



**US Army Corps
of Engineers**
Omaha District

Wyoming Stream Quantification Tool User Manual (Version 2.0)



Wyoming Stream Quantification Tool
User Manual
Version 2.0

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Ecosystem Planning and Restoration

McCarthy Ecology

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Wyoming Game and Fish Department

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- Jeremy ZumBerge, Wyoming Department of Environmental Quality (WDEQ)

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The Wyoming Stream Quantification Tool is a modification of the Functional Lift Quantification Tool for Stream Restoration Projects in North Carolina (Harman and Jones 2016) regionalized for use in Wyoming. The North Carolina tool was developed by Stream Mechanics and EPR with funding and project management support from the Environmental Defense Fund. Many of the parameters, metrics and reference curves are unique to this region. The WSQT is one of several SQTs that have been developed for use in specific states, including North Carolina (Harman and Jones 2017), Tennessee (TDEC 2018), Georgia (USACE 2018b), Colorado (USACE 2020a), Minnesota (MNSQT SC 2020), and Alaska (Alaska Stream Quantification Tool Steering Committee 2021).

Table of Contents

Chapter 1. Introduction	1
1.1. Key Considerations	2
1.2. Stream Functions Pyramid Framework	2
1.3. WSQT Components	4
Chapter 2. Wyoming Stream Quantification Tool Workbook	7
2.1. Project Summary Worksheet	7
2.2. Restoration Potential Worksheet	14
2.3. Quantification Tool Worksheet	25
2.4. Flow Alteration Module Worksheet	45
2.5. Reference Curves Worksheet	47
Chapter 3. Wyoming Stream Impact Tool Workbook	49
3.1. Project Summary Worksheet	49
3.2. Functional Loss Worksheet	51
3.3. Existing Conditions and Proposed Conditions Worksheets	57
3.4. Flow Alteration Module Worksheet	65
3.5. Reference Curves Worksheet	66
Chapter 4. Data Collection and Analysis	67
4.1. Reach Delineation and Representative Sub-Reach Selection	67
4.2. Determining Stream Types	73
4.3. Parameter and Metric Selection	77
4.4. Bankfull Identification and Verification	84
4.5. Reach Hydrology and Hydraulics Functional Category Metrics	89
4.6. Geomorphology Functional Category Metrics	103
4.7. Physicochemical Functional Category Metrics	122
4.8. Biology Functional Category Metrics	125
4.9. Flow Alteration Module (FAM)	132
Chapter 5. Applications	140
5.1. Passive Versus Active Restoration Approach Examples	140
5.2. Savery Creek Project Example	144
Chapter 6. References	147

Appendices

Appendix A – Field Data Collection Methods for the WSQT

Appendix B – Forms: Required and Optional

Appendix C – Fish Community Assemblage Lists by Basin

Appendix D – Bankfull Verification Examples (reproduced from CSQT Checklist; USACE 2021)

Appendix E – Savery Creek forms and WSQT workbooks

List of Figures

Figure 1. Stream Functions Pyramid.

Figure 2. Stream Functions Pyramid Framework.

Figure 3. User Manual Directory.

Figure 4. WSQT Workbook Project Summary Example.

Figure 5. Wyoming Bioregions.

Figure 6. Example Worksheet Naming for Copies of the QT Worksheet.

Figure 7. Site Information and Reference Selection Input Fields in QT Worksheet.

Figure 8. Field Value Data Entry in the Condition Assessment Table.

Figure 9. Monitoring Condition Assessment Table in QT Worksheet.

Figure 10. Roll Up Scoring Example in QT Worksheet.

Figure 11. Baseflow Dynamics Scoring Exception.

Figure 12. Bankfull Dynamics Scoring Exception.

Figure 13. Lateral Migration Scoring Exception.

Figure 14. Macroinvertebrates Scoring Exception.

Figure 15. Functional Change Summary Table.

Figure 16. Functional Category Report Card.

Figure 17. Function-based Parameters Summary Table.

Figure 18. Example Functional Category Score Summary Table.

Figure 19. Example Functional Category Functional Foot Score Summary Table (FF).

Figure 20. Example Flow Alteration Module Condition Assessment.

Figure 21. Example Flow Alteration Module Functional Change Summary Table.

Figure 22. WSIT Workbook Project Summary Example.

Figure 23. Functional Loss Summary Table Example.

Figure 24. Site Information and Reference Stratification Input Fields in Existing Conditions Worksheet.

Figure 25. Roll Up Scoring Example in Existing and Proposed Condition Worksheets.

Figure 26. Example WSIT Flow Alteration Module Condition Assessment.

Figure 27. Example WSIT Flow Alteration Module Functional Change Summary Table.

Figure 28. WSQT and WSIT Process Flow Chart.

Figure 29. Reach and Sub-Reach Segmentation.

Figure 30. Rosgen Stream Classification Summary.

Figure 31. Parameter Selection Checklist.

Figure 32. Basic Suite of Parameters Included in All Assessments.

Figure 33. Metric Selection Guidance for Lateral Migration Parameter.

Figure 34. Metric Selection Guidance for Fish Parameter.

Figure 35. Bankfull Verification Process Flow Chart.

Figure 36. Lateral Drainage Area for Reach Runoff.

Figure 37. Wetted Dimensions for Baseflow Dynamics.

Figure 38. Examples of Side Channels.

Figure 39. Example of an Island Splitting the Main Flow Does NOT Count as a Side Channel.

Figure 40. Expected Riparian Width Calculation Relying on Meander Width Ratio.

Figure 41. Riparian Vegetation Sample Plot Layout.

Figure 42. Passive Restoration Approach WSQT Example.

Figure 43. Moderate Restoration Approach WSQT Example.

Figure 44. Active Restoration Approach WSQT Example.

Figure 45. Savery Creek Restoration WSQT Example Reach Breaks.

List of Tables

- Table 1. Functional Capacity Definitions Used to Define Threshold Values and Develop Reference Curves for the WSQT.
- Table 2. Stream Temperature Tiers in Wyoming.
- Table 3. Functional Category Weights.
- Table 4. Summary of Impact Assessment Options.
- Table 5. Impact Severity Tiers and Example Activities.
- Table 6. Impact Severity Tiers and PCS Calculation.
- Table 7. Applicability of Parameters Across Flow Type and in Multi-thread Systems.
- Table 8. Land Use Coefficients adapted from NRCS (1986).
- Table 9. Range of W/D Observed in the Compiled Geomorphic Reference Dataset for Wyoming.
- Table 10. BEHI/NBS Stability Ratings that Represent Actively Eroding and Non-eroding Banks.
- Table 11. MWR by Valley Type. Adapted from Harman et al. (2012) and Rosgen (2014).
- Table 12. How to Calculate the Field Value for SGCN Metric.
- Table 13. Flow Alteration Module Metrics.
- Table 14. FAM Metric Selection Based on Flow Regime.
- Table 15. Summary of Restoration Approach Scenarios.
- Table 16. Summary of Proposed and Monitored Changes in Functional Feet.

List of Examples

- Example 1: Setting Goals and Objectives and Parameter Selection
- Example 2: Indicators of Human-Altered Sediment Regimes
- Example 3: Completing the Restoration Potential Worksheet
- Example 4: Volcanics Reference Curve Selection
- Example 5: Populating Index Values in WSQT
- Example 6: Determining Proposed (Post-Impact) Condition Score
- Example 7: Project Reach Delineation
- Example 8: Existing Versus Proposed Reach Breaks
- Example 9: Determining Stream Types

Example 10: Disconnected Concentrated Flow Point

Example 11: Weighted BHR Calculation

Example 12: Weighted ER Calculation

Example 13: Calculation of Dominant BEHI/NBS

Example 14: Calculation of Percent Erosion

Example 15: Riparian Extent

Example 16: Calculation of SGCN Metric

Example 17: Calculation of Game Species Biomass

Example 18: Flow Alteration in the Fraser River, CO

Preface

Document History:

The Wyoming Stream Quantification Tool (WSQT), Beta Version was released for testing and public comment by the Omaha District Wyoming Regulatory Office in August 2017 for 120 days. The Wyoming Stream Technical Team gratefully received technical comments from four agencies and six practitioners. The WSTT reviewed and responded internally to technical comments received; and revised and updated the WSQT accordingly. The WSQT v1.0 was released for program implementation in Wyoming in July 2018. Updates included simplification of the tool; consideration of other methods, approaches, parameters, and metrics; and the development of a separate scientific support document to document the scientific rationale of the WSQT.

The WSQT v2.0 was released for program implementation in Wyoming in June 2023. Updates included revising the format of the WSQT workbook to accommodate multiple reaches; removing the Debit Tool worksheet from the WSQT workbook and creating a separate Wyoming Stream Impact Tool (WSIT) workbook; adding a Flow Alteration Module; revising parameters, metrics, and reference standards; and improving clarity regarding experience requirements, methods, proposed conditions and monitoring. Additional detail was also added to inform restoration potential, bankfull verification, and stream type definitions. See version table below for specific updates.

Document Availability and Revisions:

A copy of the WSQT and associated documents can be obtained on the Omaha District Wyoming Regulatory Office Mitigation website:

<https://www.nwo.usace.army.mil/Missions/Regulatory-Program/Wyoming/Mitigation/>

Or at the Regulatory In-lieu fee and Bank Information Tracking System (RIBITS) website under Assessment Tools for Wyoming:

<https://ribits.ops.usace.army.mil/>

Or at the Stream Mechanics website:

<https://stream-mechanics.com/stream-functions-pyramid-framework/>

A copy may also be requested from the USACE Wyoming Regulatory Office.

The following workbooks and documents are available:

1. Wyoming Stream Quantification Tool (WSQT) workbook – Microsoft Excel workbook described in detail in the User Manual.
2. Wyoming Stream Impact Tool (WSIT) workbook – Microsoft Excel workbook described in detail in the User Manual.
3. Wyoming Stream Quantification Tool User Manual – This manual describes the WSQT assessment and components, including the WSQT workbook and WSIT workbook, all

calculations performed by the workbooks, and how to collect data and calculate input for the workbooks.

4. Scientific Support for the WSQT – A comprehensive review of the function-based parameters and metrics, reference standards, stratification methods, scoring, and references used in the WSQT. The Scientific Support for the WSQT also includes a list of metrics summarizing this information.
5. Wyoming Stream Mitigation Procedures (WSMP; USACE 2018) – USACE procedures for using the WSQT workbook and Stream Impact Tool workbook to calculate credits and debits.

The WSQT and WSIT workbooks can be updated and revised as necessary in the future. Their architecture is flexible and future versions can accommodate additional parameters and metrics. If a user is interested in proposing additional parameters or metrics for incorporation into the tool, they should provide a written proposal for consideration. The written proposal should include a justification and rationale (e.g., data sources and/or literature references) and should follow the framework for identifying reference curves, threshold values, and index scores outlined in the Scientific Support for the WSQT (WSTT 2023). Field data supporting refinement of reference curves and evaluation of metrics are appreciated.

Technical feedback may be submitted to the Wyoming Regulatory Office at 2232 Dell Range Boulevard, Suite 210, Cheyenne, Wyoming 82009, or contact the office at (307) 772-2300; an email address can be provided on request.

Disclaimer:

The Wyoming Stream Quantification Tool (WSQT), including workbooks and supporting documents, evaluates the functional lift or loss at Clean Water Act Section 404 (CWA §404) impact sites and compensatory mitigation projects, respectively. Metrics are scored based on their current condition, as compared to reference condition. Consultation with the local Corps office is required prior to the use of this tool related to any CWA §404 activities. In part, or as a whole, the function-based parameters, metrics, and index values should not be the basis for engineering design criteria. The U.S. Army Corps of Engineers assumes no liability for engineering designs based on the WSQT. Designers should evaluate hydrologic and hydraulic monitoring, modeling, nearby stream morphology, existing stream conditions, sediment transport requirements, and site constraints to determine appropriate restoration design variables and specifications.

