Scatter plot of large woody debris index (LWDI) to basin area across selected ecoregions in South Carolina and Tennessee: Piedmont (45), Blue Ridge (66), Ridge & Valley (67) and Southeastern Plains (65).

a) includes all 73 reference sites,

b) includes only sites draining watersheds ≤ 10.0 square miles.

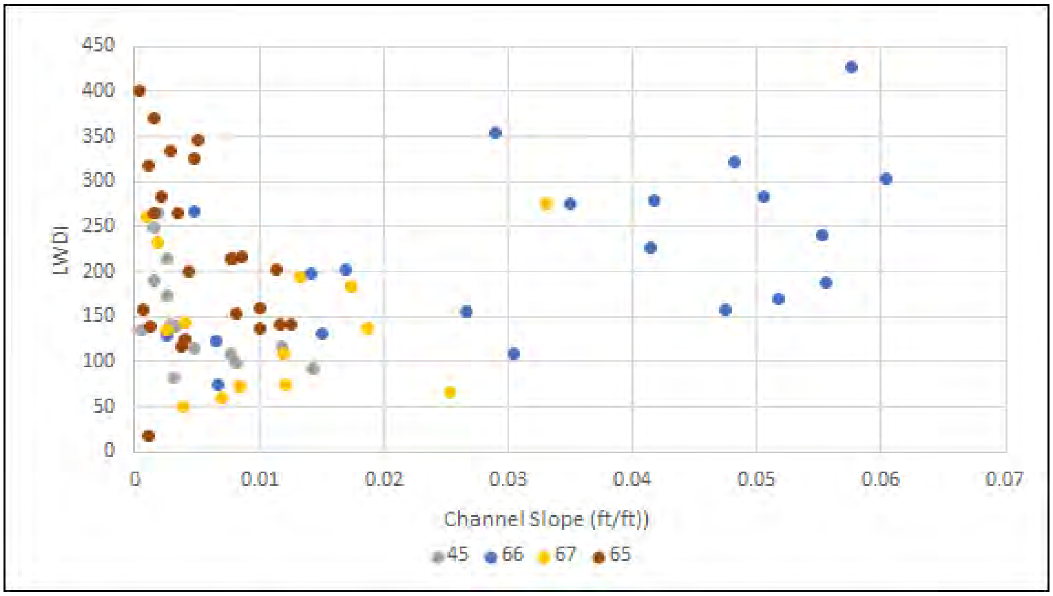


Figure C-2. Scatter plot of large woody debris index (LWDI) to channel gradient across selected ecoregions in South Carolina and Tennessee: Piedmont (45), Blue Ridge (66), Ridge & Valley (67) and Southeastern Plains (65).

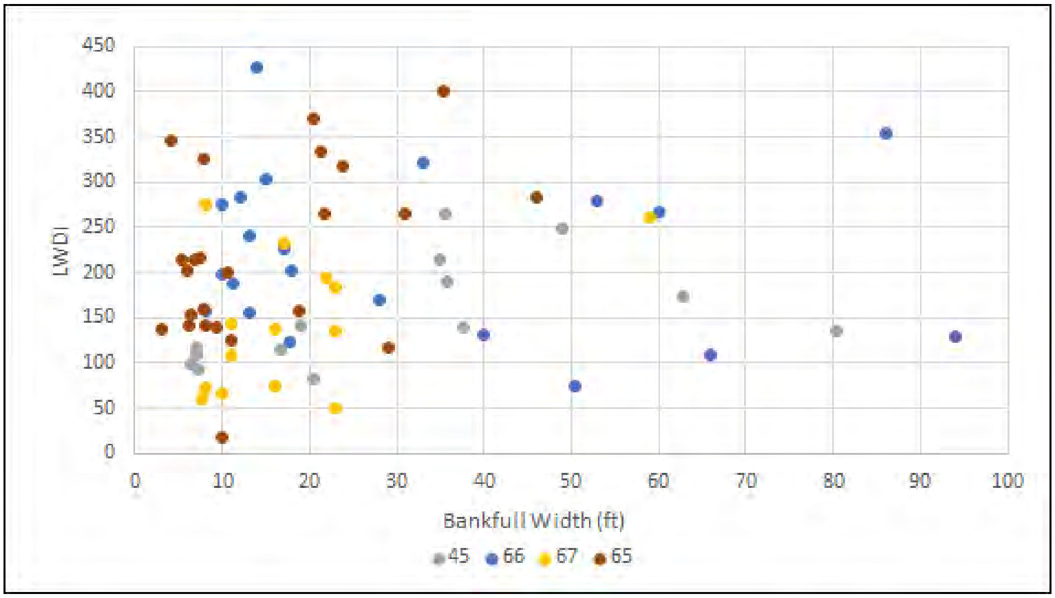


Figure C-3. Scatter plot of large woody debris index (LWDI) to mean bankfull channel width across selected ecoregions in South Carolina and Tennessee: Piedmont (45), Blue Ridge (66), Ridge & Valley (67) and Southeastern Plains (65).

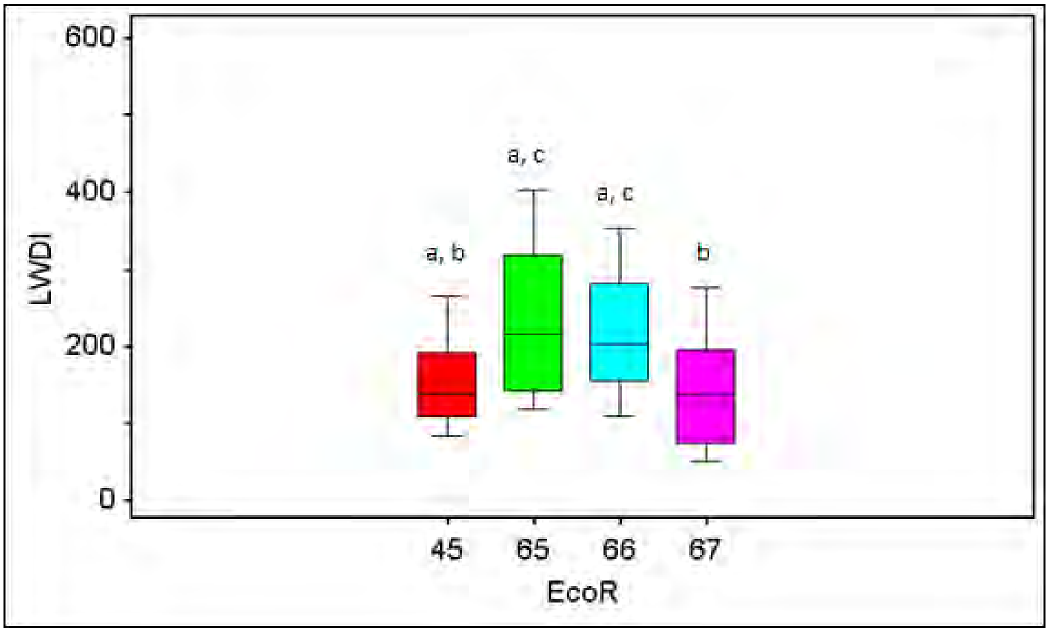


Figure C-4. Large woody debris index (LWDI) values from reference streams in the Piedmont (45), Blue Ridge (66), Ridge & Valley (67) and Southeastern Plains (65) ecoregions in South Carolina and Tennessee [n=73].

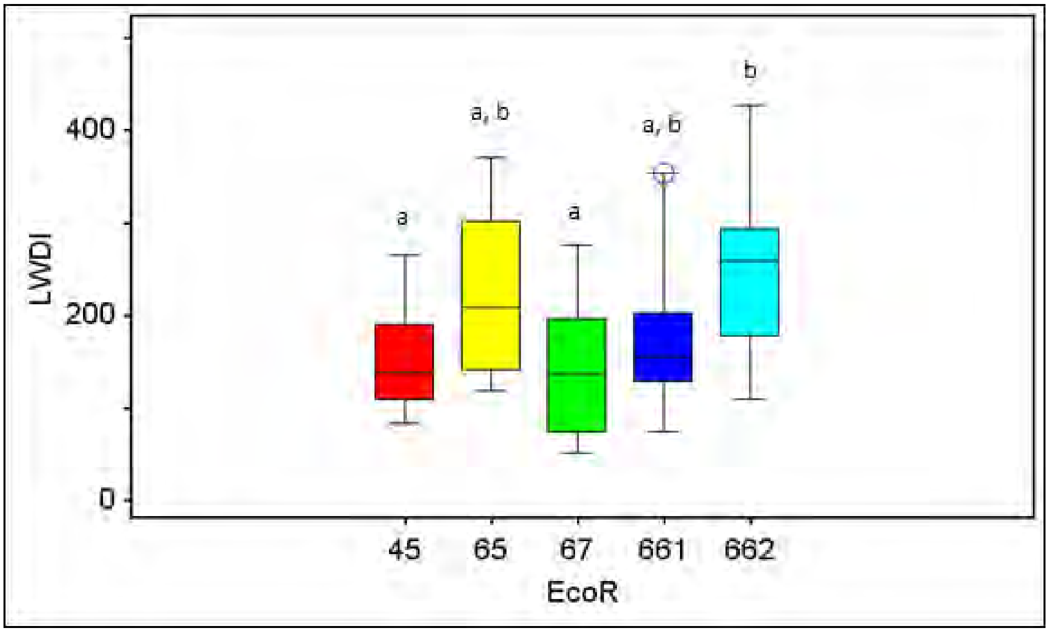


Figure C-5. Large woody debris index (LWDI) values from reference streams in the Piedmont (45), Blue Ridge (66), Ridge & Valley (67) and Southeastern Plains (65) ecoregions in South Carolina and Tennessee. Streams in the Blue Ridge are separated into two groups: “661” includes streams with < 3% slope (n= 9); “662” includes only streams ≥ 3% slope (n= 12).

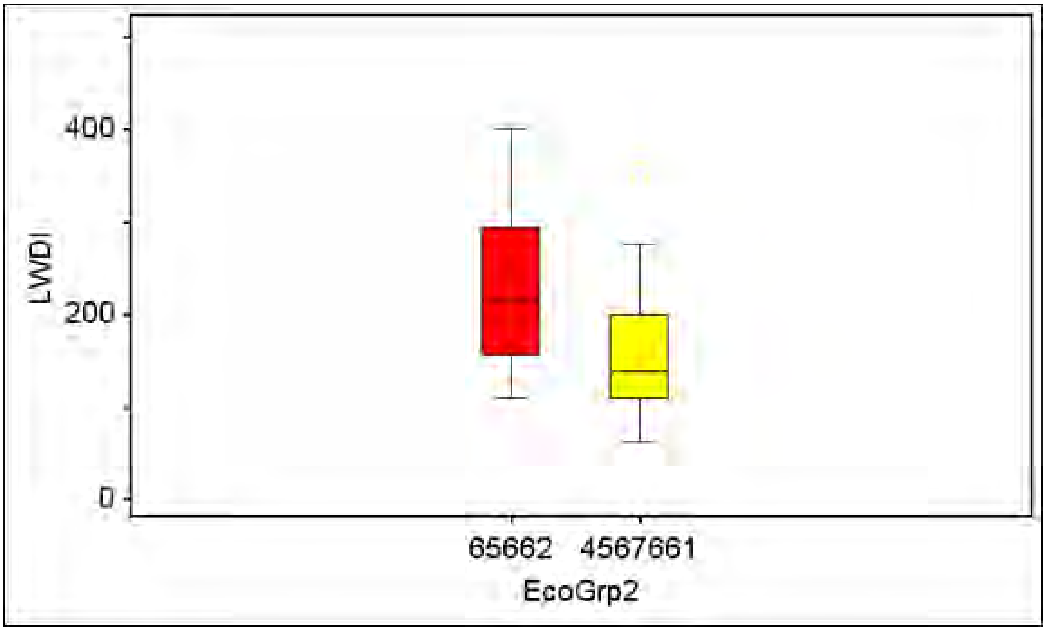


Figure C-6. Large woody debris index (LWDI) values from reference streams categorized into two groups: “65662” = streams from the Southeastern Plains (65) and streams ≥ 3% slope in the Blue Ridge (66); “4567661” = streams in the Piedmont (45), Ridge & Valley (67) and streams < 3% slope in the Blue Ridge (66).

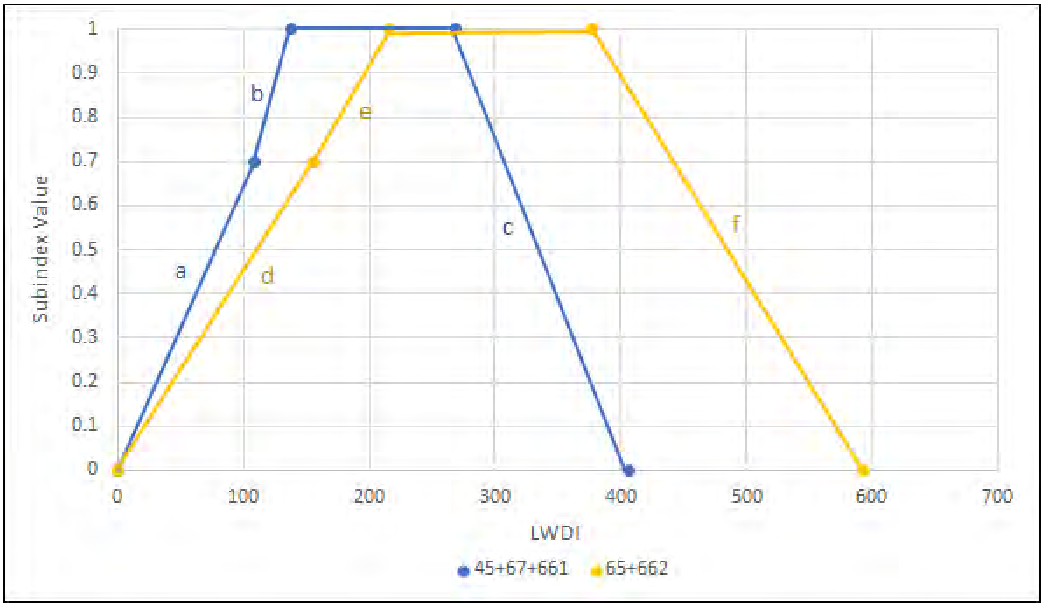


Figure C-7. Large woody debris index (LWDI) reference curves for the Georgia SQT. “4567661” = streams in the Piedmont (45), Ridge & Valley (67) and streams < 3% slope in the Blue Ridge (66); “65662” = streams from the Southeastern Plains (65) and streams ≥ 3% slope in the Blue Ridge (66).

PLATES

The following images are representative of general stream and riparian conditions associated with various large woody debris index values in the Piedmont (45), Southeastern Plains (65), Blue Ridge (66) and Ridge & Valley (67) ecoregions. They do not necessarily depict the actual stream reach where large woody debris was inventoried for SQT regionalization efforts.

Photograph: SCDNR

Plate C-1. UT Indian Creek (ecoregion 45): basin area = 0.18 square miles, channel gradient = 0.0082 ft/ft, LWDI = 99.

Photograph: SCDNR

Plate C-2. Pages Creek (ecoregion 45): basin area = 2.02 square miles, channel gradient = 0.0028 ft/ft, LWDI = 142.

Photograph: SCDNR

Plate C-3. Tools Fork (ecoregion 45): basin area = 9.73 square miles, channel gradient = 0.0019 ft/ft, LWDI = 265.

Photograph: SCDNR

Plate C-4. Mill Creek (ecoregion 65): basin area = 0.39 square miles, channel gradient = 0.0041 ft/ft, LWDI = 125.

Photograph: SCDNR

Plate C-5. UT Black Creek (ecoregion 65): basin area = 0.81 square miles, channel gradient = 0.0047 ft/ft, LWDI = 326.

Photograph: SCDNR

Plate C-6. Crane Creek (ecoregion 66): basin area = 0.27 square miles, channel gradient = 0.0171 ft/ft, LWDI = 135.

Photograph: Jennings Environmental (2017)

Plate C-7. Laurel Creek (ecoregion 66): basin area = 1.31 square miles, channel gradient = 0.0171 ft/ft, LWDI = 202.

Photograph: SCDNR

Plate C-8. UT Matthews Creek (ecoregion 66): basin area = 0.11 square miles, channel gradient = 0.035 ft/ft, LWDI = 275.

Photograph: Jennings Environmental (2017)

Plate C-9. Bearwallow Creek (ecoregion 66): basin area = 0.8 square miles, channel gradient = 0.0576 ft/ft, LWDI = 427.

Photograph: Jennings Environmental (2017)

Plate C-10. Big Ridge Creek (ecoregion 67): basin area = 0.38 square miles, channel gradient = 0.0110 ft/ft, LWDI = 109.

Photograph: Jennings Environmental (2017)

Plate C-11. White Creek (ecoregion 67): basin area = 0.9 square miles, channel gradient = 0.0187 ft/ft, LWDI = 138.

Photograph: Jennings Environmental (2017)

Plate C-12. Big Spring Creek (ecoregion 67): basin area = 0.79 square miles, channel gradient = 0.0331 ft/ft, LWDI = 275.

APPENDIX C-I

Table C-I(i). Selected characteristics of streams utilized for development of large woody debris index (LWDI) reference curves.

ID	Stream Name	State	EcoR	Rosgen Type	BA (mi2)	Slope (ft/ft)	Wbf (ft)	LWDI
1	South Rabon Creek	SC	45	C5	30	0.0033	37.7	139
2	Kings Creek	SC	45	E4	27.9	0.0026	34.9	214
3	Big Dutchman Creek	SC	45	B5c	16.8	0.0016	35.7	190
4	Tools Fork Creek	SC	45	E5	9.73	0.0019	35.6	265
5	Allison Creek	SC	45	E5	40.4	0.0015	48.9	249
6	Headleys Creek	SC	45	E5	4.94	0.0048	16.6	115
7	Pages Creek	SC	45	E5	2.02	0.0028	19	142
8	UT Indian Creek	SC	45	E5	0.18	0.0082	6.3	99
9	Joshuas Branch	SC	45	C5	2.98	0.0032	20.4	83
10	UT Kings Creek	SC	45	E5	0.32	0.0077	7.1	109
11	South Tyger River	SC	45	C5c-	94.7	0.0005	80.3	135
12	South Pacolet River	SC	45	C5	55.6	0.0025	62.8	173
13	UT1 Long Branch	SC	45	E4	0.18	0.0143	7.2	93
14	UT2 Long Branch	SC	45	E4	0.06	0.0118	7	118
62	Forks Creek (3)	TN	67	C4	0.04	0.007	7.6	61
63	Ijams Creek	TN	67	B5c	0.05	0.0085	8	73
64	Forks Creek (2)	TN	67	C4	0.29	0.0041	11	144
65	UT White Creek	TN	67	E4b	0.33	0.0253	10	67
66	Forks Creek (1)	TN	67	C3	0.35	0.0121	16	74
67	Big Ridge Creek	TN	67	C4	0.38	0.0119	11	109
68	Big Spring Creek	TN	67	E4b	0.79	0.0331	8	275
69	White Creek	TN	67	C4	0.9	0.0187	16	138
70	Mill Creek	TN	67	C4	1.1	0.0039	23	50
71	Toll Creek	TN	67	C4	1.7	0.0174	23	184
72	Forks Creek (4)	TN	67	C4	1.8	0.00184	17	233
73	Clear Creek (1)	TN	67	C4	2.6	0.0133	22	195
75	Crockett Creek	TN	67	B4c	4.7	0.0025	23	135
76	Beaver Creek	TN	67	C3	36.4	0.001	59	260
15	Middle Saluda River	SC	66	B3c	20.8	0.0067	50.4	74
16	Wattacoo Creek	SC	66	B4c	2.01	0.0066	17.7	123
17	Green Creek	SC	66	B3a	0.35	0.0555	11.3	187
18	UT Matthews Creek	SC	66	B4	0.11	0.035	9.9	275
42	False Gap Prong	TN	66	E4a	0.28	0.0474	8	157
43	Catron Branch	TN	66	B3a	0.37	0.0505	12	283
44	Bearwallow Branch	TN	66	E4	0.42	0.0141	10	199
45	UT Laurel Creek	TN	66	B4a	0.42	0.0553	13	241
46	Mids Branch	TN	66	E4b	0.69	0.0267	13	155

ID	Stream Name	State	EcoR	Rosgen Type	BA (mi2)	Slope (ft/ft)	Wbf (ft)	LWDI
47	Bearwallow Creek	TN	66	B4a	0.8	0.0576	14	427
48	Sill Branch	TN	66	B3a	1.3	0.0604	15	303
49	Laurel Creek	TN	66	C4	1.3	0.017	18	202
50	UT Little Stony Creek	TN	66	C3a	1.6	0.0415	17	227
52	Little Stony Creek	TN	66	B3a	2.3	0.0517	28	169
53	Lower Higgins Creek	TN	66	B3a	3.2	0.0482	33	322
56	Doe River	TN	66	C3	10	0.0151	40	132
57	Laurel Fork	TN	66	B4c	17.4	0.0047	60	267
58	Porters Creek	TN	66	B3	17.7	0.0304	66	109
59	Middle Prong Pigeon	TN	66	B3a	19.5	0.0417	53	280
60	Little River	TN	66	B3	31.3	0.029	86	353
61	Citico Creek	TN	66	B4c	61	0.0025	94	129
97	UT North Fork Cub Creek	TN	65	E5	0.16	0.01164	6.1	141
98	Spring Creek	TN	65	E5	8.47	0.00283	21.2	333
99	UT Little Sugar Creek	TN	65	E5	0.1	0.01	3	137
100	Cypress Creek	TN	65	E5	1.42	0.00111	9.9	18
101	UT Piney Creek	TN	65	E5	0.09	0.00863	7.5	217
102	Harris Creek	TN	65	E5	20.2	0.00206	46	284
103	Trace Creek	TN	65	E5	5.57	0.00341	21.7	264
104	Marshall Creek	TN	65	C5	6.4	0.00111	23.8	318
105	UT1 Tuscumbia River	TN	65	E5	0.12	0.01257	8.1	141
106	UT2 Tuscumbia River	TN	65	E5	0.05	0.005	4	346
113	Poplar Branch	SC	65	C5	0.25	0.0113	5.9	202
114	UT Beech Creek	SC	65	E5	0.38	0.0082	6.3	154
115	Mill Creek	SC	65	C5	0.39	0.0041	11	125
116	UT Mill Creek	SC	65	E5	0.42	0.0077	5.3	214
117	UT Black Creek	SC	65	E5	0.81	0.0047	7.8	326
118	Middle Prong Juniper Creek	SC	65	E5	1.32	0.0079	6.9	214
119	Canal Branch	SC	65	E5	1.4	0.0012	9.4	139
120	Cow Branch	SC	65	C5	1.86	0.01	7.8	160
121	Shanks Creek	SC	65	E5	3.61	0.0043	10.5	201
122	Toby Creek	SC	65	E5	10.7	0.0015	20.4	370
124	Little Fork Creek	SC	65	E4	14.7	0.0016	30.9	265
125	Brunson Swamp	SC	65	E5	20	0.0007	18.7	158
126	Fork Creek	SC	65	E4	24.4	0.0038	29.1	117
127	Black Creek	SC	65	E5	51.9	0.0004	35.3	401

Appendix D

Development of Biological Reference Curves for the Georgia SQT

Development of Trait-Based Biological Reference Curves for Stream Mitigation in Georgia

February 2021

Introduction

Assigning biological performance standards for stream mitigation projects in Georgia has historically been problematic and often inconsistent. The multi-metric macroinvertebrate index used by the Georgia Environmental Protection Division ambient monitoring program was not designed to assess the efficacy of stream mitigation efforts and has not proven widely useful for this purpose within the typical timeframe of post-construction monitoring periods. This has been especially of concern in small headwater streams, where most compensatory mitigation for the Clean Water Act (CWA), Section 404 program in Georgia occurs.

We developed trait-based macroinvertebrate indices for assessment of headwater stream restoration (HStR) projects for each major Georgia ecoregion where stream compensatory mitigation is common. Each HStR index incorporates the full range of stream conditions present in the respective ecoregion. Federal regulations define *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,” (33 CFR 332.2; 40 CFR 230.92). Collection of a reference data set that spans the condition gradient of a region and development of reference curves based on those data allow for changes to the biological community following stream mitigation to be objectively documented over time. It further allows for all projects within the region to be assessed and evaluated using the same regional reference data, instead of *ad hoc* collection of presumptive reference data for each individual project.

Methods

Compilation of Applicable Data

The availability of stream macroinvertebrate data collected from our target ecoregions and from streams consistent with our targeted size (i.e., small headwater streams) varied. Consequently, so did our approach to obtaining sufficient data.

Blue Ridge and Piedmont Ecoregions

We obtained stream macroinvertebrate data for 268 headwater streams draining watersheds of 3 square miles or less in the Blue Ridge and Piedmont ecoregions of North Carolina. Each of these streams was sampled by the North Carolina Division of Water Resources (NCDWR) between 2007-2017. We obtained these data from North Carolina for the following reasons:

- Commonality with Georgia ecoregions;
- North Carolina’s ambient biological monitoring program has consistently been among the more productive programs in the Southeastern U.S.;
- Effective data management and storage by the North Carolina ambient monitoring program allows for consistent and efficient queries and data retrieval;

- Sampling protocols have remained generally consistent over time and are easy to understand and execute.