Version

<u>WSQT Version</u>	<u>Date finalized</u>	<u>Description</u>
BETA	July 2017	Draft version for review and comment.
1.0	July 2018	Revised in response to public comments and peer review.
2.0	June 2023	<p>Workbook and parameter edits:</p> <ul style="list-style-type: none"> • Formatted copies of QT worksheet can be made for multiple reaches • Aesthetic updates • Separate WSIT workbook, Debit Tool worksheet removed • Within the WSIT the following were updated: terminology associated with debits, impact assessment options, impact severity tier descriptions and multipliers, and default scores • Restoration Potential worksheet incorporates the Catchment Assessment • Added flow alteration module • Flow alteration and plan form parameters were removed from the reach-scale assessment • Baseflow and bankfull dynamics parameters were added to the reach-scale assessment <p>Additionally, the following metrics were updated:</p> <ul style="list-style-type: none"> • Side channel metric was added to assess floodplain connectivity parameter • Percent fines metric replaced the size class pebble count analyzer for bed material characterization parameter • Aggradation ratio metric was removed from bed form diversity parameter • Riparian extent replaced the riparian width to assess the riparian vegetation parameter • Reference curves were also updated, including those for land use coefficient, bank height ratio, entrenchment ratio, greenline stability rating, percent riffle, all four riparian metrics, and native fish species richness. <p>Relevant sections of this document and the Scientific Support document have been updated accordingly.</p> <p>Revisions were made throughout the manual and Appendix A for clarity regarding experience requirements, methods, proposed conditions, and monitoring. Additional revisions include: Appendix A content; the restoration potential process; stream type inputs and definitions; bankfull identification and verification process; lateral migration scoring exception; and assessment methods for land use coefficient, all riparian vegetation metrics, and fish sampling. Field forms were also updated and required documentation forms were added.</p>

Acronyms

BHR	– Bank Height Ratio
BEHI/NBS	– Bank Erosion Hazard Index / Near Bank Stress
CFP	– Concentrated Flow Point
CFR	– Code of Federal Register
CWA §404	– Section 404 of the Clean Water Act
ECS	– Existing Condition Score
EPA	– US Environmental Protection Agency
ER	– Entrenchment Ratio
FAM	– Flow Alteration Module
FF	– Functional Feet
GSR	– Greenline Stability Rating
LWD	– Large Woody Debris
LWDI	– Large Woody Debris Index
MCS	– Monitored Condition Score
MWAT	– Maximum Weekly Average Temperature
MWR	– Meander Width Ratio
PCS	– Proposed Condition Score
QT	– Quantification Tool, as in QT worksheet
RH&H	– Reach Hydrology and Hydraulics
RIVPACS	– River Invertebrate Prediction and Classification System
SGCN	– Species of Greatest Conservation Need
TMDL	– Total Maximum Daily Load
USACE	– United States Army Corps of Engineers, also abbreviated as the Corps
WDEQ/WQD	– Wyoming Department of Environmental Quality, Water Quality Division
WGFD	– Wyoming Game and Fish Department
WSII	– Wyoming Stream Integrity Index
WSIT	– Wyoming Stream Impact Tool
WSMP	– Wyoming Stream Mitigation Procedure
WSQT	– Wyoming Stream Quantification Tool
WSTT	– Wyoming Stream Technical Team
WYPDES	– Wyoming Pollutant Discharge Elimination System

Glossary of Terms

Affected stream length – Pertaining to the flow alteration module (FAM), the length of stream defined at the upstream end where impacts or flow protection would initiate, and at the downstream end by the location of the next water rights user, significant tributary junction, or terminus beyond which the flow modification has no material effect on SQT parameters.

Alluvial valley – Valley formed by the deposition of sediment from fluvial processes. See also definitions for confined alluvial valley and unconfined alluvial valley.

Armoring – Any rigid, human-made stabilization practice that permanently prevents lateral migration processes. More natural approaches to reduce excessive bank erosion, like toe protection and/or bioengineering, are not considered armoring. Examples of armoring include rock rip rap, gabion baskets, concrete, and other engineered materials that prevent streams from meandering.

Bankfull – Bankfull is a discharge that forms, maintains, and shapes the dimensions of the channel as it exists under the current climatic regime. The bankfull stage or elevation represents the break point between channel formation and floodplain processes (Wolman and Leopold 1957). Bankfull can also be referred to as the effective discharge, dominant discharge, or channel forming discharge.

Catchment – Land area draining to the downstream end of the project reach.

Colluvial or V-shaped valley – Valley formed by the deposition of sediment from hillslope erosion processes. Colluvial valleys are bowl-shaped and typically confined by terraces or hillslopes. Colluvium is material that originates on the hillslopes and moves down slope through mass wasting processes to the valley bottom. These valleys are confined and support straighter, step-pool type channels (e.g., Rosgen A, B, Bc, F). These valley types typically have a valley width ratio less than 7 and a meander width ratio less than 3. V-shaped valleys are often found in steep gradient headwater valleys.

Concentrated flow points – Storm drains, outfalls, eroding or constructed features, such as swales, gullies, or ditches. Natural ephemeral tributaries and outlets of stormwater best management practices (BMPs) are not considered concentrated flow points in this method.

Condition – The relative ability of an aquatic resource to support and maintain a community of organisms having a species composition, diversity, and functional organization comparable to reference aquatic resources in the region (33 CFR §332.2).

Condition score – A score from 0.00 to 1.00 that represents the condition or quality of a metric based on the departure from a reference condition. Metric-based condition scores (see also index value) are averaged to characterize condition for each parameter, functional category, and overall project reach.

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

Confined alluvial valley – Valley formed by the deposition of sediment from fluvial processes, typically confined by terraces or hillslopes that supports transitional stream types between step-pool and meandering or where meanders intercept hillslopes (e.g., Rosgen C, Bc). These valley types typically have a valley width ratio less than 7 and a meander width ratio between 3 and 4.

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).

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).

Field value – A field or desktop-derived measurement or calculation input into the WSQT for a specific metric. Units vary based on the metric or measurement method used.

Functional capacity – The degree to which an area of aquatic resource performs a specific function (33 CFR §332.2).

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

Functional category – The organizational levels of the stream quantification tool: Reach Hydrology and Hydraulics, Geomorphology, Physicochemical, and Biology. Each category is defined by functional statement(s).

Functional feet (FF) – Functional feet are the primary unit for communicating functional lift and loss. The functional feet for a stream reach are calculated by multiplying an overall reach condition score by the project reach length. The change in functional feet (ΔFF) is the difference between the Existing FF and the Proposed FF.

Functional lift – The difference in the condition score or functional feet before and after restoration or a permitted impact which results in improved function.

Functional loss – The difference in the condition score or functional feet before and after restoration or a permitted impact which results in a loss of function.

Functional Loss worksheet – This is a worksheet in the Wyoming Stream Impact Tool (WSIT) workbook and is used to calculate the functional loss due to proposed impacts.

Function-based parameter – A measure which characterizes a condition at a point in time, or a process (expressed as a rate) that describes and supports the functional statement for a given functional category.

Geomorphic pools – Pools that remain intact over time and across a range of flow conditions and are associated with large planform features. Examples include pools associated with the outside of a meander bend (streams in alluvial valleys) and downstream of a large cascade or step (streams in colluvial valleys).

Index values – Dimensionless values between 0.00 and 1.00 that express the functional capacity and relative condition of a metric field value compared with reference condition. Index values convert the different units used in the assessment methods to one scale. These values are derived from reference curves for each metric. Index values are combined to create parameter, functional category, and overall reach condition scores (see condition score).

Impact severity tiers – The Functional Loss worksheet provides estimates of proposed condition based upon the magnitude of proposed impacts, referred to as the impact severity tier. Higher tiers impact more stream functions.

Large woody debris – Dead and fallen wood over 1m in length and at least 10 cm in diameter at the largest end.

Measurement method – A specific tool, equation or assessment method used to inform a metric. Where a metric is informed by a single data collection method, metric and measurement method are used interchangeably (see Metric).

Metric – A specific tool, equation, measured value or assessment method used to evaluate the condition of a structural measure or function-based parameter. Some metrics can be derived from multiple measurement methods. Where a metric is informed by a single data collection method, metric and measurement method are used interchangeably (see Measurement method).

Multi-thread channel – A multi-thread channel consists of at least 3 primary flow paths that are active at baseflow for most of the reach length.

Native species – Riparian plant species that are native per the USDA PLANTS Database <http://plants.usda.gov>. Native cover excludes species that are introduced (i.e., non-native or naturalized).

Native flow – Estimates of the stream flows that would result from natural hydrologic processes such as rainfall-runoff and snowmelt-runoff without anthropogenic influence at a given location.

Performance standards – 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)

Project area – The geographic extent of a project. This area may include multiple project reaches where there are variations in stream physical characteristics and/or differences in project designs.

Project reach – A homogeneous stream reach within the project area, i.e., a stream segment with similar valley morphology, stream type (Rosgen 1996), stability condition, riparian vegetation type, and bed material composition. Multiple project reaches may exist in a project area where there are variations in stream physical characteristics and/or differences in project designs.

Reference aquatic resources – 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). Reference aquatic resources represent the full range of functional capacity characterized by SQT condition scores or index values.

Reference condition – The relative functional capacity of reference standard resources, characterizing the range of natural variability under undisturbed or least disturbed condition and representing the subset of reference aquatic resources that exhibit the highest level of function. In the SQT, this condition is considered functioning, culturally unaltered, or pristine for the metric being assessed (see Reference standard).

Reference curves – A relationship between observable or measurable metric field values and dimensionless index values. These curves take on several shapes, including linear, polynomial, bell-shaped, and others, to best represent the degree of departure from a reference condition for a given field value. These curves are used to determine the index value for a given metric in a project reach.

Reference standard – The subset of reference aquatic resources that are least disturbed and exhibit the highest level of function (see Reference condition).

Representative sub-reach – A length of stream within the project reach that is selected for field data collection of parameters and metrics. Sub-reach length and relative location within the project reach will vary by parameter.

Restoration potential – The highest level of restoration that can be achieved based on an assessment of the contributing catchment, reach-scale constraints, and the results of the reach-scale function-based assessment (Harman et al. 2012).

Riffle – Riffles are shallow, steep-gradient channel segments typically located between pools. Riffles are the river's natural grade control feature (Knighton 1998) and are sometimes referred to as fast-water channel units (Hawkins et al. 1993; Bisson et al. 2017). For purposes of the SQT, in meandering streams riffles broadly represent the section between lateral-scour pools known as a crossover, regardless of bed material size. Therefore, the term riffle also refers to the crossover section (ripples) in a sand bed channel or the cascade section of steep mountain streams. Riffles are measured from head of riffle to head of pool; thus, runs are considered riffles and glides are considered pools.

Riparian extent – The observed riparian extent reflects the percentage of the historic or expected riparian extent that currently contains riparian vegetation and is free from utility-related, urban, or otherwise soil disturbing land uses. The expected riparian extent corresponds to (Merritt et al. 2017):

- Substrate and topographic attributes -- the portion of the valley bottom influenced by fluvial processes under the current climatic regime,
- Biotic attributes -- riparian vegetation characteristic of the region and plants known to be adapted to shallow water tables and fluvial disturbance, and
- Hydrologic attributes -- the area of the valley bottom flooded at the stage of the 100-year recurrence interval flow.

Riparian vegetation – Plant communities contiguous to and affected by shallow water tables and fluvial disturbance within the stream corridor.

Side channels – Small open water channels that are connected to the main channel at one or both ends at a depth of at least one-half the bankfull riffle maximum depth.

Significant pools – Significant pools must be deeper than the riffle, have a concave shaped bed surface and a width that is at least half the width of the channel. The pool may also have a flatter water surface slope than the riffle; however, this is not always the case, e.g., a pool downstream of a log in a steep-gradient channel. Significant pools are often associated with wood, boulders, convergence, or backwater in the main channel.

Stream Functions Pyramid Framework – The Stream Functions Pyramid is comprised of five functional categories stratified based on the premise that lower-level functions support higher-level functions and that they are all influenced by local geology and climate. The Stream Functions Pyramid Framework includes the organization of function-based parameters, metrics (measurement methods), and performance standards to assess the functional categories of the Stream Functions Pyramid (Harman et al. 2012).

Stream restoration – 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). The term is used in this document to represent stream compensatory mitigation methods including rehabilitation, reestablishment, and enhancement.

Stream type – Stream types are based on the Rosgen stream type classification system and the basic fluvial landscapes where they typically occur, which are described in detail in Applied River Morphology (Rosgen 1996) and in Part 654 Stream Restoration Design National Engineering Handbook (NRCS 2007). Refer to Section 4.2 for additional detail.

- Existing stream type = Rosgen stream type before impact or restoration activities. Corresponds with the conditions observed during the existing condition assessment.
- Design stream type = Rosgen stream type that will be constructed. Also referred to as the as-built stream type
- Proposed stream type = Rosgen stream type post-impact or restoration activities. Corresponds with the conditions that are predicted for the proposed condition assessment that will be verified by monitoring in the WSQT workbook.
- Reference stream type = The Rosgen stream type that would naturally occur in a given valley, absent from human influences.

Threshold values – Criteria used to develop the reference curves and index values for each metric. These criteria differentiate between three condition categories: functioning, functioning-at-risk, and not functioning and relate to performance standards.

Unconfined alluvial valleys – Wide, low gradient (typically less than 2% slope) valleys that support meandering and anastomosed stream types (e.g., Rosgen C, E, DA). In alluvial valleys, rivers adjust pattern without intercepting hillslopes. These valleys typically have a valley width ratio greater than 7 (Carlson 2009) or a meander width ratio greater than 4 (Rosgen 2014).

Wyoming Stream Impact Tool (WSIT) workbook – The Microsoft-Excel workbook file used to evaluate loss at impact sites.

Wyoming Stream Quantification Tool (WSQT) – The WSQT consists of two workbooks, the WSQT workbook and the Wyoming Stream Impact Tool (WSIT) workbook. The WSQT are spreadsheet-based calculators that scores the difference in stream condition and functional feet before and after restoration or impact activities to determine functional lift or loss, and can also be used to determine restoration potential, develop monitoring criteria, and assist in other aspects of project planning (see WSQT workbook and WSIT workbook).

WSQT workbook – The Microsoft-Excel workbook file used to evaluate change in condition at project reaches.

Wyoming Stream Technical Team (WSTT) – Group tasked with developing function-based parameters, measurement methods, and reference standards for the WSQT.

Chapter 1. Introduction

The purpose of the Wyoming Stream Quantification Tool (WSQT) is to calculate functional lift and loss associated with restoration and impact activities within streams that fall within the scope of the Clean Water Act Section 404 (CWA §404) regulatory program to ensure that authorized stream impacts are adequately mitigated. The WSQT can be used for a proposed or active stream restoration project or a proposed stream impact requiring a CWA §404 permit. The WSQT can also be applied to restoration projects outside of the CWA §404 regulatory context.

The WSQT consists of two spreadsheet-based calculators, the WSQT and Wyoming Stream Impact Tool (WSIT) Excel Workbooks. Referred to together as the WSQT, these workbooks quantify change between an existing and future stream condition to inform permitting and compensatory mitigation decisions within the CWA §404 program. The workbooks characterize stream ecosystem functions by evaluating a suite of metrics representing structural or compositional attributes of a stream and its underlying processes. Metrics in the WSQT represent parameters that are often impacted by authorized projects or affected (e.g., enhanced or restored) by mitigation actions undertaken by restoration providers. As such, the **WSQT is not a comprehensive assessment of stream function**. The WSQT is an application of the Stream Functions Pyramid Framework (Harman et al. 2012) and uses function-based parameters and metrics to assess four functional categories: reach hydrology and hydraulics, geomorphology, physicochemical, and biology.

A main goal of the WSQT is to produce **objective, verifiable, and repeatable results** by consolidating well-defined procedures for quantitative measures of structural or compositional attributes of a stream and its underlying processes. Users may tailor their data collection to their particular site or project by selecting from 13 parameters and 29 metrics included in the WSQT, plus up to six metrics within the Flow Alteration Module. Metrics included in the WSQT represent parameters that are often impacted by authorized projects or affected (e.g., enhanced or restored) by mitigation actions undertaken by restoration providers. While some metrics and parameters available in the WSQT can be tailored to particular sites and projects, there is a base-set of metrics and parameters in the WSQT that should be assessed for all projects to provide consistency between impacts and compensatory mitigation and allow for more consistent accounting of changes in condition. Teams collecting and analyzing these data should have experience and expertise in botany, aquatic ecology, hydrology, and geomorphology as well as experience and expertise applying the assessment methods used to calculate the metrics included in the SQT. Interdisciplinary teams of at least two people with a combination of these skill sets are necessary to ensure consistent and accurate data collection and analyses.

This manual describes the WSQT and how to collect and analyze data used in the WSQT. The companion document, the Wyoming Stream Mitigation Procedure (WSMP) v2, provides policy direction for how and when the WSQT will be used for the CWA §404 regulatory program and how WSQT results are translated into credits and debits. Users are required to contact the Corps to obtain project-specific direction. The Scientific Support for the WSQT is a companion document that provides rationale for scoring in the WSQT and describes how measured stream conditions are converted into dimensionless index scores (WSTT 2023).

1.1. Key Considerations

The WSQT and supporting documentation have been developed primarily for use in the CWA §404 program to meet the function-based approaches set forth in the 2008 Rule (USACE 2008a). Therefore, several concepts are critical in understanding the applicability and limitations of the tool:

- The parameters and metrics in the tool were, in part, selected due to their sensitivity in responding to reach-scale changes associated with the types of activities commonly encountered in the CWA §404 program and commonly used in stream restoration. These parameters do not comprehensively characterize all structural measures or processes that occur within a stream.
- The WSQT assesses the same metrics at a site over time, thus providing information on the degree to which the condition of the system changes following impacts or restoration activities. We refer to the WSQT as a delta tool for this reason – it detects changes at a site over time. The same parameters and metrics must be used to compare scores across sites.
- The WSQT itself does not score or quantify watershed condition. Watershed condition reflects the external elements that influence functions within a project reach. Watershed condition is an important consideration when selecting a project site, determining the restoration potential of a site, and informing project design. Section 2.2 of this manual describes how watershed condition informs site selection and restoration potential.
- The WSQT is not a design tool. Many function-based parameters are critical to a successful restoration design but sit outside of the scope of the WSQT. The WSQT instead measures the hydraulic, geomorphological, and ecological responses or outcomes at a reach scale.

1.2. Stream Functions Pyramid Framework

The Stream Functions Pyramid (Figure 1) includes five functional categories: Level 1: Hydrology, Level 2: Hydraulics, Level 3: Geomorphology, Level 4: Physicochemical, and Level 5: Biology¹. The Pyramid organization recognizes that lower-level functions generally support higher-level functions (although the opposite can also be true) and that local geology and climate influence all functions. A functional statement defines each functional category.

The Stream Functions Pyramid Framework illustrates a hierarchy of stream functions but does not provide specific mechanisms for addressing functional capacity, establishing performance standards, or communicating functional change. The diagram in Figure 2 expands the Pyramid concept into a more detailed framework to quantify functional capacity, establish performance standards, evaluate functional change, and establish function-based goals and objectives.

¹ The WSQT merges the original Hydrology and Hydraulics categories into a new combined category (referred to as the Reach Hydrology and Hydraulics category).

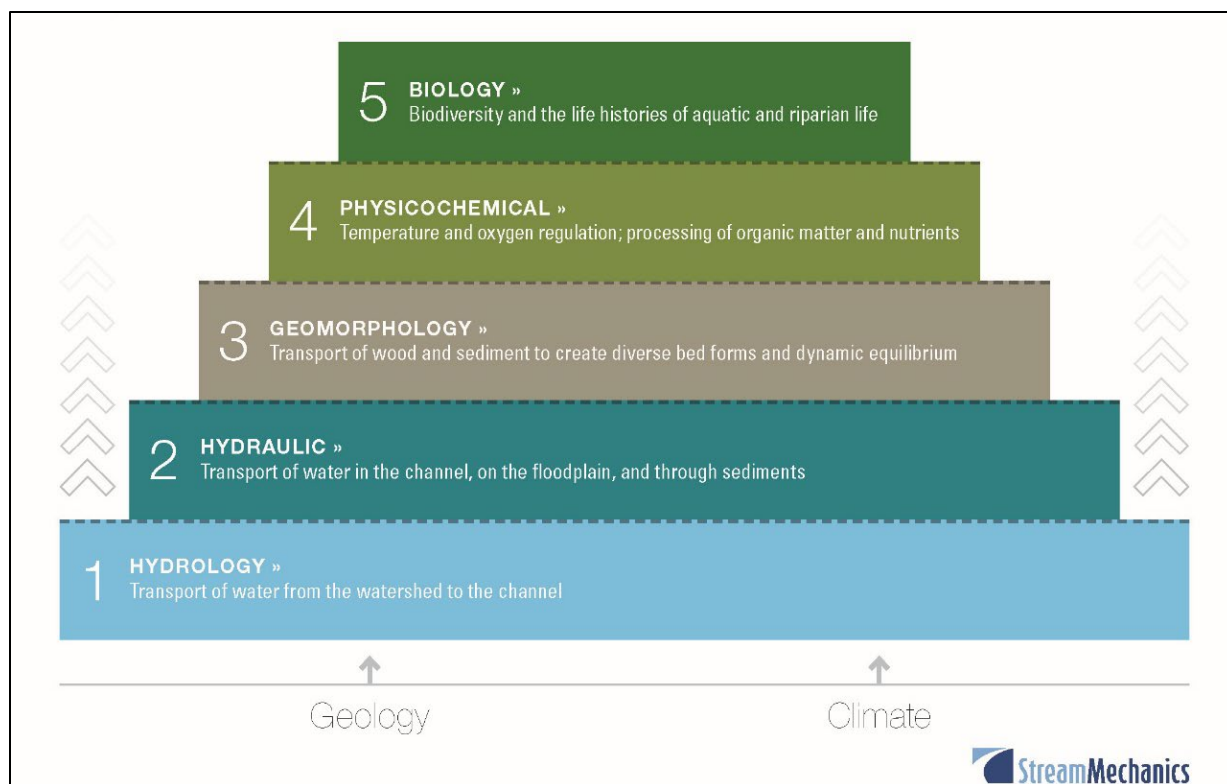


Figure 1. Stream Functions Pyramid (Image from Harman et al. 2012).