We omitted sites that NCDWR indicated were non-perennial and those that did not otherwise conform to the requirements of the NCDWR *Small Stream Criteria* for bioclassification (NCDWR, 2016; NCDWQ, 2009). All streams retained for analysis had been sampled using the NCDWR Qual-4 protocol (NCDWR, 2016).

Each of the remaining 188 sites was assigned a bioclassification tier consistent with NCDWR (2016), which allowed us to cluster sites into groups based on the “quality” of the benthic macroinvertebrate community within the sampled streams. We then used existing databases and taxonomic literature (Table D-1) to assign habit traits (e.g., clinger, burrower, swimmer, etc.) and trophic traits (e.g., scraper, shredder, collector-gatherer, etc.) to each taxon following nomenclature by Poff et. al. (2006). Sites were partitioned separately into their respective level III ecoregions for analysis: Blue Ridge (ecoregion 66) and Piedmont (ecoregion 45). All data were then imported into MS Access, and the results of custom data queries were exported to MS Excel and/or PC Ord v.6.08 for plotting and analysis.

Coastal Plain (Southeastern Plains Ecoregion)

Sufficient macroinvertebrate data on small streams do not exist for the Southeastern Plains ecoregion (ecoregion 65) in North Carolina. Unlike the Blue Ridge and Piedmont ecoregions, level IV ecoregions within the larger Southeastern Plains of North Carolina also differ from those in Georgia. Consequently, we collected benthic macroinvertebrate data ourselves from streams located in the three largest level IV ecoregions of Georgia’s Southeastern Plains: Dougherty Plain (ecoregion 65g), Tifton Upland (ecoregion 65h) and Atlantic Southern Loam Plains (ecoregion 65l) (Griffith et al. 2001).

Site Selection & Field Sampling

We targeted 30 total sites draining watersheds of less than approximately 7.0 square miles in each of the above-referenced level IV ecoregions in the Southeastern Plains. Effort was made to target sites spanning the full range of conditions in each ecoregion, including at least five to ten high quality sites in each ecoregion. However, we had little first-hand knowledge of any streams or watersheds in the study area. We first reviewed previous studies in the region (both published and unpublished) and interviewed private environmental consultants, academics and non-government organizations with experience in the region to identify potential high-quality sites.

We delineated watersheds draining ≤7.0 square miles throughout the study area using ArcGIS and identified initial candidate high-quality sites using the geospatial StreamCat dataset (Hill et al., 2016). We assumed that watersheds with a high percent-forest cover in the contributing watershed would be most likely to support healthy robust assemblages of benthic macroinvertebrates and thus representative of least disturbed conditions. We assigned a filter to highlight watersheds with no greater than 30 percent cumulative land cover of hay/pasture, row crop, grass land and scrub-shrub in the 2011 National Land Cover Dataset (NLCD). The resulting pool of 2,500 candidate streams was further narrowed by iteratively refining threshold percentiles of six watershed-scale and three riparian-scale land cover characteristics until we had identified 15 to 30 final candidate high-quality watersheds in each level IV ecoregion. We then reviewed contemporary aerial photography to investigate potential landscape changes that may have taken place since NLCD 2011 and selected final high-quality sites to target for sampling using best professional judgement. We concurrently used aerial photographs and NLCD 2006/2011 watershed traits in the USGS StreamStats platform (USGS 2016) to identify significantly degraded sites and those with intermediate levels of watershed disturbance (i.e., low to moderate percent forest cover in the watershed).

Field sampling took place between February 4 and March 13, 2019. Data collection included benthic macroinvertebrates, in-situ water quality and physical habitat data at each site. In order to remain as consistent as possible with collection methods used for the Blue Ridge and Piedmont data, we used a slightly modified version of the NCDWR (2016) Qual-4 sample method in the Southeastern Plains. Macroinvertebrates were sampled with 600µm mesh D-frame sweep nets in a 100m reach of stream. Collections included one riffle kick (approximately 2m^2 of riffle habitat); a timed (10-minute) sweep collection targeting macrophyte beds, root mats, undercut banks, detritus deposits, bedrock, moss, silt/sand deposition areas, etc.; one leaf pack collection; and a timed (30-minute) visual collection targeting microhabitats that were not sampled using any of the other collection methods. All organisms were preserved in the field using 95% ethyl alcohol and returned to the lab for identification and enumeration. In-situ water quality parameters included dissolved oxygen, temperature, pH, specific conductance and turbidity. Physical habitat was characterized using a rapid, largely qualitative to semi-quantitative template also based on NCDWR (2016), similar to the EPA Rapid Bioassessment Protocol physical stream habitat assessment (Barbour et al., 1999).

All organisms collected at each site were identified to the lowest practical taxonomic level. Quality assurance of macroinvertebrate taxonomy was performed by having a second taxonomist identify organisms from a randomly selected subset of sites (n=5), with an acceptable Percentage Taxonomic Disagreement threshold of <15%.

Some targeted sites could not be sampled due to site access limitations (e.g., locked gates), unexpected recent land use changes (e.g., timber harvest adjacent to targeted stream reaches or construction of farm ponds upstream) or impoundment of target stream reaches by beaver (*Castor canadensis*). A total of 83 sites was sampled, ranging from 27 to 28 sites per level IV ecoregion (Figure D-1).

Abiotic Disturbance Gradient

We had no means to classify the biological community of sites sampled in the Southeastern Plains, so we developed an abiotic disturbance gradient based on land use and physiochemical stream conditions from which an initial classification could be undertaken. We generally followed procedures used by Blocksom and Johnson (2009) to identify an abiotic disturbance gradient using ordination of abiotic variables (Zampella and Bunnell, 1998; Ferreira et al., 2005; Bressler et al., 2006), where high quality or least disturbed sites are differentiated from highly degraded sites using the results of the ordination (Ferreira et al., 2005).

The EPA Region 4, Geospatial and Analysis Team in the GIS Section of the Water Division compiled information on landscape-scale anthropogenic stressors for each sampled site using the Analytical Tools Interface for Landscape Assessments (ATtILA). ATtILA is an ArcGIS toolbox created by the USEPA Office of Research and Development (https://www.epa.gov/enviroatlas/attila-toolbox) that calculates many commonly used landscape metrics, including landcover characteristics, riparian zone characteristics and human stressors (e.g., road density, road/stream crossings, etc.) for catchments defined upstream of a user defined “pour point”. Land cover characteristics were calculated throughout the catchment upstream of each sample reach and within a 100m wide riparian zone and a 50m wide riparian zone centered on all NHDPlus streamlines upstream of each sampled reach based on NLCD 2016.

Inspection of abiotic variables following initial ordination runs of principal component analysis (PCA) revealed several sites that had pH <5. These sites likely represent blackwater streams, which can be biologically limited by adverse sublethal pH values (e.g., Wiederholm 1984; Allan 1995). Although natural, these distinctive acidic streams represented outlier sites in our data set. Lacking more sites of this type, we removed them from the analyses and re-ran the PCA on the remaining 76 sites.

We performed PCA on various combinations of watershed and riparian zone land use, in-situ water quality and physical habitat variables in PC-Ord, v.6.08. We included only those variables having a Pearson coefficient of less than $|0.71|$ with other abiotic variables (Stoddard et al., 2008). A correlation coefficient of $|0.71|$ means that the two variables share information 50:50, or stated another way, one variable explains 50% of the second variable. The only exception was for specific conductivity and pH, both of which were included despite a Pearson coefficient $r = 0.75$. Dow and Zampella (2000) found that stream specific conductivity and pH were collectively strong indicators of watershed disturbance in coastal plain New Jersey streams, and Sawyer et al. (2004) found both specific conductance and pH to be important environmental variables affecting macroinvertebrates in southeastern Alabama streams. We note that Sawyer et al. (2004) used $|r| \leq 0.8$ as a threshold coefficient to eliminate redundant environmental variables in southeastern Alabama, and Barbour et al. (1996) used $|r| \leq 0.9$ during development of stream biological criteria for Florida.

Ten abiotic variables were used in the final PCA, including ones describing in-situ water quality (specific conductivity, pH, turbidity), physical stream characteristics (in-stream habitat, bottom substrate, total habitat score), watershed land use (percent forest, percent wetland) and riparian zone land use within a 50m buffer adjacent to all streams upstream of the sample reach (percent forest, percent wetland). Although PCA requires multivariate normality if statistical inference is to be made, these assumptions may be relaxed if the purpose of the PCA is purely descriptive (McCune and Grace, 2002). We considered our own use of PCA to be descriptive in nature, but nonetheless relativized any necessary abiotic variable to reduce skewness to a range of -1 to 1 (McCune and Grace, 2002). Specific conductivity, turbidity and percent forest in the 50m riparian zone were log10(x) transformed, and total habitat score was arcsine square root transformed prior to running the PCA.

We then assigned sites into one of three abiotic condition classes (e.g., Good, Fair, Poor) using the Axis 1 coordinate scores of the PCA. The 75th and 25th percentiles of the coordinate scores were used to assign sites to the Good and Poor condition classes, respectively. All remaining sites were assigned to the Fair class.

Data Analysis

Blue Ridge and Piedmont Ecoregions

We focused on metrics representing proportion of taxa richness rather than enumerated percentages of individual organisms present in the samples (Table D-2). We first examined box plots of the full range of each metric to evaluate the data distribution among biological condition classes defined by NCDWR. NCDWR uses five bioclassification tiers, which we consolidated into three classes: Excellent, Good/Good-Fair/Fair, and Poor. Box plots allowed us to identify the subset of metrics best able to effectively discriminate among condition classes. Discriminatory power was based on the degree to which the IQR and median of each group of sites overlap (Figure D-2). After reviewing box plots based on species-level data, we repeated the exercise using genus-level data. Metrics with good discriminatory efficiency and for which there was no appreciable loss of information or resolution using the genus-level data were retained for further evaluation.

Proportion-based biological metrics of genus level data demonstrating good discriminatory power were then standardized per ecoregion using the percent of standard method (Barbour et al., 1999) across the full range of sites, so that they could be uniformly compared and aggregated (Barbour et al., 1999; Blocksom, 2003; Stoddard et al., 2008). This method uses ceilings and floors to limit the influence of biological assemblages having metric values outside of the 95th percentile and 5th percentile, respectively. Metrics with a negative correlation with abiotic stressors were standardized using (ceiling - *metric*) / (ceiling - floor) x 100, while those positively correlated with stressors were standardized using (*metric* - floor) / (ceiling - floor)) x 100. Any standardized value greater than 100 was corrected to equal 100. Similarly, any unstandardized value less than zero was corrected to equal zero.

It is worth noting that while standardization of the data is necessary for the metrics to be uniformly compared and aggregated at a common scale (e.g., 0 to 1.0), it also masks the true proportion of the sampled macroinvertebrate community comprised of taxa with applicable shared target traits. For example, the genus-level proportion of shredders in a sampled stream community may be only 15 percent, but standardization of the data for the genus-level proportion shredders metric may change that 15 percent to 70 percent. The HStR index is ultimately based on these standardized data, so relationships between the unstandardized metric data and the standardized metric data should be reviewed for additional clarity (see Appendix D-I).

Coastal Plain (Southeastern Plains Ecoregion)

Specific conductivity and turbidity of streams in ecoregion 65g varied more and pH varied less than those in ecoregions 65h or 65l. Instream habitat and total habitat scores varied more and were generally lower (i.e., reflecting poorer physical conditions) in ecoregion 65g than the other ecoregions. Percent forest in the watershed and in the 50-meter riparian zone of streams in ecoregion 65g was generally less than either ecoregion 65h or 65l.

The first three PCA axes were significant after random permutations and cumulatively accounted for approximately 71 percent of the total variance among all 76 sites. Axes 1, 2 and 3 explained 31.3%, 24.8% and 14.8% variance, respectively. Component loadings for axis 1 reflected a gradient of physical stream habitat (including total habitat score (0.84), in-stream habitat (0.72), channel bottom substrate (0.72)), percent wetland in the 50-meter riparian zone (0.65) and turbidity (-0.63). Axis 2 reflected a gradient of percent wetland in the watershed (-0.72), specific conductivity (-0.7), percent forest in the 50-meter riparian zone (0.67) and pH (-0.63). The gradient explained by axis 3 included duplicative variables explained by axis 2, principally percent forest in the 50-meter riparian zone (0.62) and pH (0.61).

The percent forest variables used in the PCA were strongly inversely related to percent agriculture in watersheds and riparian zones of streams in all three level IV ecoregions (│r│ > 0.85). Thus, while only percent forest was included to limit redundancy in the PCA, the disturbance gradient also reflects percent agriculture by default. Although there is considerable overlap in the distribution of sites per level IV ecoregion along the first two PCA axes, the centroid of sites per ecoregion illustrates that sites in ecoregion 65g are generally more disturbed than those in ecoregions 65h or 65l (Figure D-2).

We further investigated the ecoregion-based differences of abiotic variables suggested by the PCA using multi-response permutation procedures (MRPP). MRPP is a nonparametric method for testing whether there is a difference between two or more groups (McCune and Grace, 2002). A pairwise comparison of the abiotic data grouped by ecoregion in MRPP using the same Euclidean distance measure used for the PCA further confirmed that abiotic conditions of sites in ecoregion 65g differ from those in each of the other two ecoregions [65g vs 65h, T= -5.31, A= 0.05, p=0.002; 65g vs 65l, T= -6.4, A= 0.07, p<0.001; 65h vs 65l, T= 0.43, A= -0.005, p= 0.57].

Stream restoration projects in ecoregion 65g may not be capable of the same biological response to restoration as streams in the other two ecoregions due to the degree of landscape (i.e., watershed) disturbance in ecoregion 65g. Holding restoration projects in ecoregion 65g to the same standards as projects in the other ecoregions would therefore be inequitable. We consequently elected to classify the abiotic condition of sites per level IV ecoregion using PCA coordinate scores only of streams within each respective ecoregion. For example, streams in ecoregion 65g were assigned to condition classes based on the PCA coordinate scores of only streams in ecoregion 65g. Streams in ecoregions 65h and 65l were similarly classified based only on the coordinate scores of sites in those respective ecoregions. Thus, while a Good site in ecoregion 65g may not be abiotically equivalent to a Good site in ecoregion 65h or ecoregion 65l and may only rarely have macroinvertebrate assemblages similar to those in the other ecoregions, it is nonetheless representative of least disturbed conditions in 65g.

Candidate biological metrics in the Southeastern Plains were identified per level IV ecoregion and standardized as described above for the Blue Ridge and Piedmont ecoregions. Benthic macroinvertebrate metrics were assessed for acceptable range and responsiveness to the abiotic condition gradient derived from the PCA, while also checking for redundancy with other biological metrics.

Results

Blue Ridge and Piedmont Ecoregions

Five biological metrics displayed fair to excellent discriminatory power among NCDWR biological classes in the Blue Ridge and Piedmont ecoregions: genus taxa richness, proportion genus-level EPT, proportion genus-level burrower, proportion genus-level clinger and proportion genus-level shredder. However, the discriminatory power was not equivalent per metric or per ecoregion (Figure D-3), and therefore different combinations of metrics were chosen to develop the HStR index in each respective ecoregion (Table D-3).

There was no trend apparent among any of the above referenced metrics for the [Good] and [Excellent] sites linearly regressed against watershed size in the Blue Ridge ($R^2 <0.06$) or Piedmont ($R^2 \leq 0.2$); data not shown. To test for metric redundancy, we reviewed correlation matrices using only the [Good] and [Excellent] sites to restrict our assessment to natural gradients and thereby avoid inadvertent elimination of metrics based solely on similar responses to stressor gradients (Stoddard et al., 2008). The only pair of biological metrics that were correlated more strongly than the threshold proposed by Stoddard et al. (2008) ($|r| < 0.71$) was proportion genus-level EPT richness and proportion genus-level clinger richness in the Blue Ridge ecoregion (Table D-4). However, with r = 0.74, these two metrics were only slightly more strongly correlated than the target threshold, and we elected to retain them both for development of stream mitigation biological performance standards.

Coastal Plain (Southeastern Plains ecoregion)

Rainfall during the three months preceding field sampling was generally normal to above normal in the eastern portion of the study area and well above normal in the central and western portions of the study area.

A total of 176 genera was collected from 73 families at the 76 streams sampled. Genus taxa richness per site ranged from 8 to 40, with an average of 25. Total taxa richness was generally lower in ecoregion 65g than the other two ecoregions.

Initial review of biological metrics per abiotic condition class per level IV ecoregion in the Southeastern Plains suggested little discriminatory power for any metric. Fifty-nine of the above referenced 176 total genera were in the family Chironomidae. These genera comprised 40 percent or more of the genus taxa richness in 30 percent of the 76 sample sites and over 50 percent of genus taxa richness at three sites. Rabeni and Wang (2001) found that macroinvertebrate bioassessment metrics showed the same or greater sensitivity in two Missouri ecoregions when Chironomidae taxa were excluded from the data prior to calculation of the metrics. We hypothesized that the “noise” created by these ubiquitous organisms of coastal plain streams may be contributing to the lack of differentiation among condition classes. We consequently consolidated all Chironomidae genera into a single target taxon, free of any trophic or habit trait assignment, and recalculated the proportion-based biological metrics. Thus, while the resulting single Chironomidae taxon adds +1 to the total genus taxa richness of a sample site and thereby adds +1 to the denominator of proportion-based metrics, it has no effect on the numerator of such metrics.

Six biological metrics effectively discriminated Good sites from Poor sites in at least one level IV ecoregion in the Southeastern Plains following consolidation of all Chironomidae genera: genus taxa richness, proportion genus-level EPT richness, proportion genus-level clinger richness, proportion genus-level collector-filterer richness, proportion genus-level swimmer richness and proportion genus-level shredder richness. However, these six biological metrics did not display equal discriminatory power across all three level IV ecoregions, nor did they equally discriminate Good sites from Fair sites or Fair sites from Poor sites (Figure D-4). Specific metrics chosen for each ecoregion consequently varies (Table D-3). The correlation among discriminatory biological metrics per ecoregion was $|r| \leq 0.69$ for all metrics, except for proportion genus-level EPT richness and proportion genus-level clinger richness in ecoregion 65g ($r = 0.74$) (Table D-4). As in the Blue Ridge, these two metrics were only slightly more strongly correlated than the target threshold, and were both retained for development of stream mitigation biological performance standards.

Individually, no applicable biological metric per level IV ecoregion had a Pearson coefficient greater than $|0.66|$ with any of the ten abiotic variables used in the PCA to define the abiotic condition gradient (Table D-5). Although the strength of these correlations was generally low to moderate, the direction of their relationship (+, -) was consistent with expectations.

Development of HStR Indices and Mitigation Reference Curves

As previously indicated, standardization of biological metric data utilized the full range of conditions per discriminatory metric exhibited by the entire data set in the Blue Ridge and Piedmont ecoregions, respectively. By contrast, the HStR indices for the Blue Ridge and Piedmont were developed without inclusion of the [Excellent] sites from either ecoregion. We chose to exclude [Excellent] sites from the Blue Ridge and Piedmont HStR indices and concomitant reference curves to avoid overestimating the potential for biological responses to stream mitigation activities within the typical post-construction monitoring period. Building the SQT reference curves without incorporating the NCDWR [Excellent] sites increases the potential mitigation credit derived from the Biology functional category of the GA SQT relative to what would be possible if the [Excellent] sites had been included in the Blue Ridge (BR)-HStR and Piedmont (P)-HStR indices.

In contrast to the BR-HStR and P-HStR indices, all Southeastern Plains sites in each level IV ecoregion were used for both standardization of discriminatory metric data and development of applicable Coastal Plain (CP)-HStR indices. This approach was principally based on the weaker differentiation of sites among abiotic condition classes derived from the PCA in these ecoregions relative to that exhibited by the biological condition classes assigned by NCDWR to the Blue Ridge and Piedmont sites.

Derivation of the HStR index followed the same protocol across all ecoregions. The standardized biological metric data for each applicable discriminatory metric per site was averaged to obtain a HStR score for each site. For example, the P-HStR index uses four discriminatory metrics, as illustrated in Table D-3. The HStR score for any specific site in the Piedmont is thus the average of the four standardized proportion metric values for that site.

As a final check on the discriminatory power of the CP-HStR scores per level IV ecoregion in the Southeastern Plains before derivation of the CP-HStR index, we plotted CP-HStR scores per level IV ecoregion against the abiotic condition classes derived from the PCA (Figure D-6).

These box plots illustrate good discriminatory power by the CP-HStR scores to differentiate among abiotic conditions classes in the Southeastern Plains.

The reference curve (HStR index) for each ecoregion is based on threshold SQT values between 0 and 1.0 (y) as proposed by Harman et al. (2012) and designated percentiles of the respective ecoregion's HStR scores (x) (Table D-6). The resulting (x)(y) values were plotted, and the equation of the line fitted to connect each (x)(y) point, allowing for conversion of any HStR score to its corresponding HStR index value. Mitigation reference curves based on respective HStR indices are illustrated in Figure D-7 for the Blue Ridge, Figure D-8 for the Piedmont, and Figures D-9 thru D-11 for the Dougherty Plain, Tifton Upland and Atlantic Southern Loam Plains, respectively.

Updates and revisions to these biological reference curves for headwater streams in Georgia may be made as additional data become available. Refer to the most recent version of the *Georgia Interim Stream Quantification Tool* and *User Manual*, available on the U.S. Army Corps of Engineers Savannah District RIBITS web site for more information.

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TABLES

Table D-1. Data integration rules for assigning trophic and habit traits to benthic macroinvertebrate taxa for the Georgia SQT.

Benthic macroinvertebrate taxa in the *“Georgia SQT Macroinvertebrate Genus Traits”* table (USACE Savannah District RIBITS web page) are assigned traits using the following references. References are consulted in the order in which they appear. If one source does not have a trait assigned, move to the next source on the list.

Source	Field
1. Poff et al. (2006) ~ “Poff”	Trophic Habit; Habit (genus-level matches)
2. Vieira et al. (2006) ~ “USGS”	Feed_mode_prim; Habit_prim
3. USEPA National River & Stream Assessment 2008-2009 (USEPA, 2016) ~ “NRSA”	FFG; Habit
4. USEPA Wadeable Stream Assessment 2004 (USEPA, 2006) ~ “WSA”	FFG; Habit
5. Merritt, Cummins & Berg (2008) ~ “MCB”	Trophic Relationships; Habit
6. USEPA Freshwater Biological Traits database (USEPA, 2012) ~ “EPA12”	Feed_mode_prim; Habit_prim

- If more than one trait is assigned to multiple species within a genus (not uncommon in Vieira et al. (2006)), the one that occurs most frequently is entered (= majority rules).
- If different traits are recorded for species in the same genus the same number of times (not uncommon in Vieira et al. (2006)), or if one source includes two different traits for a genus (not uncommon in NRSA), then the next source is used as a tie breaker. For example: (1) if Vieira et al. (2006) has two species of the same genus listed as CF and two as SH, and the NRSA entry for the genus is SH, then SH is assigned; (2) if NRSA has a genus listed as <SH, PR>, and WSA lists the genus as SH, then SH is assigned).
- If unable to resolve based on these sources, no trait is assigned.

Table D-2. Biological metrics evaluated for development of the HStR index.

Genus taxa richness	Proportion genus-level shredder richness
Proportion genus-level EPT[1] richness	Proportion genus-level predator richness
Proportion genus-level climber richness	Proportion genus-level scraper richness
Proportion genus-level clinger richness	Proportion genus-level collector-filterer richness
Proportion genus-level burrower richness	Proportion genus-level collector-gatherer richness
Proportion genus-level sprawler richness	

[1] Taxa in Ephemeroptera, Plecoptera and Tricoptera orders (i.e. mayflies, stoneflies and caddisflies).

Table D-3. Selected metrics for development of HStR indices per ecoregion.

Ecoregion	Metrics
Blue Ridge (66)	Genus taxa richness Proportion genus-level EPT richness Proportion genus-level clinger richness Proportion genus-level burrower richness Proportion genus-level shredder richness
Piedmont (45)	Genus taxa richness Proportion genus-level EPT richness Proportion genus-level clinger richness Proportion genus-level shredder richness
Dougherty Plain (65g)	Genus taxa richness Proportion genus-level EPT richness Proportion genus-level clinger richness Proportion genus-level collector-filterer richness
Tifton Upland (65h)	Genus taxa richness Proportion genus-level EPT richness Proportion genus-level clinger richness Proportion genus-level swimmer richness
Atlantic Southern Loam Plains (65l)	Genus taxa richness Proportion genus-level EPT richness Proportion genus-level clinger richness Proportion genus-level collector-filterer richness Proportion genus-level shredder richness

Table D-4. Pearson correlation among biological metrics used in HStR indices per ecoregion for the Georgia SQT.