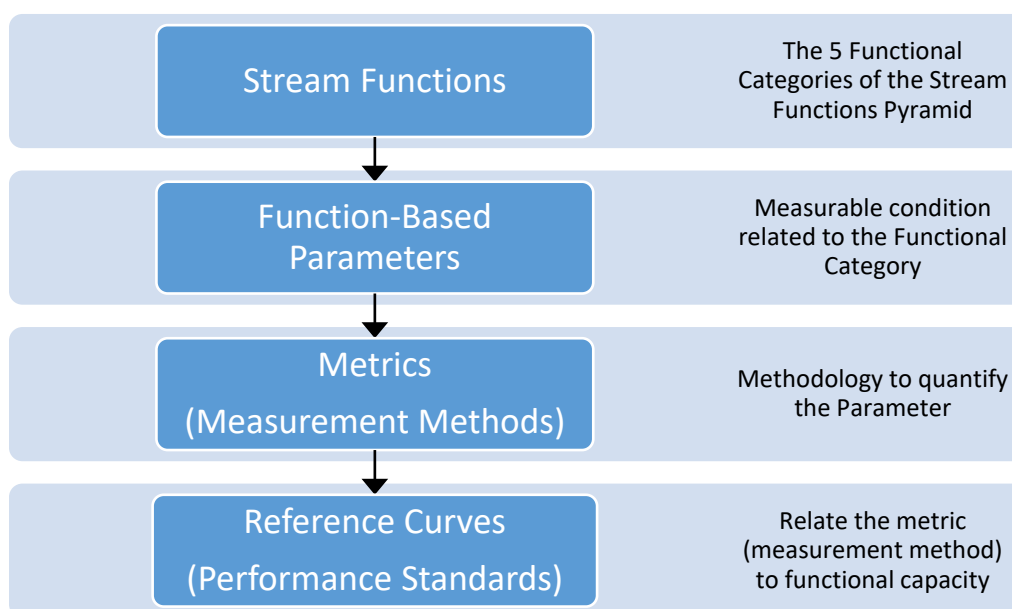


Figure 2. Stream Functions Pyramid Framework. Note: terms have been modified from Harman et al. (2012) to reflect WSQT application.

This comprehensive framework details forms of analysis to quantify stream functions and indicators of underlying stream processes. In this framework, function-based parameters describe and support the functional statements of each functional category, and the metrics (measurement methods) are specific tools, equations, and/or assessment methods that characterize site condition and inform function-based parameter scores. Performance standards are measurable or observable end points of stream restoration.

1.3. WSQT Components

The WSQT consists of two workbooks: the WSQT workbook and the Wyoming Stream Impact Tool (WSIT) workbook. Both workbooks include function-based parameters and metrics to quantify stream condition across the ecoregions and stream types found in Wyoming. Not all portions of the WSQT workbook or WSIT workbook will be applicable to all projects. Figure 3 can assist in navigating the user manual for specific project types. The WSQT workbook is a Microsoft Excel workbook used to calculate the change in metric scores resulting from a project, comparing the existing, pre-project, condition to the proposed, post-project condition. Monitoring is a key component of the WSQT workbook that verifies the proposed post-project conditions are achieved. The WSIT workbook incorporates the same parameters and metrics but provides a simplified approach to estimate functional loss for a project that is impacting stream functions. There is no monitoring component to verify estimates of functional loss in the WSIT workbook.

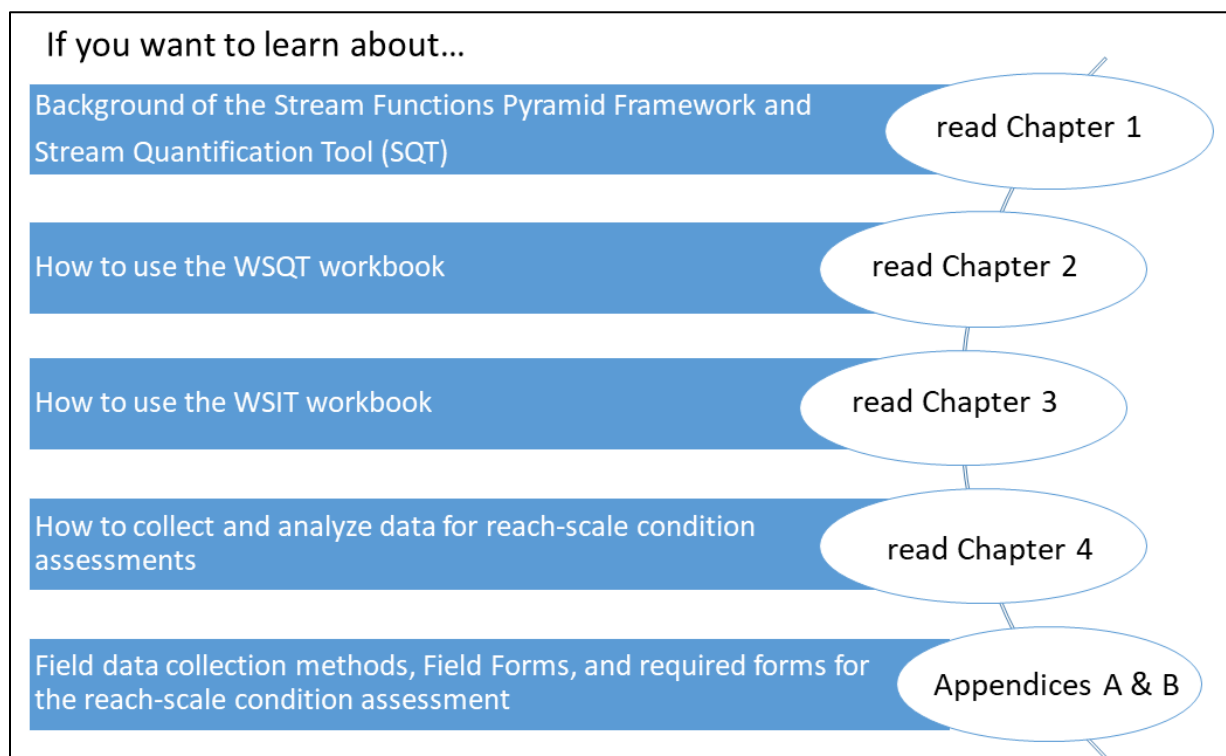


Figure 3. User Manual Directory. Other Chapters and Appendices contain examples and method specific data.

Each metric is linked to reference curves that relate measured field values to a regional reference condition. Field values for a metric are assigned an index value (0.00 – 1.00) using the applicable reference curves. The numeric index value range is standardized across metrics by determining how field values relate to functional capacity, i.e., functioning, functioning-at-risk and not functioning condition (Table 1). Reference curves are tied to specific benchmarks (thresholds) that represent the degree to which the aquatic resources are functioning and the degree to which condition departs from reference. Additional detail on function-based parameters and metrics and their reference curve development and stratification is provided in the Scientific Support for the WSQT (WSTT 2023).

Table 1. Functional Capacity Definitions Used to Define Threshold Values and Develop Reference Curves for the WSQT.

Functional Capacity	Definition	Index Value Range
Functioning	A functioning index value means that the metric is quantifying or describing the functional capacity of one aspect of a function-based parameter in a way that supports aquatic ecosystem structure and function. In other words, it is functioning at reference condition. ² A score of 1.00 represents minimally impacted to pristine condition. A range of index values (0.70-1.00) represents the range of natural variability in field values that may occur across reference sites, including least disturbed and minimally disturbed sites within reference datasets.	0.70 to 1.00
Functioning-at-risk	A functioning-at-risk index value means that the metric is quantifying or describing one aspect of a function-based parameter in a way that may support aquatic ecosystem structure and function but does not reflect reference condition nor is significantly degraded or impaired.	0.30 to <0.70
Not functioning	A not functioning index value means that the metric is quantifying or describing one aspect of a function-based parameter in a way that does not support aquatic ecosystem structure and function. An index value less than 0.30 represents an impaired or severely altered condition, and an index value of 0.00 represents a condition that provides no functional capacity for that metric.	0.00 to <0.30

For users proposing on-site compensatory mitigation for CWA §404, in most cases the impacted area and mitigation area will be located on different project reaches within the overall project area. In these cases, users would rely on the WSIT workbook to evaluate functional loss at the impacted reach and the WSQT workbook to evaluate functional lift at the mitigation reach. For example, if a user is proposing to channelize a portion of a stream, the functional loss would need to be calculated for the channelized, impacted, stream reach using the WSIT workbook.

² The reference standard concept aligns with the definition laid out by Stoddard et al. (2006) for a reference condition for biological integrity.

The user would have a separate WSQT workbook to calculate the functional lift for the stream reach that is restored to offset those impacts.

On the restoration side, functional change can be estimated during the design or mitigation plan phase and verified during post-construction monitoring events in the WSQT workbook. The 2008 Compensatory Mitigation for Losses to Aquatic Resources; Final Rule (2008 Rule; USACE 2008a) defines restoration as 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). The term is used more broadly in this document to represent compensatory mitigation methods including establishment, re-habilitation, reestablishment, and enhancement as defined in the 2008 Rule (USACE 2008a).

The WSQT workbook can also help determine if a proposed site has the potential to be a stream restoration or mitigation project and provides a framework to guide restoration planning. The process drivers, catchment assessment, and restoration potential process accompanying the WSQT (described in Chapter 2) help users determine factors that may limit what can be achieved by a stream restoration or mitigation project. This information can be used to develop project goals that match the restoration potential of a site. Quantifiable objectives, performance standards, and monitoring plans can be developed that link restoration activities to measurable changes in functional category condition and function-based parameters assessed by the tool.

On the impact side, functional loss can be estimated several ways using the WSIT workbook (Chapter 3). In the circumstance where impacts and mitigation are proposed within the same project reach, the user should consult with the Corps to determine which workbook to apply. For example, there may be circumstances where the underlying purpose of a project (e.g., stabilization, grade control) will result in a functional loss for certain parameters, while improvements to other parameters or metrics are proposed (e.g., riparian vegetation, native vegetation cover). Additionally, if post-project monitoring is needed, the WSQT workbook can be used to evaluate and monitor changes in condition within the project reach.

Chapter 2. Wyoming Stream Quantification Tool Workbook

The WSQT workbook (WSQT v2.xlsx) is a Microsoft Excel workbook comprised of five visible worksheets and one hidden worksheet. This workbook can be used to calculate functional change and track monitoring events within project reaches. There are no macros in the workbooks and all formulas are visible, though locked worksheets prevent editing.

The WSQT workbook is a project- or stream-based workbook that includes input for up to 10 reaches in a project area. Copies of the Quantification_Tool (QT) and Flow_Alteration_Module (FAM) worksheets can be made, as needed, for additional reaches within a project area.

The worksheets in the WSQT workbook include:

- Project Summary
- Restoration_Potential
- Quantification_Tool (QT)*
- Flow_Alteration_Module (FAM)*
- Reference Curves
- Pull Down Notes – This hidden worksheet contains all the inputs for drop-down menus throughout the workbook.

* Users can make copies of the QT and FAM worksheets to capture multiple project reaches within a project area. The Project Summary worksheet will summarize data from up to ten QT worksheets and three FAM worksheets. For projects with more than 10 reaches, more than one workbook will be needed.

Each of the worksheets are described in the following sections.

2.1. Project Summary Worksheet

The purpose of the Project Summary worksheet is to describe the proposed project and provide a summary of the project reaches within the project area. This worksheet should be completed for all projects. Users input values into the gray cells and select inputs from the drop-down menus in the blue cells; white cells are locked and will auto-populate with input provided on another worksheet.

Programmatic Goals (Figure 4) – Programmatic goals are big-picture goals that generally represent the funding source or regulatory driver for the project. They are often broader than function-based design goals (described below) and are determined by the project owner or funding entity. Example programmatic goal statements include providing compensatory mitigation credit, meeting total maximum daily load (TMDL) requirements, addressing a watershed need like nutrient reduction, or addressing a species of concern. These goals tie back to the funding goals of a project but do not specifically tie to the reach-scale problem and solution.

A drop-down menu provides with the following options: Mitigation – Credits, Mitigation – Debits, TMDL, Grant, or Other. Space is provided for the user to expand on the programmatic goals of the project.