Blue Ridge (Ecoregion 66)

	Genus taxa rich	*Prop_EPT rich*	*Prop_Cling rich*	*Prop_Burro rich*	*Prop_Shred rich*
Genus taxa rich	1.0				
Prop_EPT rich	-0.27	1.0			
Prop_Cling rich	0.02	0.74	1.0		
Prop_Burro rich	0.07	-0.59	-0.65	1.0	
Prop_Shred rich	-0.59	0.28	-0.09	-0.05	1.0

Piedmont (Ecoregion 45)

	Genus taxa rich	*Prop_EPT rich*	*Prop_Cling rich*	*Prop_Shred rich*
Genus taxa rich	1.0			
Prop_EPT rich	0.27	1.0		
Prop_Cling rich	0.33	0.69	1.0	
Prop_Shred rich	-0.25	0.19	-0.06	1.0

Dougherty Plain (Ecoregion 65g)

	Genus taxa rich	*Prop_EPT rich*	*Prop_Cling rich*	*Prop_CF rich*
Genus taxa rich	1.0			
Prop_EPT rich	0.4	1.0		
Prop_Cling rich	0.28	0.74	1.0	
Prop_CF rich	-0.56	-0.21	0.1	1.0

Tifton Upland (Ecoregion 65h)

	Genus taxa rich	*Prop_EPT rich*	*Prop_Cling rich*	*Prop_Swim rich*
Genus taxa rich	1.0			
Prop_EPT rich	0.36	1.0		
Prop_Cling rich	0.27	0.52	1.0	
Prop_Swim rich	0.38	0.58	-0.01	1.0

Atlantic Southern Loam Plains (Ecoregion 65l)

	Genus taxa rich	*Prop_EPT Rich*	*Prop_Cling Rich*	*Prop_CF Rich*	*Prop_Shred Rich*
Genus taxa rich	1.0				
Prop_EPT Rich	0.5	1.0			
Prop_Cling Rich	0.46	0.66	1.0		
Prop_CF Rich	-0.26	-0.1	0.08	1.0	
Prop_Shred Rich	0.1	0.51	0.32	-0.11	1.0

Table D-5. Pearson correlation among biological metrics and abiotic variables used in the Coastal Plain HStR index per level IV ecoregion in the Southeastern Plains.

Dougherty Plain (65g)																	
	Ax 1 PCA	Spec Cond^1	pH	Turb^1	Instrm Hab	Btm Subst	Hab Sum^2	wFrs	wWetl	rz50 Frs^1	rz50 Wetl	Gen TR	Prop EPT	Prop CF	Prop Cling	Prop Shred	Prop Swim
Ax 1 PCA	1.00																
Spec Cond^1	0.01	1.00															
pH	0.31	0.75	1.00														
Turb^1	-0.60	-0.25	-0.31	1.00													
Instrm Hab	0.85	0.17	0.40	-0.45	1.00												
Btm Subst	0.70	-0.04	0.06	-0.31	0.49	1.00											
Hab Sum^2	0.91	0.19	0.46	-0.46	0.86	0.67	1.00										
wFrs	0.54	0.02	0.28	-0.29	0.41	0.22	0.48	1.00									
wWetl	0.43	0.37	0.50	-0.19	0.36	0.00	0.35	0.08	1.00								
rz50 Frs^1	0.48	0.10	0.20	-0.26	0.50	0.19	0.51	0.81	-0.03	1.00							
rz50 Wetl	0.52	-0.02	0.25	-0.30	0.25	0.09	0.30	0.16	0.79	-0.10	1.00						
Gen TR	0.50	0.24	0.47	-0.39	0.62	0.19	0.56	0.26	0.28	0.25	0.17	1.00					
Prop EPT	0.27	0.25	0.35	-0.46	0.16	0.35	0.32	-0.14	0.07	-0.11	0.11	0.40	1.00				
Prop CF	-0.31	0.11	-0.24	0.06	-0.40	0.02	-0.30	-0.18	-0.27	-0.26	-0.25	-0.56	-0.21	1.00			
Prop Clin	0.31	0.00	0.09	-0.41	0.00	0.43	0.25	0.10	0.01	-0.12	0.22	0.28	0.74	0.10	1.00		
Prop Shred	0.11	0.10	0.30	-0.14	0.09	-0.05	0.16	0.17	0.06	0.09	0.14	0.58	0.43	-0.31	0.39	1.00	
Prop Swim	0.10	0.33	0.20	-0.07	0.23	0.32	0.30	-0.12	-0.13	0.08	-0.36	0.33	0.64	-0.20	0.33	0.13	1.00
Tifton Upland (65h)																	
	Ax 1 PCA	Spec Cond^1	pH	Turb^1	Instrm Hab	Btm Subst	Hab Sum^2	wFrs	wWetl	rz50 Frs^1	rz50 Wetl	Gen TR	Prop EPT	Prop CF	Prop Cling	Prop Shred	Prop Swim
Ax 1 PCA	1.00																
Spec Cond^1	-0.23	1.00															
pH	-0.16	0.69	1.00														
Turb^1	-0.46	-0.21	-0.02	1.00													
Instrm Hab	0.67	0.18	0.05	-0.39	1.00												
Btm Subst	0.64	-0.01	-0.14	-0.18	0.20	1.00											
Hab Sum^2	0.74	0.05	0.12	-0.10	0.58	0.71	1.00										
wFrs	0.32	-0.62	-0.15	0.42	-0.08	0.19	0.24	1.00									
wWetl	0.53	0.38	0.40	-0.51	0.54	0.14	0.25	-0.12	1.00								
rz50 Frs^1	-0.37	-0.42	-0.25	0.59	-0.38	-0.13	-0.28	0.47	-0.63	1.00							
rz50 Wetl	0.71	0.09	0.22	-0.45	0.47	0.24	0.40	0.01	0.74	-0.65	1.00						
Gen TR	0.60	-0.24	0.09	-0.42	0.24	0.33	0.40	0.27	0.41	-0.14	0.44	1.00					
Prop EPT	0.47	0.10	0.26	-0.24	0.22	0.24	0.32	0.26	0.57	-0.38	0.55	0.36	1.00				
Prop CF	-0.39	0.47	0.42	0.02	-0.06	-0.47	-0.36	-0.18	0.18	-0.04	-0.07	-0.38	0.05	1.00			
Prop Clin	0.25	-0.01	0.07	-0.24	0.10	-0.04	-0.05	0.17	0.50	-0.05	0.33	0.27	0.52	0.35	1.00		
Prop Shred	0.11	0.03	-0.01	-0.23	-0.15	0.38	0.02	-0.09	-0.01	-0.17	0.10	0.02	0.24	-0.37	-0.06	1.00	
Prop Swim	0.52	-0.03	0.04	-0.36	0.43	0.24	0.47	0.13	0.22	-0.31	0.38	0.38	0.58	-0.34	-0.01	0.13	1.00
Atlantic Southern Loam Plains (65l)																	
	Ax 1 PCA	Spec Cond^1	pH	Turb^1	Instrm Hab	Btm Subst	Hab Sum^2	wFrs	wWetl	rz50 Frs^1	rz50 Wetl	Gen TR	Prop EPT	Prop CF	Prop Cling	Prop Shred	Prop Swim
Ax 1 PCA	1.00																
Spec Cond^1	-0.65	1.00															
pH	-0.53	0.87	1.00														
Turb^1	-0.42	0.10	0.31	1.00													
Instrm Hab	0.54	-0.20	0.00	0.03	1.00												
Btm Subst	0.63	-0.30	-0.25	-0.11	0.09	1.00											
Hab Sum^2	0.59	-0.03	0.08	-0.10	0.53	0.46	1.00										
wFrs	0.41	-0.76	-0.52	0.04	0.13	0.03	-0.11	1.00									
wWetl	0.29	-0.02	-0.01	0.03	0.13	0.23	0.06	-0.22	1.00								
rz50 Frs^1	0.16	-0.50	-0.33	0.22	0.15	-0.03	0.08	0.74	-0.48	1.00							
rz50 Wetl	0.49	-0.22	-0.18	-0.40	0.03	0.23	-0.03	0.08	0.65	-0.49	1.00						
Gen TR	0.31	-0.03	0.05	-0.02	0.32	0.42	0.46	-0.06	-0.16	0.16	-0.12	1.00					
Prop EPT	0.51	-0.26	-0.11	0.14	0.48	0.29	0.66	0.21	0.26	0.37	-0.09	0.50	1.00				
Prop CF	-0.46	0.53	0.41	-0.01	-0.28	-0.27	-0.09	-0.48	-0.01	-0.36	-0.20	-0.26	-0.10	1.00			
Prop Clin	0.42	-0.17	-0.02	-0.05	0.23	0.43	0.34	0.14	0.30	0.12	0.11	0.46	0.66	0.08	1.00		
Prop Shred	0.62	-0.39	-0.16	-0.14	0.44	0.34	0.56	0.31	0.09	0.22	0.16	0.10	0.51	-0.11	0.32	1.00	
Prop Swim	-0.12	0.20	-0.06	-0.11	-0.13	-0.10	0.18	-0.25	-0.05	0.08	-0.27	0.17	0.18	-0.09	-0.07	-0.24	1.00

1 Variable log10(x) transformed.

2 Variable arcsine square root transformed.

Table D-6. Applicable percentile of HStR score data per ecoregion used to generate stream mitigation biological reference curves for the Georgia SQT.

SQT Index Value	Percentile
0	5th
0.3	25th
0.7	median
1.0	75th

FIGURES

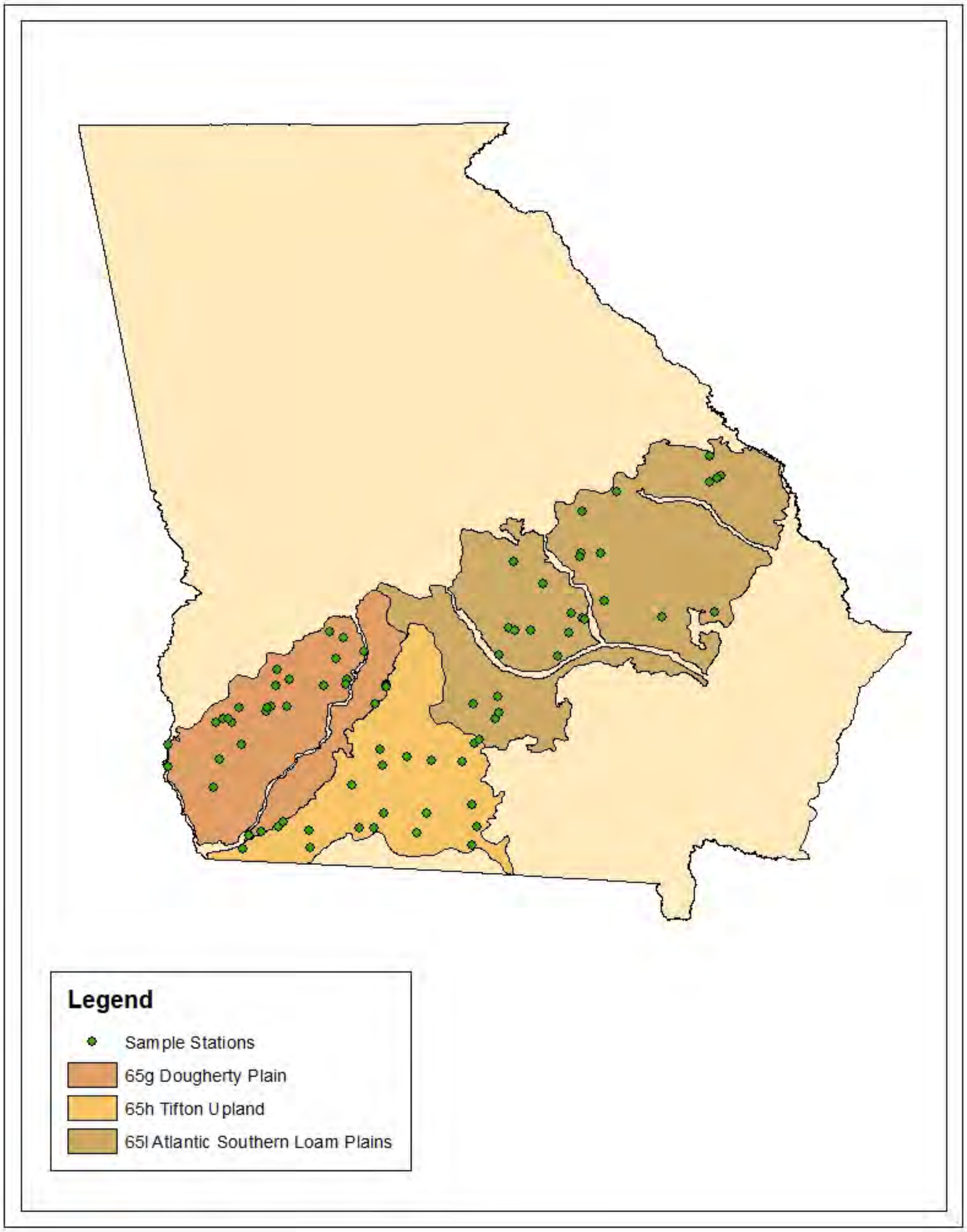


Figure D-1. Sample sites in selected level IV ecoregions of the Southeastern Plains in Georgia.