Programmatic Goals					
Select:	Other				
Expand on the programmatic goals of this project:					
Improve stream function, aquatic habitat, maintain existing facilities, maintain wetland mitigation, establish riparian vegetation.					
Project Description					
Project Name:	Savery Creek				
Project ID:					
Ecoregion:	Basins				
Bioregion:	Wyoming Basin				
River Basin:	Green River				
12-digit HUC:	140500030401				
Reach Summary					
Worksheet Title	Reach ID	Reach Description & Reach Break Criteria	ECS	PCS	ΔFF
QT_8	Reach 8-9	Sheet pile weir 8 to sheet pile weir 9, conditions between weirs are distinct.	0.43	0.55	156.0 P3
QT_9	Reach 9-10	Sheet pile weir 9 to sheet pile weir 10	0.44	0.56	265.4 P3
QT_10	Reach 10-11	Sheet pile weir 10 to sheet pile weir 11	0.43	0.47	43.6 P3
QT_11	Reach 11-12	Sheet pile weir 11 to sheet pile weir 12	0.39	0.53	141.4 P3

Figure 4. WSQT Workbook Project Summary Example.

Project Description (Figure 4) – Enter the following information, where applicable:

- Project name
- Project ID (e.g., permit number)
- Ecoregion (drop-down) – The ecoregion is based on the Level I Ecoregion descriptions from the USEPA: Great Plains, North American Deserts, and Northwestern Forested Mountains. In Wyoming, the North American Desert Ecoregion consists of the Wyoming Basin and is referred to as the 'Basins' ecoregion in the WSQT. The Great Plains ecoregion is referred to as the 'Plains'; and the Northwestern Forested Mountains is referred to as 'Mountains' in the WSQT.
- Bioregion (drop-down) – Bioregions are defined by WDEQ to classify groups of streams with similar physical, chemical, and biological traits (Figure 5; Hargett and Zumberge 2011). Bioregions are delineated using a hybrid classification approach that uses integrated cluster analyses of reference site macroinvertebrate data, GIS, nonmetric multidimensional scaling (NMS), and best professional judgment. The boundaries of the eleven bioregions were constructed using USEPA Level IV Ecoregions, elevation contours, watershed boundaries, bedrock geology, and stream origins and should not be considered precise boundaries. When a site falls on the edge of two bioregions, professional judgment may be needed to determine the appropriate bioregion.

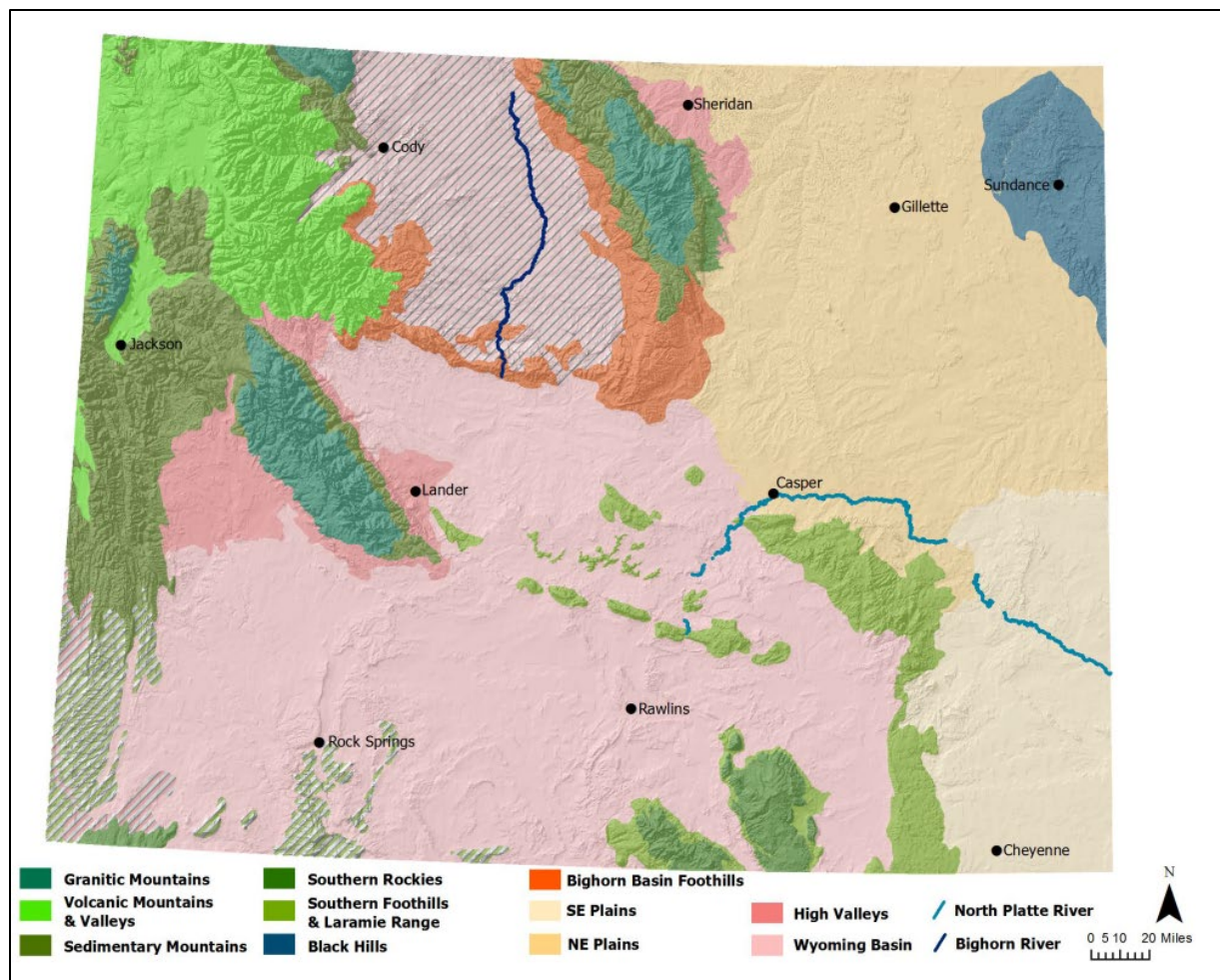


Figure 5. Wyoming Bioregions (reproduced from Hargett 2011). Cross-hatched areas are assumed similar to the bioregion of the same color.

- River Basin (drop-down) – Wyoming is subdivided into six large river basins (WGFD 2017): Bear River, Green River, NE Missouri Basin, Platte River, Snake/Salt River, and Yellowstone River. Select the river basin that the project reach falls within.
- 12-digit Hydrologic Unit Code (HUC)

Reach Summary (Figure 4) – Includes the following information for each project reach in the workbook:

- Worksheet title – enter the title for each relevant QT worksheet. The title must not include spaces and must be entered as an exact match into this cell (Figure 5).
- Reach ID – Each project reach within a project area should be assigned a unique identifier. See Section 4.1 for guidance on delineating project reaches.
- Reach Description – describe each reach.
- Reach Break Criteria – describe the characteristics that separate it from the other reaches in the project (see Section 4.1 for guidance on identifying project reaches).

- Existing condition score (ECS); proposed condition score (PCS); and change in functional feet (Δ FF) will auto-populate from the relevant QT worksheet (terms are defined in Section 2.3).

Flow Alteration Module Summary – Include the following information for each FAM:

- Worksheet title – enter the title for each relevant FAM worksheet. The title must not include spaces and must be entered as an exact match into this cell.
- Reach ID will auto-populate from the relevant FAM worksheet.
- Affected Reach Description & Reach Break Criteria – describe how affected stream length was determined, including the criteria for the beginning and end terminus of the affected stream length (see Section 4.9 for guidance on how to determine the affected stream length).
- Module ECS (mECS); module PCS (mPCS); and module change in functional feet (m Δ FF) will auto-populate from the relevant FAM worksheet.

Project Total Δ FF – The Project Total Δ FF will calculate the total Δ FF for the project based on the values in Column H from the Reach Summary and Flow Alteration Module Summary tables.

Aerial Photograph – There is space in the worksheet to insert an aerial photo of the project area. The imagery should label the upstream and downstream extent of each of the reaches (if there are multiple reaches).

Reach-scale Design Goals and Objectives – The first column includes Reach IDs, which will auto-populate from the relevant QT worksheet. The second column includes space for the user to explain their design goals and objectives for each reach (described in Section 2.1). Once the design goals and objectives have been completed, they will automatically display in the QT worksheet for each reach.

2.1.a. Developing Function-based Design Goals and Objectives

Design goals and objectives should be developed after the restoration potential has been determined (Section 2.2). Guidance on developing function-based goals and objectives is provided below based on Harman et al. (2012).

Design goals are statements about why the project is needed at the reach scale and describes a functional problem or desired solution. Common function-based design goals include:

- Restore [insert native fish species] to a reference condition.
- Improve habitat for [insert native fish species].
- Reduce sediment supply from eroding streambanks to improve channel stability.
- Reduce nitrogen and phosphorus loading from adjacent land uses.

Simple goal statements effectively communicate why the project is being done. Notice that these goal statements are specific, and do not simply state that the goal is to improve habitat and water quality. While improving habitat and water quality are common and needed goals, without a qualifier, they are too broad. A habitat only goal does not specify who the habitat is for, and different fish species require different habitats, e.g., cold water versus warm water fish. The same is true for water quality. Projects that address sediment as a water quality problem are

common. However, if the water quality issue is from metals or other contaminants, an entirely different approach may be needed, and it might not involve reach-scale channel improvements.

Tie Design Goals to Restoration Potential

Design goals should be cross referenced with the restoration potential of the reach to ensure that the goals do not exceed the restoration potential. Generally, goals that relate to channel stability and habitat can be achieved with a partial restoration potential result. Goals stating that there will be more fish, and certainly goals that anticipate restoring fish populations to reference condition, must have a full restoration potential result. The goal cannot exceed the restoration potential; a project cannot return a reach to reference condition without a full restoration potential. However, a project with partial restoration potential can create large amounts of functional uplift.

In the first example goal above, it states that a native fish species will be restored to a reference condition. This goal could be expanded to include different life stages, species diversity, etc. Regardless, since the goal is stating that there will be a fish community in the project reach that matches reference condition, the restoration potential results should equal “full,” meaning that the watershed condition along with the reach-scale restoration will support a reference condition fish community.

In the second goal example above, it states that the fish habitat will be improved. This goal could be achieved with a partial restoration potential because the goal does not relate to there being more (or any) fish in the reach after restoration construction is completed. In this framework, habitat is not biology. Biology includes the life histories of aquatic and riparian animal life. Habitat includes the water, bedforms, thermal regime, and other lower-level forms and processes on the Stream Functions Pyramid that support biology.

Function-based Objectives

Objectives explain *how* the project goals will be achieved. Objectives are specific, tangible and can be validated with monitoring and performance standards. Design objectives, in combination with the stated design goals, describe what the practitioner will do to address the functional impairment. Typically, objectives will explain how key function-based parameters like floodplain connectivity, flow dynamics, bed form diversity, lateral migration, and riparian vegetation will be changed to meet the goals. Example objectives that also communicate functional lift and state performance standards include the following:

- Improve floodplain connectivity by reducing bank height ratios from 2.0 to 1.0 and increasing entrenchment ratios from 1.2 to greater than 5.0.
- Improve bedform diversity by decreasing the pool spacing ratio from 10 to a range of 4 to 6, increasing the pool depth ratio from 1.5 to a range of 2 to 3, and decreasing the percent riffle from 95% to a range of 55 to 65%.
- Improve lateral migration by removing all armoring; changing the dominant BEHI/NBS rating from high/high to low/high; and reducing percent erosion from 30 to less than 5%.
- Improve riparian vegetation by increasing the observed riparian extent to equal the expected riparian extent and increasing the woody vegetation cover from 0 to 50%.