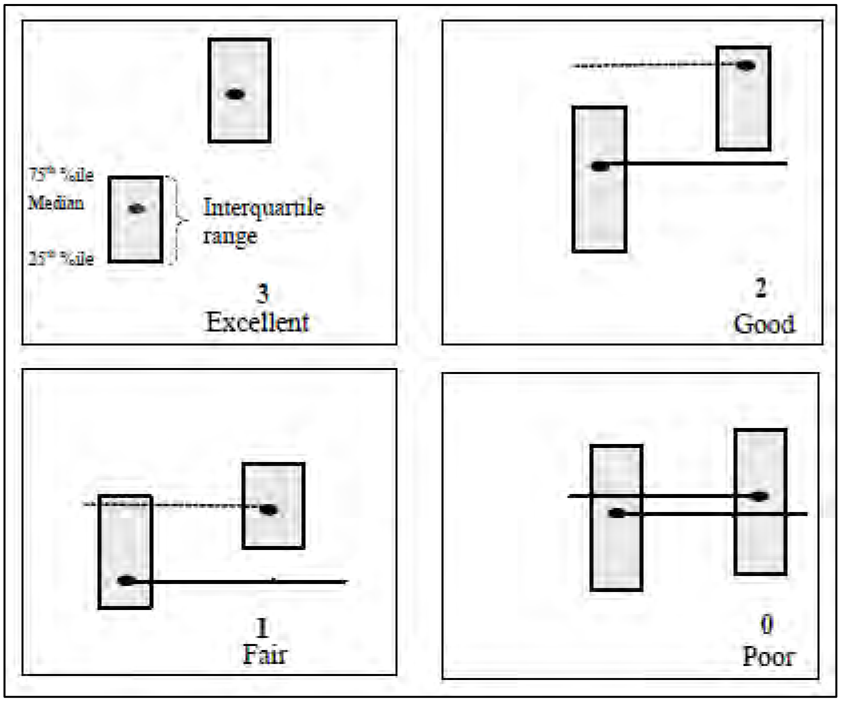


Figure D-2. Hypothetical box plots illustrating discriminatory power (Pond et al., 2003; after Barbour et al., 1996).

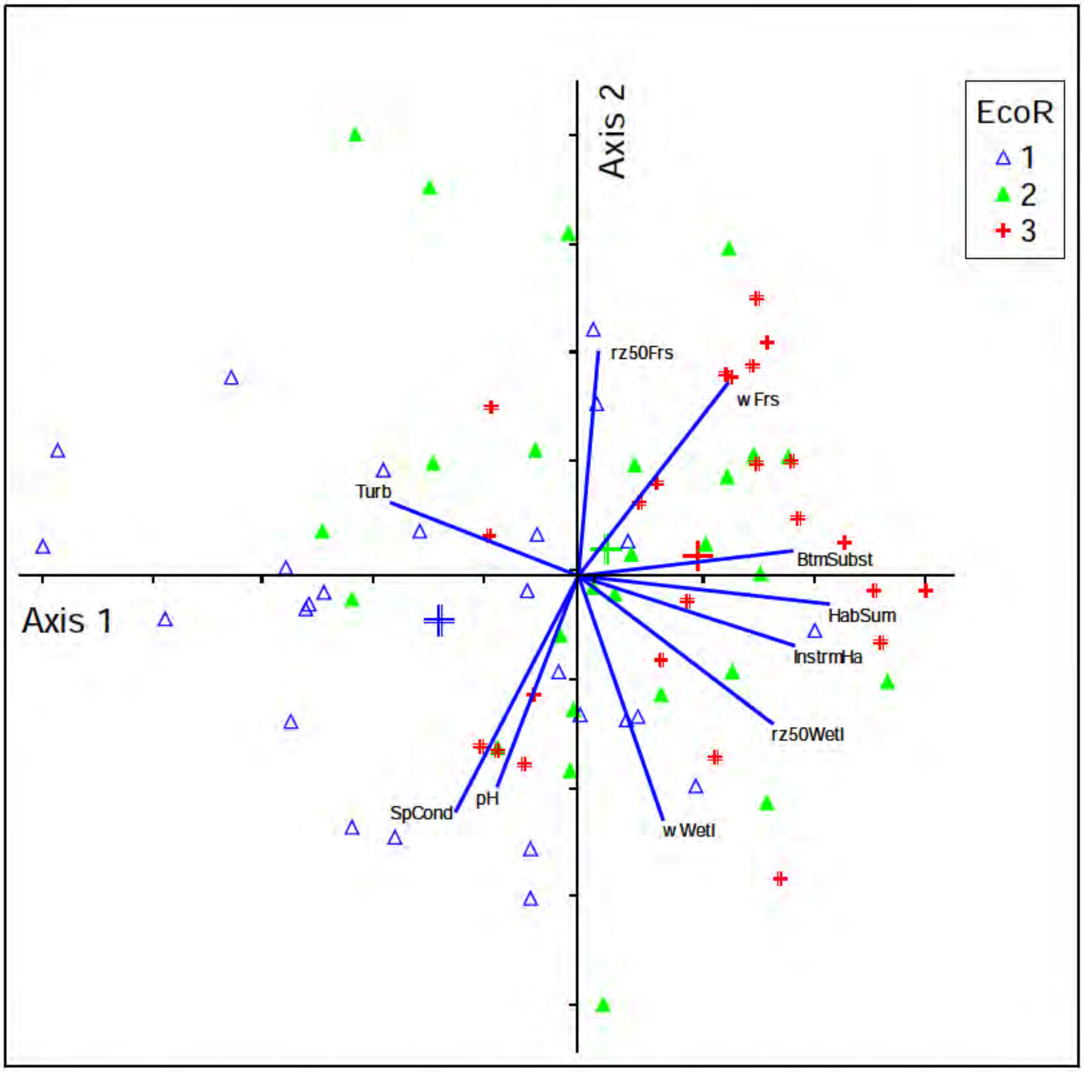
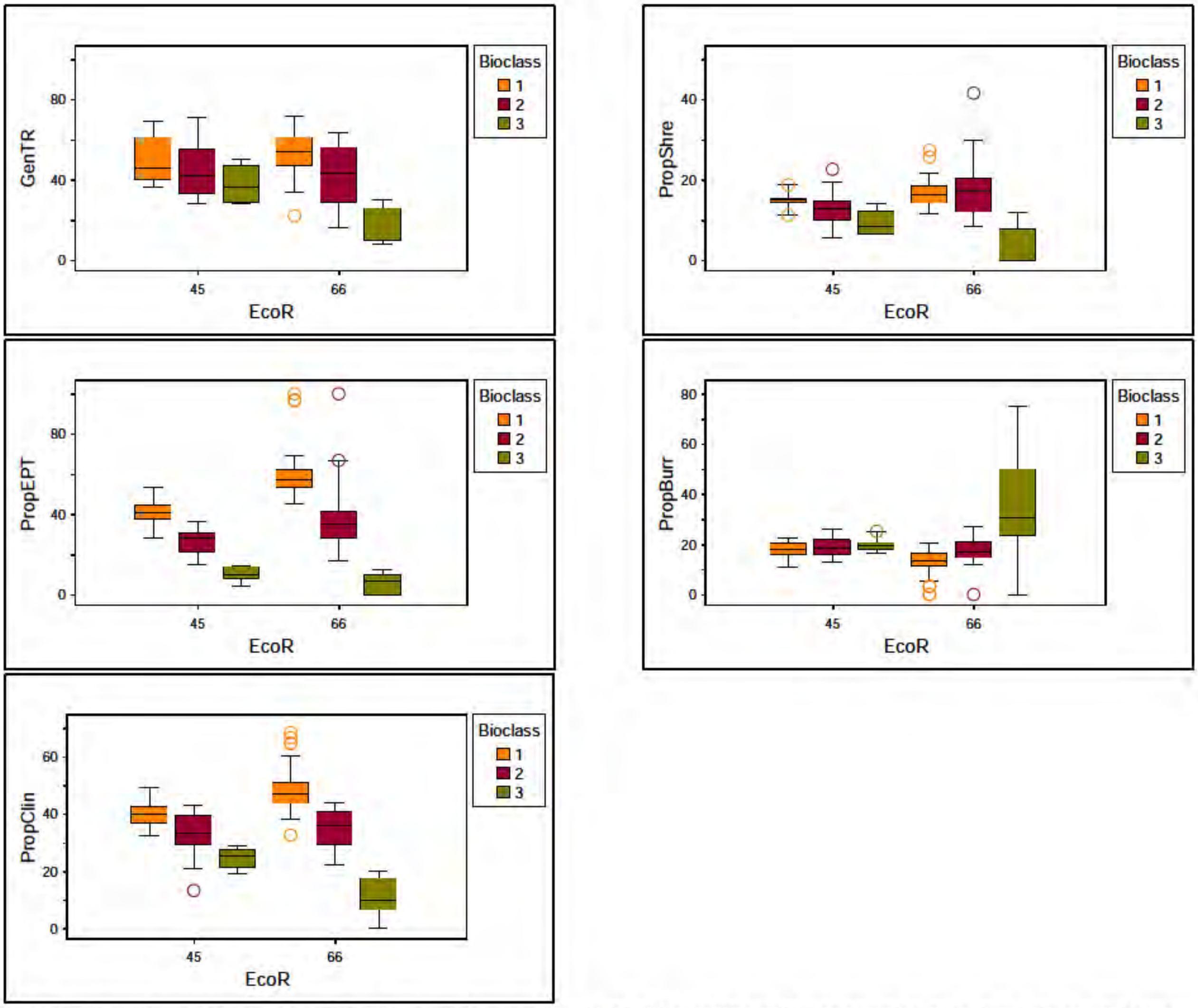
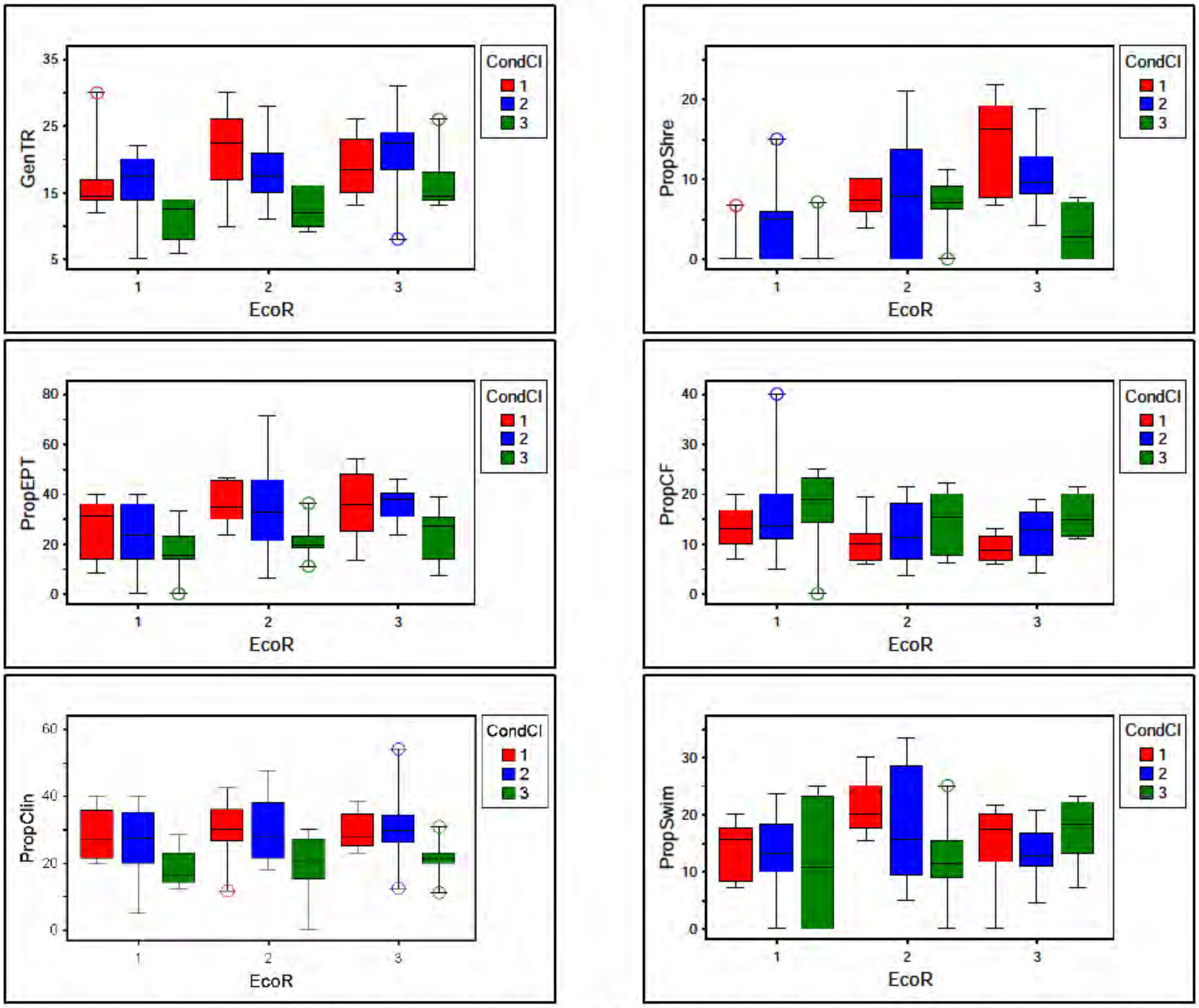


Figure D-3. PCA ordination of abiotic data collected from 83 sites in selected level IV ecoregions of the Southeastern Plains in Georgia. EcoR 1 = Dougherty Plain (65g); EcoR 2 = Tifton Upland (65h); EcoR 3 = Atlantic Southern Loam Plains (65l).



GenTR = Genus taxa richness; PropEPT = Proportion genus-level EPT richness; PropClin = Proportion genu-level clinger richness; PropShre = Proportion genus-level shredder richness; PropBurr = Proportion genus-level burrower richness. Bioclass 1 = NCDWR "Excellent" sites; Bioclass 2 = NCDWR "Good+Good/Fair+Fair" sites; Bioclass 3 = NCDWR "Poor" sites.

Figure D-4. Discriminatory biological metrics in the Piedmont (45) and Blue Ridge (66) ecoregions. Note that not every metric demonstrates suitable discriminatory power in both ecoregions. See text for additional discussion.



GenTR = Genus taxa richness; PropEPT = Proportion genus-level EPT richness; PropClin = Proportion genu-level clinger richness; PropShre = Proportion genus-level shredder richness; PropCF = Proportion genus-level collector-filterer richness; PropSwim = Proportion genus-level swimmer richness. CondCl 1 = Good abiotic conditions; CondCl 2 = Fair abiotic conditions; CondCl 3 = Poor abiotic conditions. EcoR 1 = Dougherty Plain (65g); EcoR 2 = Tifton upland (65h); EcoR 3 = Atlantic Southern Loam Plains (65l).

Figure D-5. Discriminatory biological metrics in selected level IV ecoregions of the Southeastern Plains in Georgia. Note that not every metric demonstrates suitable discriminatory power in all ecoregions. See text for additional discussion.

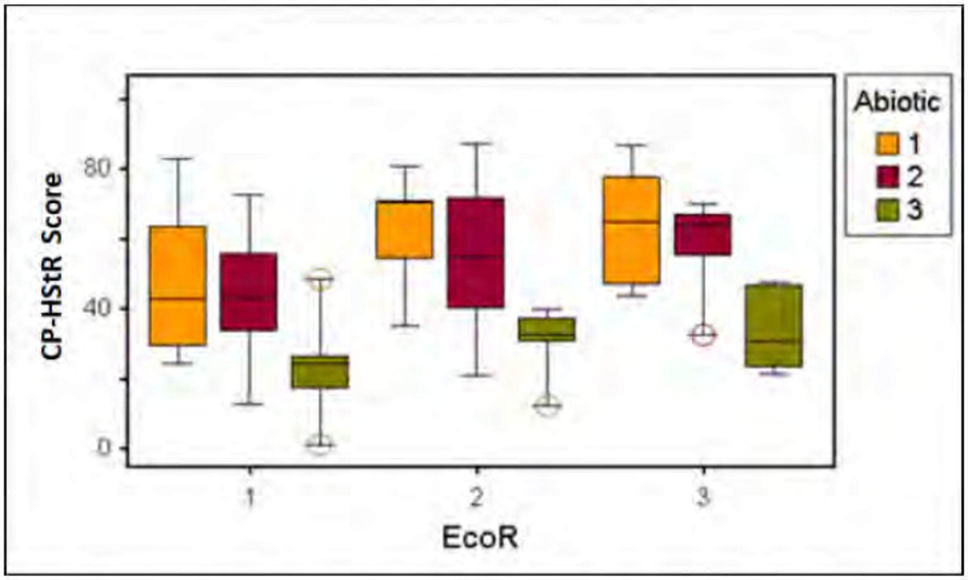


Figure D-6. Discriminatory power of CP-HStR scores to differentiate sites among abiotic condition classes derived from PCA in the Southeastern Plains ecoregion of Georgia. Abiotic 1 = Good abitoic conditions; Abiotic 2 = Fair abiotic conditions; Abiotic 3 = Poor abiotic conditions; EcoR 1 = Dougherty Plain (65g); EcoR 2 = Tifton Upland (65h); EcoR 3 = Atlantic Southern Loam Plains (65l).

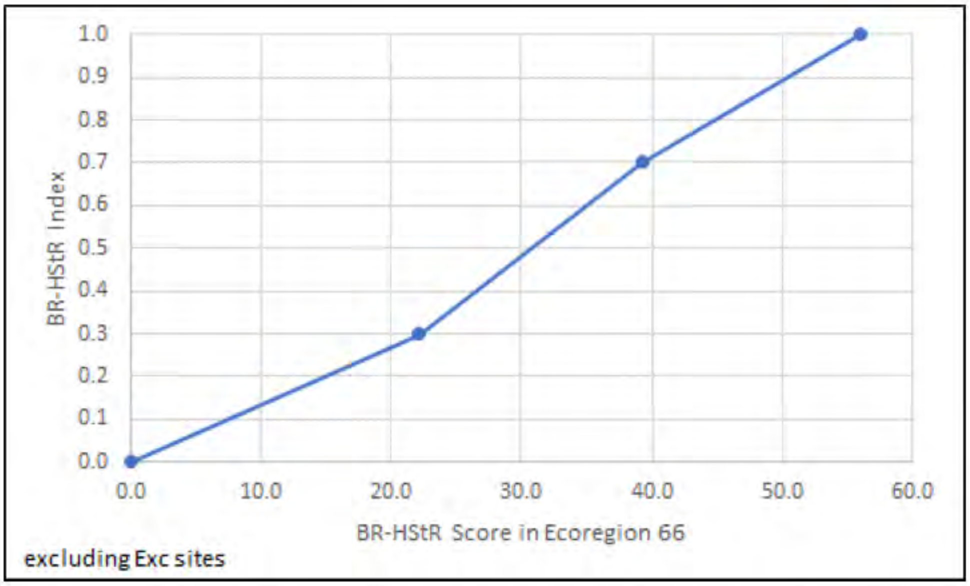


Figure D-7. Georgia SQT stream mitigation biological reference curve for the Blue Ridge ecoregion (66).

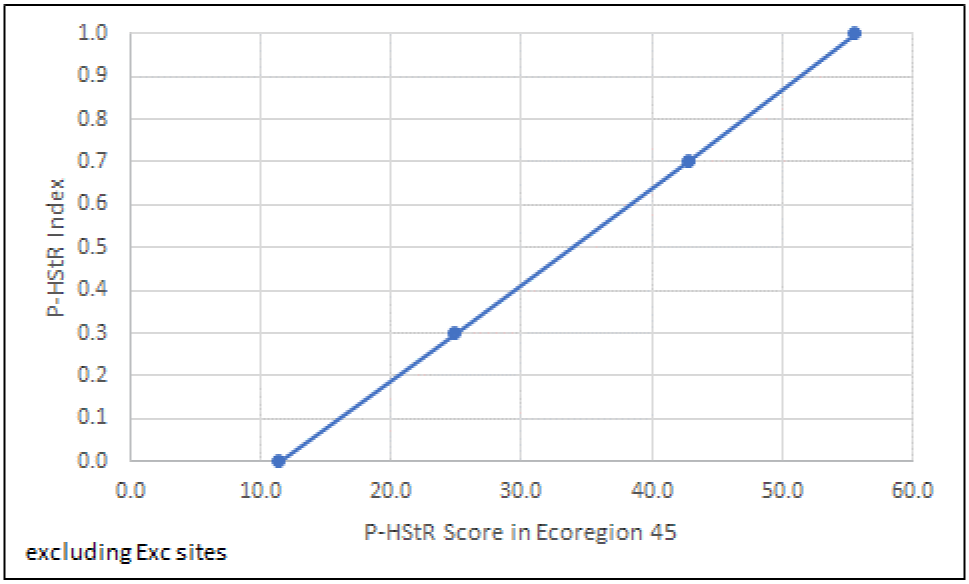


Figure D-8. Georgia SQT stream mitigation biological reference curve for the Piedmont ecoregion (45).

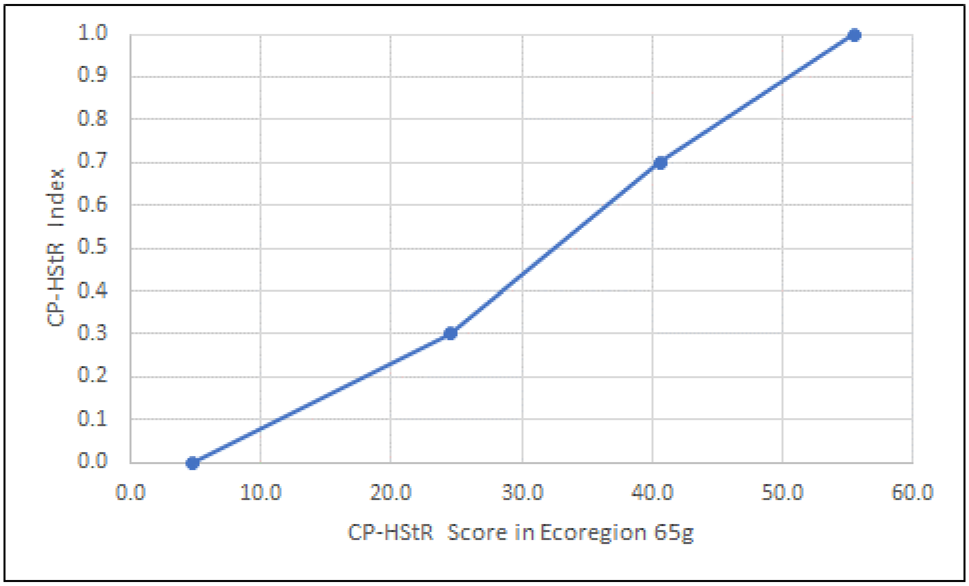


Figure D-9. Georgia SQT stream mitigation biological reference curve for the Dougherty Plain ecoregion (65g).

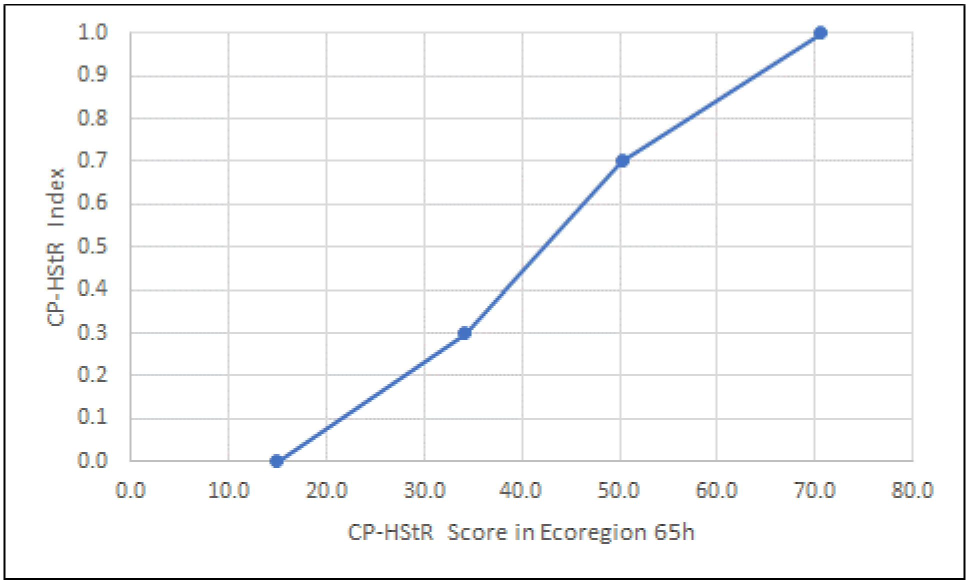


Figure D-10. Georgia SQT stream mitigation biological reference curve for the Tifton Upland ecoregion (65h).

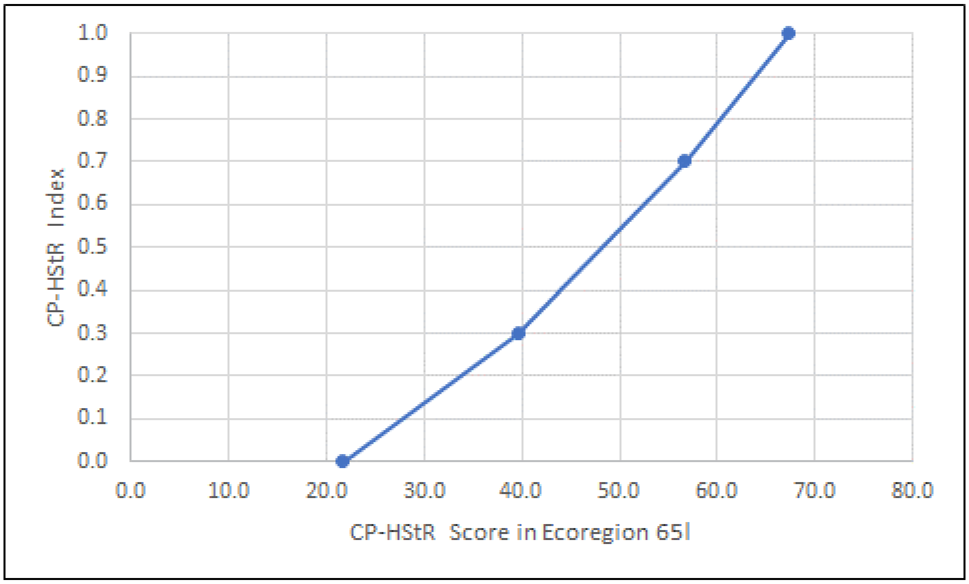


Figure D-11. Georgia SQT stream mitigation biological reference curve for the Atlantic Southern Loam Plains ecoregion (65l).