The above bullets are just examples. The final list of objectives should include all the function-based parameters and metrics applicable to the project reach. The values in the objective

statements should match the proposed condition field values expected at the end of the monitoring period only, and not the ultimate endpoint. For example, a restoration reach that starts as a cornfield will not achieve reference condition for riparian metrics within a five-year monitoring period.

How Goals and Objectives Assist with Parameter Selection

Design goals and objectives, along with restoration potential, can also be used to inform parameter selection (Section 4.3). For projects that have a partial restoration potential with goals that focus on channel stability, users may not need to include parameters in the physicochemical and biology categories. For projects that have a partial restoration potential that focus on habitat, users may include parameters in physicochemical and biology if the watershed condition is good enough to see an increase in index scores. In this example, it is okay if the functional capacity is not in the functioning range. For example, a project that is in a rural landscape setting with no or minor stressors in the catchment, and where the land use change is not trending towards more agriculture or urban may show an improved biology from not-functioning to functioning-at-risk. For projects that have full restoration potential and goals that include returning biology to a reference standard, users should include parameters through biology.

Example 1a: Setting Goals and Objectives and Parameter Selection

Consider a project that has 'Partial' restoration potential (Section 2.2). The catchment draining to the project is mostly range- or irrigated hay land. While the overall catchment health is fair, biological improvements are limited.

Goals: Improve aquatic habitat for native fish communities and reduce sediment supply from bank erosion.

Objectives: Improve bank stability by fencing out cattle and replanting riparian vegetation, improve bedform diversity (habitat) by adding large wood and reconstructing portions of channel.

Possible Parameter List:

- Reach Runoff
- Bankfull Dynamics
- Floodplain Connectivity
- Large Woody Debris
- Lateral Migration
- Bed Form Diversity
- Riparian Vegetation
- Nutrients*
- Macroinvertebrates*
- Fish*

*Note, because the goals and objectives focus on improving geomorphology functions, users may choose to monitor only metrics within reach hydrology & hydraulics and geomorphology categories. However, monitoring may also include physicochemical or biological metrics where a project is expected to show some improvement, even if the project is not expected to restore nutrients, macroinvertebrates, and fish parameters to a reference condition.

Example 1b: Setting Goals and Objectives and Parameter Selection

Consider an urban project with a primary goal of stabilization to protect a sewer line that shares the valley with the stream channel. The project reach has 'Partial' restoration potential (Section 2.2). The catchment draining to the project is mostly urban. Since the overall catchment health is fair/poor, biological improvements are not expected.

Programmatic goals: Protect the sewer line by creating a stable channel that requires no or minimal maintenance. Minimize impacts to stream functions (i.e., project yields minimal or no debits).

Design goals: Protect sewer line, improve sediment transport, reduce bank erosion, improve riparian vegetation.

Objectives:

- No functional loss of lateral migration by hard armoring 25% of streambanks to protect infrastructure by changing the dominant BEHI/NBS rating from high/high to moderate/moderate and reducing percent streambank erosion from 80 to 25%.
- Streambank erosion will be reduced through hard armoring banks critical to sewer line protection and stabilizing other eroding banks throughout the reach. Bank stabilization includes decreasing the slope ('laying the banks back'); installing biodegradable coir fiber matting with native seed mix and plantings to provide long-term stability; and installing in-stream structures that center the flow and reduce near bank stresses.
- Bed form diversity will be improved through installation of in-stream structures that create deeper pools than the existing pools.
- Sediment transport improvements will be observed through the long-term observation of reduced bank erosion and maintenance of the pool depths using the pool depth ratio metric.
- The streamside riparian vegetation will be improved through increased woody cover that will be managed and maintained regularly by the City.

Possible Parameter List:

- | | |
|---------------------------|-----------------------------------|
| • Reach Runoff | • Bed Material Characterization * |
| • Bankfull Dynamics | • Lateral Migration |
| • Floodplain Connectivity | • Bed Form Diversity |
| • Large Woody Debris * | • Riparian Vegetation |

*Use of LWD and bed material parameters would depend on the reference condition for the reach (pre-urbanization) related to natural LWD supply and natural bed material. Use of bed material characterization as a surrogate for sediment transport processes is encouraged if the metric is applicable. LWD would likely be managed in the urban setting but should be assessed if applicable.

2.2. Restoration Potential Worksheet

When applying the SQT for site selection, or at a mitigation or restoration site, users will need to determine the restoration potential for each reach within a project by completing the Restoration Potential worksheet, which considers both watershed and reach-scale factors that may influence the outcome of a project. Once the Restoration Potential worksheet has been completed, restoration potential results will automatically display in the QT worksheet for each reach. *The Restoration Potential worksheet does not need to be completed for impact-only projects that are using the WSQT workbook.*

Restoration potential is the highest level of restoration that can be achieved based on an assessment of the contributing catchment, reach-scale constraints, and the results of the reach-scale function-based assessment (Harman et al. 2012). Restoration potential is determined by the degree to which physical, chemical, and biological processes at both watershed and reach scales are maintained or restored. The “highest level” refers to the functional categories in the Stream Functions Pyramid, and whether a project can restore functional capacity within each of the categories to a reference condition.

Full Restoration Potential – The project has the potential to restore functions within all categories, including biology, to a reference condition (see Table 1 in Section 1.3). This is consistent with the ‘full-restoration’ concept identified by Beechie et al. (2010), where actions restore habitat-forming processes and return the site to its natural or reference range of biological conditions and dynamics.

Partial Restoration Potential – The project has the potential to improve some functions compared with pre-project or baseline conditions. One or more functional categories may be restored to conditions typical of or approaching reference condition, but some catchment stressors or reach-scale constraints are preventing the site from reaching full potential.

Partial restoration is the most common restoration-potential level for stream restoration projects. Watershed processes and reach-scale constraints influencing a project site may allow for some functions, such as floodplain connectivity, dynamic equilibrium, and in-stream habitat to be restored, but may limit the restoration of physicochemical and/or biological functions to reference condition. For partial restoration projects, improvements in all categories may be observed, but these improvements may not reflect a reference condition. This is similar to the ‘partial-restoration’ concept identified in Beechie et al. (2010), where actions restore some processes and functions, but do not return the site fully to its natural or reference range of conditions and dynamics.

There are likely situations where even partial restoration is not possible due to the severity of the catchment stressors and reach-scale constraints that may be outside the control of the practitioner. For example, flow alteration (a catchment-scale stressor) may modify the hydrologic and sediment transport processes within a catchment to such a degree that partial restoration is not feasible. In these cases, restoration potential may be limited to such a degree that the site may not be suitable for restoration activities.

2.2.a. Catchment Assessment – Step 1 for Determining Restoration Potential

The Restoration Potential worksheet outlines seven steps, including a catchment assessment, to assist in determining restoration potential for restoration and mitigation projects. The

catchment assessment is a decision-support tool rather than a quantitative scoring tool. Therefore, results from the catchment assessment are not scored in the WSQT but are used to help inform a restoration potential decision.

For many projects, only one catchment assessment will be needed for the project area. However, there may be instances where more than one watershed-scale assessment is needed, for example, where two (or more) streams with different catchment conditions occur within a project area. If this is the case, additional copies of the catchment assessment should be provided at the bottom of this worksheet and should be completed as needed.

The catchment assessment includes descriptions of processes and stressors that exist outside of the project reach and may limit restoration potential. The catchment assessment does not pertain to stressors within the project reach that can be addressed as part of restoration. The catchment assessment evaluates conditions upstream and sometimes downstream of the project reach. Instructions for collecting data and describing each process and stressor are provided in this section. The catchment assessment relies on spatial data available from various online or local resources and site-specific data that can be obtained through site walks or other observations within the project area. There are eleven defined categories, with space for an additional user-defined category. There are three choices to describe the catchment condition for each category: Good, Fair and Poor. Data needed to assess each category are described below along with good, fair, and poor descriptions. Data used to support each selection should be documented. Once the catchment assessment is completed, the user should rely on the results to complete Steps 2-4 in the Restoration Potential worksheet.

1. Impoundments

Impoundments are structures that can impede longitudinal (river corridor) connectivity. The presence of a dam or other barrier to fish passage downstream of the project may limit the potential to increase fish biomass in the project reach. A dam upstream of the project may allow organism recruitment from downstream; however, it may still limit longitudinal connectivity, impact catchment hydrology, alter sediment and temperature regimes, and impede delivery of organic material to the project reach.

Catchment assessment ratings: Catchments in good condition have no impoundments upstream or downstream of the project area. An impoundment that is proximate or otherwise has an adverse effect on the project area and/or fish passage would result in a lower rating.

Data Collection: The location of dams or other impoundments within the catchment can be determined through field walks, recent aerial imagery, or review of other landscape-scale information. Generally, this metric can be evaluated at the local level (e.g., within several stream miles or at the HUC 12 or HUC 14 watershed level); however, consideration should be given to large impoundments or critical fish barriers that may be less proximate but affect a large catchment area.

2. Flow Alteration

Flow alteration represents the role impoundments, water allocation, and effluent discharges can play in altering catchment hydrology and stream physicochemical and aquatic habitat conditions. Users should consider any alterations to the timing, magnitude, frequency, duration, and rate of change, as compared with the natural flow regime. Examples of flow alteration

include diversion dams withdrawing water for irrigation or municipal/industrial use, water storage reservoirs, hydroelectric operations, large effluent discharges, and trans-basin diversions (either depleting or augmenting flows). Landscape-scale information can be used to inform conclusions about flow alteration, including dam storage ratios, dam density, and the density of agricultural ditches. Dam storage ratios reflect the storage within the watershed compared with the average annual flow. Dam density is calculated as dams per kilometer of stream within each watershed.

Catchment assessment ratings: A catchment in good condition has a natural flow regime with little to no reduction or augmentation occurring upstream of the project reach. A catchment in poor condition has stream flows that are heavily depleted or augmented. A fair or poor rating may also occur where more than one aspect of the flow regime is altered (e.g., alterations to the timing, magnitude, frequency, duration, and rate of change), or where a single aspect of the natural flow regime is substantially modified.

Data Collection: The user can check e-permits through the Wyoming State Engineer's Office.³ Dam storage ratios, dam density, and the density of agricultural ditches are available through EPA's 2017 Preliminary Healthy Watersheds Assessment for each HUC 12 watershed in Wyoming. The location of dams, diversions, effluent discharges or other facilities within the catchment can be determined through field walks, recent aerial imagery, or review of other landscape-scale information. Flow alteration can also be determined by examining USGS or Wyoming State Engineer's Office gage records.

3. Urbanization

Land use is temporally variable and catchments that are currently in good or fair condition can degrade quickly with development. Active construction within a catchment can cause excessive erosion and sediment supply. Urban and residential development can drastically change the hydrology and quality of water coming into the project reach.

Catchment assessment ratings: A catchment in good condition, based on land use change, consists of rural or otherwise slow growth potential communities. Catchments evaluated as poor in this category, such as urban or urbanizing communities, have ongoing development or imminent large-scale development.

Data Collection: Trends in land use can be determined through examining aerial imagery from the last 20 years or by examining land cover data available online through the National Land Cover Database (NLCD).⁴ The NLCD will provide datasets for percent impervious cover, developed, and forested land from 1992, 2001, 2006, 2011, 2016, and 2019. Zoning designations and development plans can also be obtained from local governments and assessed for the project catchment. Landscape-scale information is also available through EPA's 2017 (updated 2021) Preliminary Healthy Watersheds Assessment for each HUC 12 watershed in Wyoming.⁵ Relevant data from this assessment include natural cover within the watershed, population density, imperviousness, and road density.