APPENDIX D-I

Blue Ridge

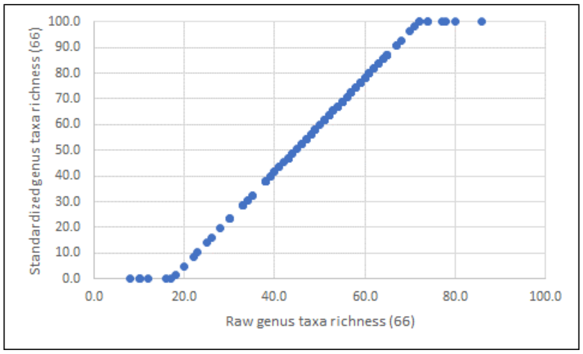


Figure D-I(a). Raw vs. standardized genus taxa richness in the Blue Ridge ecoregion (66).

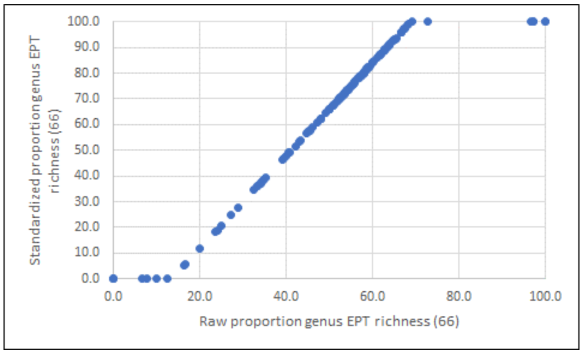


Figure D-I(b). Raw proportion vs. standardized proportion of genus EPT richness in the Blue Ridge ecoregion (66).

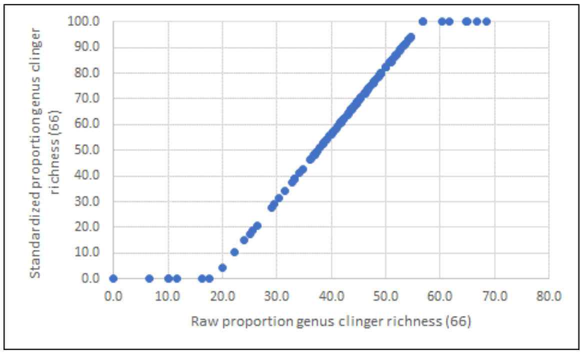


Figure D-I(c). Raw proportion vs. standardized proportion of genus clinger richness in the Blue Ridge ecoregion (66).

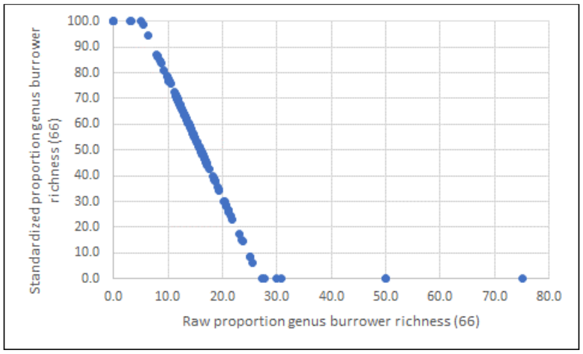


Figure D-I(d). Raw proportion vs. standardized proportion of genus burrower richness in the Blue Ridge ecoregion (66).

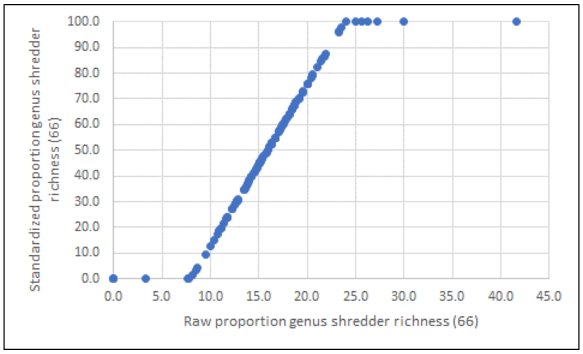


Figure D-I(e). Raw proportion vs. standardized proportion of genus shredder richness in the Blue Ridge ecoregion (66).

Piedmont

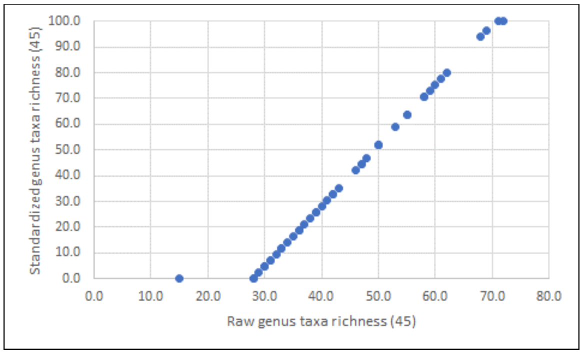


Figure D-I(f). Raw vs. standardized genus taxa richness in the Piedmont ecoregion (45).

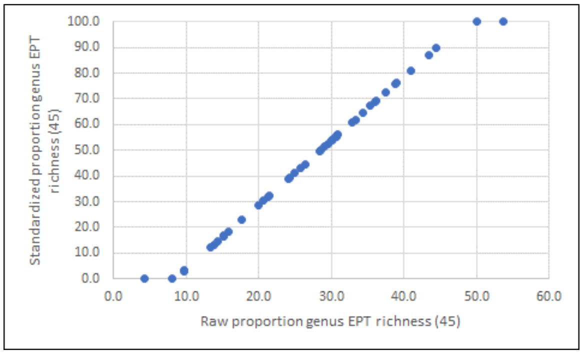


Figure D-I(g). Raw proportion vs. standardized proportion of genus EPT richness in the Piedmont ecoregion (45).

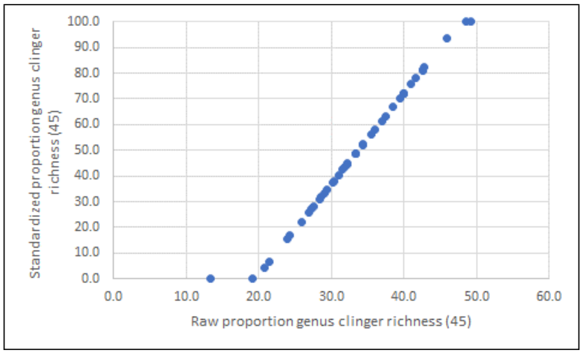


Figure D-I(h). Raw proportion vs. standardized proportion of genus clinger richness in the Piedmont ecoregion (45).

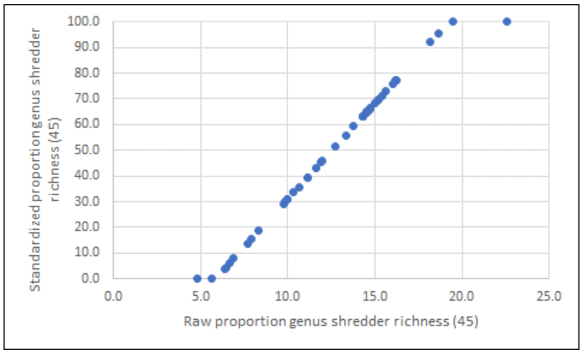


Figure D-I(i). Raw proportion vs. standardized proportion of genus shredder richness in the Piedmont ecoregion (45).

Southeastern Plains

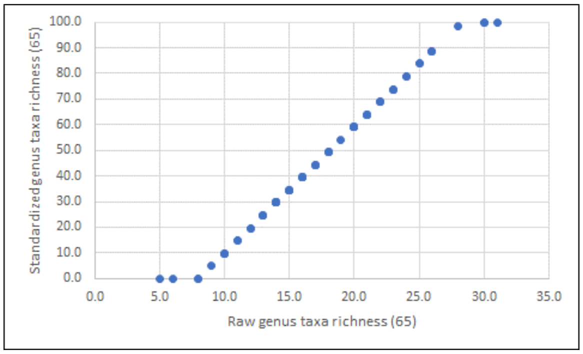


Figure D-I(j). Raw vs. standardized genus taxa richness in the Southeastern Plains ecoregion (65).

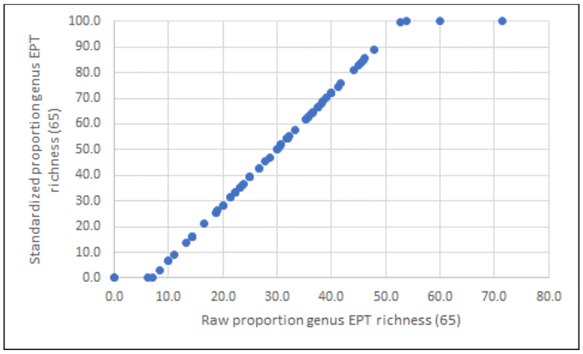


Figure D-I(k). Raw vs. standardized genus EPT richness in the Southeastern Plains ecoregion (65).

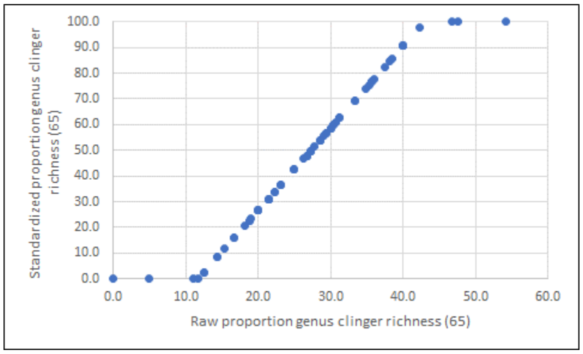


Figure D-I(l). Raw vs. standardized genus clinger richness in the Southeastern Plains ecoregion (65).

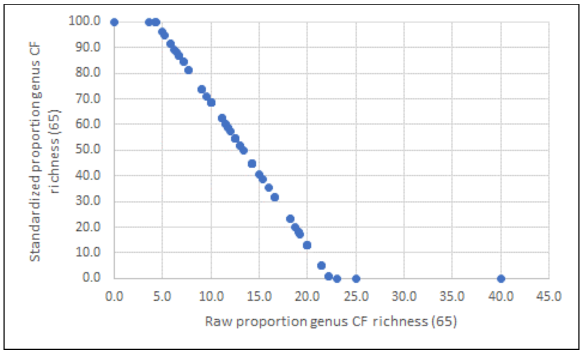


Figure D-I(m). Raw vs. standardized genus collector-filterer richness in the Southeastern Plains ecoregion (65).

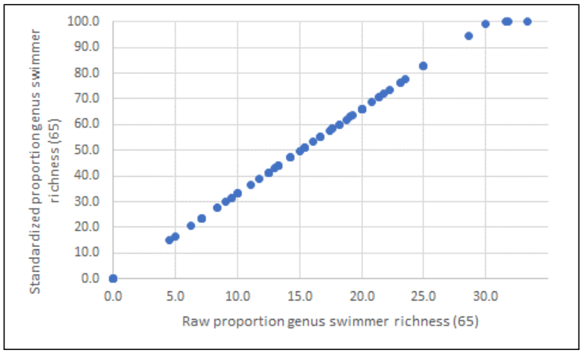


Figure D-I(n). Raw vs. standardized genus swimmer richness in the Southeastern Plains ecoregion (65).

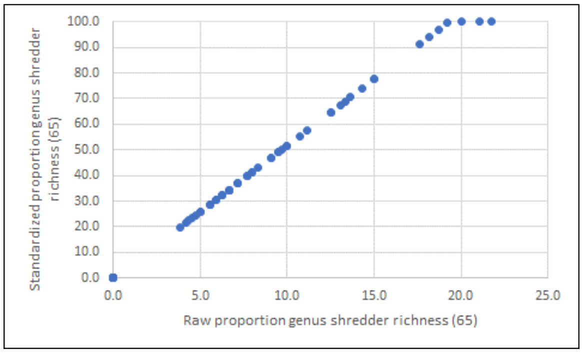


Figure D-I(o). Raw vs. standardized genus shredder richness in the Southeastern Plains ecoregion (65).