³ <https://seo.wyo.gov/>

⁴ <https://gapanalysis.usgs.gov/gaplandcover/data/download/>

⁵ <https://www.epa.gov/hwp/download-preliminary-healthy-watersheds-assessments>

4. Fish Passage

This metric takes into consideration anthropogenic barriers that reduce the mobility of aquatic species or otherwise limit their natural ranges. These barriers can include impoundments but can also include other anthropogenic factors that limit natural movements of fish, such as culverts, low head dams, and other physical or hydraulic barriers. This metric should be evaluated even in situations where these barriers are only historically present within the system.

Catchment assessment ratings: Catchments in good condition have no anthropogenic barriers while catchments in poor condition have fish passage barriers within 10 miles of the project.

Data Collection: Information sources described in the flow alteration and impoundment sections can be used to inform this metric. The Southeast Aquatic Resources Partnership has an aquatic barrier inventory.⁶

5. Organism Recruitment

Aquatic organisms rely on a variety of channel substrate sizes and characteristics to survive and reproduce. Impaired channel substrates, or other factors that limit the presence of aquatic organisms, surrounding the project reach can negatively impact macroinvertebrate community recruitment and the ability of fish to spawn. Recruitment and colonization of aquatic organisms within stream reaches is affected by the presence of desired communities in proximity to the project site (Blakely et al. 2006; Hughes 2007; Lake et al. 2007; Sundermann et al. 2011; Tonkin et al. 2014). Impairments to the channel, such as hardened substrates, excessive sedimentation, culverts, or piping, may prevent macroinvertebrate communities from inhabiting a stream reach and extended length of channel impairments may reduce the possibility of organism recruitment.

Catchment assessment ratings: Catchments in poor condition have substantial channel impairments preventing desirable taxa from inhabiting areas immediately upstream or downstream of the project reach (e.g., within 1 km). If the channel substrate immediately upstream or downstream of the project reach is impaired, but some proximate stream reaches support desirable aquatic communities, then the catchment is in fair condition. Impairment can include excessive deposition of fine sediments, hardened or armored channels (e.g., concrete channels or grouted riffles), culverts or piped channels or other similar modifications to the channel substrate.

The most important source of recolonization of benthic insects is drift from upstream. If upstream reaches or tributaries are hardened, recolonization of restored reaches will take much longer. Emphasis needs to be given to the quality of upstream reaches for organism recruitment. This category may not limit future restoration potential since benthic insects can recolonize via adult egg deposition from nearby catchments if drift from upstream reaches is unlikely. However, this kind of recruitment process may take much longer.

Data Collection: This category can be assessed by walking the site and the stream reaches immediately upstream and downstream of the project reach to determine if there are any impairments to organism recruitment including concrete, piped or hardened stretches of channel.

⁶ <https://connectivity.sarpdata.com/>

6. Wyoming Integrated Report (305(b) and 303(d) status) for Fisheries and Aquatic Life Uses

The Wyoming Department of Environmental Quality, Water Quality Division (WDEQ/WQD) maintains a list of impaired waterbodies (category 5 waters; the 303(d) list) as part of its biennial Integrated Report to EPA.

Catchment assessment ratings: Catchments in fair or poor condition include waters with Category 4 or 5 ratings. Category 5 waters with impaired fisheries or aquatic life uses are not attaining water quality standards and require a TMDL to determine pollutant reductions necessary to achieve standards. When a TMDL is completed and approved by EPA, the impaired waterbody is removed from Category 5 and placed in Category 4A (TMDL completed but not yet restored) until additional monitoring shows water quality standards are achieved. It is therefore important to check the State's most recent Integrated Report for both category 4A and category 5 (303(d) listed) waters in the catchment. Most stream restoration and compensatory mitigation projects do not restore a sufficient portion of the stream or catchment to overcome poor water quality. A poor or fair catchment condition in this category would indicate that a full restoration potential would be difficult or impossible unless a large percent of the catchment is restored.

Catchments in good condition include waters within Categories 1, 2 or 3, or waters that are unassessed. There may be waters with degraded biological condition that are unassessed, and thus are not on the 303(d) list. The other categories in this catchment assessment will assist in identifying potentially degraded waters that are not on the 303(d) list or do not have an approved TMDL. Additionally, recent water quality data can be used to justify a poor condition rating in this category even if the water is not listed as impaired by WDEQ.

Data Collection: Consult the most recent biennial Integrated Report.

7. Development (oil, gas, wind, solar, pipeline, mining, timber harvest, roads)

Development near the project site can significantly impact the functioning and restoration potential of a stream reach depending on the type of development and proximity to the project site. This category addresses large-scale land uses common to Wyoming that are often independent from urbanization. For example, roads or other infrastructure associated with energy development that is adjacent to or crossing a project reach is a design constraint that may limit the restoration potential of the project. Road embankments alter hydraulics while roads themselves can directly connect impervious surfaces to the stream channel.

Catchment assessment ratings: Catchments in poor condition have high levels of development in the contributing watershed, development proximate to project (within 1 mile), and/or the development has the potential to severely impact stream function. Existing or planned development with a high potential to impact the project reach would include sites that are significant sources of contaminants and/or sediment during rain events.

Data Collection: The presence of energy infrastructure, mining and silviculture operations, and roads near the project site can be determined in the field or using available aerial imagery and/or spatial data. Spatial data are available from the Wyoming Geospatial Hub⁷ and the

⁷ <http://geospatialhub.org/>

Wyoming Natural Resources and Energy Explorer (NREX).⁸ The most recent State Transportation Improvement Program (STIP)⁹ is available from the Wyoming Department of Transportation (WY DOT) to determine what projects are expected to receive funding during a 5-year time span. Landscape-scale information is also available through EPA's 2017 (updated 2021) Preliminary Healthy Watersheds Assessment for each HUC 12 watershed in WY¹⁰. Relevant data from this assessment includes mining density, road density, and road-stream crossing density.

8. WYPDES Permits

The Wyoming Pollutant Discharge Elimination System (WYPDES) program regulates water quality and monitoring procedures for point source discharges to water bodies. While the program ensures discharged water meets minimum water quality standards, standards may not exist for all relevant parameters (e.g., nutrients), or effluent limits may be technology-based rather than water quality-based (e.g., dissolved solids, conductivity, oil and grease), thus discharges may limit full restoration potential.

Catchment assessment ratings: A catchment in good condition would have no major and few minor WYPDES facilities upstream of the project reach while a poor catchment in this category would have WYPDES permitted facilities comprising a high percentage of the baseflow in the project reach or one or more facilities present within two miles upstream of the project reach. WYPDES stormwater and temporary discharge permits are excluded from consideration for this parameter.

Data Collection: The WDEQ hosts public data of the minor and major WYPDES permitted facilities.¹¹

9. Historic Railroad Tie Drives

From 1867 through the early 1900's, Wyoming trees were harvested in great numbers and milled into railroad ties. Ties were frequently cut in the winter and stacked near rivers to be run downstream in the spring during high flows. To accommodate the ties, channels were straightened, natural wood jams were removed, banks were sloped, and channels were generally simplified. There are many channels today that are still adjusting to the effects of this anthropogenic disturbance. Rivers throughout the Medicine Bow and Big Horn Mountains, and the upper Wind River and Green River basins all had periods of tie drives.

Catchment assessment ratings: A catchment in which many of the streams experienced tie drives may today still be degraded, especially for channel complexity and large woody debris metrics.

Data Collection: Streams within the noted watersheds should be assessed through field walks, aerial imagery, or review of other landscape-scale information to determine the extent of historic tie drives and resulting impairments.

⁸ <https://nrex.wyo.gov/>

⁹ http://www.dot.state.wy.us/home/engineering_technical_programs/stip_project_listing.default.html

¹⁰ <https://www.epa.gov/hwp/download-preliminary-healthy-watersheds-assessments>

¹¹ <https://deq.wyoming.gov/water-quality/wypdes/>

10. Riparian Vegetation

Riparian vegetation protects the stream channel from erosive runoff velocities and provides physicochemical benefits to surface runoff and groundwater contributions to stream channels. Wider riparian corridors provide more nutrient and pollutant removal benefits, but the relationship between width and benefit is not linear (Mayer et al. 2006).

Catchment assessment ratings: Catchments in good condition will have natural riparian plant communities extending across the majority (e.g., more than 2/3) of the 100-year floodplain, and riparian corridors that are over 80% contiguous along the contributing catchment stream length. Catchments in poor condition will have limited natural plant communities (e.g., extending across less than 1/3 of the 100-year floodplain), and/or gaps in the riparian corridor that exceed 30% or more of the contributing catchment stream length. These numeric examples are approximate and based on best professional judgment of the WSTT and select reviewers.

Data Collection: The 100-year floodplain can be estimated using available spatial data or Federal Emergency Management Agency delineated floodplains.¹² The prevalence of riparian vegetation on streams draining to the project reach can be determined using recent aerial imagery and/or by field observations within the catchment. Landscape-scale information is also available through EPA's 2017 (updated 2021) Preliminary Healthy Watersheds Assessment for each HUC 12 watershed in WY.¹³ Relevant data from this assessment could include population density within the riparian zone, road density within the riparian zone, natural cover within the hydrologically active zone, and high intensity land cover in the riparian zone.

11. Sediment Supply

The sediment supply entering a restoration reach plays an important role in determining restoration potential. Unnaturally high sediment loads from upstream bank erosion, upland erosion, or from the movement of sediment stored in the bed creates a challenging design problem (Example 2). If the design does not adequately address the sediment load, the restoration project could aggrade. Note that this category addresses human-altered sediment regimes; systems with naturally high sediment supplies would not score poorly unless the natural sediment transport processes were altered.

Catchment assessment ratings: If there are multiple lines of evidence

Example 2: Indicators of Human-Altered Sediment Regimes

Alternating point bars lacking vegetation indicate sediment storage in the channel that can be mobilized during high flows. Sediment is also being supplied to the channel from bank erosion.



¹² Notes: Verify floodplain mapping reflects recent topography and development. Consider that floodplain maps may not be reflective of the historic floodplain in urban or developed areas.

¹³ <https://www.epa.gov/hwp/download-preliminary-healthy-watersheds-assessments>

demonstrating excess sediment then there is a high sediment supply – if this is unnatural, the catchment condition is poor. If there are only a few small sources of sediment or sediment sources are naturally occurring, then the catchment condition is good.

Data Collection: Users should review recent aerial imagery of the catchment and walk as much of the upstream channel as possible looking for evidence of high sediment loads, including extensive bank erosion, mid-channel bars, lateral bars, sediment fans at mouths of tributaries and other evidence of excess human sources of sediment (see Example 2).

There are also tools available to estimate the sediment load from surrounding land use, including the Spreadsheet Tool for Estimating Pollutant Loads (STEPL v4.1; Tetra Tech, Inc. 2011) or the Watershed Assessment of River Stability and Sediment Supply (WARSSS; Rosgen, 2006). WARSSS is an intensive level of effort that is not necessary for this catchment assessment but could be used here if WARSSS was applied for other reasons in the project.

12. Other

This option is provided for the user to identify and document any stressor observed in the catchment that is not listed above but could limit the restoration potential or impair the hydrologic functioning of the project reach. For example, intense grazing practices upstream but outside of the project area may limit functional uplift within the project area.

2.2.b. Step 2 for Determining Restoration Potential

Review the ratings for each category in the catchment assessment and identify any categories with a 'poor' catchment condition. Are any of these stressors so severe they would prevent the project reach from achieving even partial restoration? A stressor that prohibits partial restoration may be considered a “deal breaker” that could affect site selection until catchment-scale stressors can be improved. For step 2, list any stressors that would prevent the project from achieving even partial restoration.

2.2.c. Step 3 for Determining Restoration Potential

For each category rated as 'fair' or 'poor', determine whether the stressor could be overcome by watershed management activities that are planned or actively occurring in the watershed but not directly associated with the proposed project. For example, if discontinuous flow is occurring upstream of the project reach, restoration may not be successful unless the practitioner can restore important aspects of the flow regime. Broad-scale efforts could include managing sources of sediment imbalances within the contributing watershed, improving stormwater management practices, restoring more natural hydrology, removing connectivity barriers, etc. Note: evaluating and addressing stressors to underlying hydrologic or sediment transport processes will require additional design and/or modeling analyses that are outside the scope of the SQT.

2.2.d. Step 4 for Determining Restoration Potential

Consider the project limits (Section 2.1) and the drainage area (Section 2.3.a). Compare the project size to the catchment size (length and/or area). Can the fair or poor ratings for each individual category be overcome by the scale or type of restoration project or by doing additional work in the catchment? For small catchments where the length or area of the restoration project is large compared to the total stream length or catchment area, reach-scale activities may be

able to overcome the stressors and perturbations. If many of the ratings can change from fair or poor to good, then full restoration may be possible. If not, then partial restoration is more likely.

2.2.e. Step 5 for Determining Restoration Potential

For each reach within the project, identify reach-scale human-caused constraints. Explain how they could limit restoration potential. Constraints are human-caused conditions, structures and land uses that inhibit restoration activities at the reach scale and are outside of the control of the practitioner. A constraint is different than a stressor which occurs at the catchment-scale, outside of the project reach. Constraints can negatively affect processes needed to support full restoration potential (and in extreme cases can even prohibit partial restoration).

Common constraints include land uses within the floodplain or valley bottom that minimize stream-corridor width; affect natural timing, magnitude, duration, frequency or rate of change of flows; function as migration barriers for fish; or prevent streambed elevation changes during design (e.g., roads, easement widths, levees/berms, dams/diversions etc.). Note that natural conditions are not constraints. For example, the presence of bedrock can limit changes to bed elevation and even prevent some aquatic species from migrating upstream. However, these are natural conditions that create habitat heterogeneity. They are not considered constraints in this methodology and would therefore not limit the restoration potential.

2.2.f. Step 6 for Determining Restoration Potential

For each reach within the project, determine the baseline, existing condition of the reach. Where possible, users should rely on field data entered in the QT worksheet to determine the baseline, existing condition of the reach. The QT worksheet will characterize functional capacity by parameter and functional category. In early planning stages, where data are not available to inform an existing condition assessment, estimates of baseline condition can be made from available site information. List the function-based parameters that are not-functioning or functioning-at-risk. Consider whether these parameters could be addressed as part of the project.

2.2.g. Step 7 for Determining Restoration Potential

Based on the results from Steps 1-6, determine whether the restoration potential is Full or Partial. Explain the reasons for your selection. Consider whether the parameters identified in Step 6 could be addressed as part of the project. Identify which parameters/functions could be restored to a functioning (reference) condition and which may not. The restoration potential for each project reach is displayed in the Site Information and Reference Selection section of the QT worksheet and the description is displayed in a text box at the top of the QT worksheet.

Example 3 shows the seven steps of the restoration potential process.

2.2.h. Using the WSQT to assist in Site Selection

The following section describes how the WSQT workbook, and in particular the Restoration Potential worksheet, can be used to assist with selecting or ranking the priority of a potential stream restoration or mitigation site. The key word here is “assist.” There are many other elements to include in a thorough site-selection process (ELI et al. 2016; Starr and Harman 2016); this section only illustrates the role of the WSQT. The Restoration Potential analysis combines information on the condition of the upstream watershed with reach-scale assessment

and constraints to gain an understanding of each site's restoration potential, and the results can be used to compare the restoration potential, site condition and level of restoration effort across multiple sites.

In the WSQT, functional lift is estimated from the difference in pre- and post-project condition scores, expressed as an overall change in functional feet. Therefore, if the user is deciding between multiple sites, the WSQT can be used to rank sites based on restoration potential, the amount of functional lift available and site condition. Due to time constraints, the user may want to evaluate potential mitigation or restoration project sites using rapid methods available for some metrics (see Chapter 4 and Appendix A). At this stage, a user will likely have to estimate post-project condition using best professional judgement. The user could model a variety of design approaches to see how much lift is reasonable for each parameter and how that lift relates to the programmatic goals, and reach-scale function-based goals. For example, a grant program with a programmatic goal of restoring a native fish species of greatest conservation need might look for stream reaches that are marginally degraded and with minimal stressors in the upstream watersheds.

The programmatic goals of a project will also influence site selection. For example, if the programmatic goal is to restore fish populations, users would need to identify a site with full restoration potential, meaning the reach-scale problems can be addressed through restoration activities and the fish community can rebound to a reference condition. Programmatic goals related to providing mitigation credit may prioritize different sites than the example above since they may look to maximizing lift, and thus credit, at a project site. Modest reach-scale problems yield a smaller amount of lift even though the final condition score may be high. Mitigation project site selection may prioritize highly degraded sites with the potential to improve as many function-based parameters as possible. The most uplift will occur on a site that has low existing functional capacity with full restoration potential. However, substantial uplift can also occur in highly degraded reaches with partial restoration potential.

Example 3: Completing the Restoration Potential Worksheet

In this hypothetical example, a 3,500 lf project is in open rangeland and the stream has been channelized. The drainage area to the downstream end of the project reach is 40 mi². Due to the presence of bedrock, the stream has not incised. Channelization, specifically channel straightening and removal of large wood, has prevented pool-forming processes and created over-widened conditions within the reach. Riparian vegetation has been substantially grazed, which negatively affects lateral migration; however, floodplain connectivity and reach runoff are in the functioning range of condition.

Step 1: Complete the catchment assessment.

For this example, the following ratings apply:

- | | |
|---|------------------------------|
| • Impoundments – Good | • Development – Fair |
| • Flow Alteration – Good | • WYPDES Permits – Good |
| • Urbanization – Fair | • Historic Tie Drives – Good |
| • Fish Passage – Good | • Riparian Vegetation – Fair |
| • Organism Recruitment – Fair | • Sediment Supply – Fair |
| • Wyoming Integrated Report status – Good | |

Example 3 Continued: Completing the Restoration Potential Worksheet

Step 2: Review the stressors identified in Step 1. Are there any stressors that are so severe they prevent even partial restoration potential? If so, list them here: **NONE**

Step 3: Review the stressors identified in Step 1. Are there any stressors that can be overcome by planned or actively occurring watershed management activities that are not associated with the stream restoration project. For example, the implementation of stormwater BMPs. **No. There are no activities planned for the upstream watershed that would change a rating on the catchment assessment form.**

Step 4: Compare the project size (length and area) to the catchment size. Can the scale of the restoration overcome catchment stressors and perturbations? Can the stressors be overcome by the size of the project or by doing additional work in the catchment? If many of the stressors can change Yes to No, then full restoration is likely. If not, then partial restoration is more likely. **No, the project reach length is small (3,500 feet) relative to the watershed size (40 mi²). This means that reach-scale improvements are unlikely to overcome watershed influences of physicochemical and biological functions.**

Step 5, 6 and 7:

For this example, ECS = 0.42 and existing FF = 1470. For Step 5, there are no reach-scale human-caused constraints.

Step 6: Determine the baseline condition of the reach and list the parameters that are not-functioning or functioning-at-risk. Whenever possible, use data from the SQT existing condition assessment performed on the reach, or other available site information.	Step 7: Based on results from the above steps, described the restoration potential. State as Partial or Full. Of the parameters listed in Step 6, identify the parameters/functions that could be restored to full functional capacity and which may not. Explain the reasons for your selection.	
	Description	Restoration Potential
Large woody debris and riparian vegetation are in a non-functioning (NF) range of condition; lateral migration and bedform diversity are in a functioning-at-risk (FAR) range of condition. Nutrients and macroinvertebrates are NF and fish communities are FAR, although these parameters were not selected in Parameter Selection.	Based on a design approach that includes fencing out cattle, re-establishing a channel pattern to create riffle-pool sequences, and adding large wood, the following changes are expected within a 5-year monitoring period: Riparian vegetation- NF to FAR, bedform diversity- FAR to F, large woody debris- NF to FAR, and lateral migration- FAR to F.	Partial

2.3. Quantification Tool Worksheet

The Quantification Tool (QT) worksheet calculates the change in condition for a project reach. There are three areas for data entry:

- Site Information and Reference Selection,
- Existing and proposed condition assessment field values,
- Monitoring condition assessment field values.

The QT worksheet also includes several summary tables discussed in the Scoring section below, as well as text boxes describing the reach's restoration potential and goals and objectives. Information in the summary tables is automatically calculated once field values have been entered in the QT worksheet. Text boxes are auto populated from information entered elsewhere in the WSQT workbook. Tables that contain monitoring data have alternating columns with and without stipple formatting for vertical tracking of data in the columns.

Use one QT worksheet for each reach within a project area. The user can duplicate this worksheet when the project area contains multiple reaches. Rename the worksheet to identify the project reach ID. **The worksheet title cannot contain spaces. The worksheet title must match the entry provided in the Project Summary worksheet. The text strings must match to populate results in the Reach Summary table** (Figure 6).

Reach Summary						
Worksheet Title	Reach ID	Reach Description	Reach Break Criteria	ECS	PCS	ΔFF
QT_8	Reach 8-9			0.44	0.56	156.0 P3
QT_9	Reach 9-10			0.15	0.26	243.3 P3

Project Summary	Restoration_Potential	QT_8	QT_9
-----------------	-----------------------	------	------

Figure 6. Example Worksheet Naming for Copies of the QT Worksheet. Top figure is from the Project Summary worksheet; bottom shows worksheet titles.

Users input values into the gray cells and select inputs from the drop-down menus in the blue cells; white cells are locked and will auto populate with input provided on another worksheet.

2.3.a. Site Information and Reference Selection

The Site Information and Reference Selection section consists of general site information and classifications to determine which reference curve(s) to apply in calculating index values for relevant metrics (Figure 7). For some metrics, reference curves are stratified by physical stream characteristics like stream type, temperature, and ecoregion. Information on each and guidance on how to select values is described below. While it may not be necessary to complete all fields (depending on parameter selection), some metrics will not be scored or may be scored incorrectly if data are not provided in this section.

The user should ensure entries in this section are accurate, **incorrect information in the Site Information and Reference Selection section may result in reference curves that are not suitable for the project.**

Users input values into the gray cells and select inputs from the drop-down menus in the blue cells; white cells are locked and will auto-populate with input provided on another worksheet. For fields with drop-down menus, if the correct selection is not included in the drop-down menus, the data to inform relevant metric index values are not available and users should review the Parameter and Metric Selection (Section 4.3) to determine if it is appropriate to assess relevant metrics at the project site. Additional information on how reference curves are stratified is included in the Scientific Support for the WSQT (WSTT 2023).

Site Information and Reference Selection	
Project Name:	Savery Creek
Reach ID:	Reach 8-9
Restoration Potential:	Full
Ecoregion:	Basins
Bioregion:	Wyoming Basin
River Basin:	Green River
Existing Stream Length (ft):	1300
Proposed Stream Length (ft):	1300
Existing Stream Type:	C
Design Stream Type:	C
Proposed Stream Type:	C
Reference Stream Type:	C
Valley Type:	Unconfined Alluvial
Drainage Area (sq. mi.):	28.25
Stream Slope (%):	0.22
Bankfull Width (ft):	
Strahler Stream Order:	3
Flow Type:	Perennial
Bed Material:	Gravel
Reference Vegetation Cover:	Woody
Stream Temperature:	Tier I (Cold)
Stream Productivity Rating:	Yellow or Green Ribbon
Not in Volcanic Mountains & Valleys bioregion. Option not available.	
Downstream Latitude (decimal degrees):	1
Downstream Longitude (decimal degrees):	2
Existing Sinuosity:	3
Proposed Sinuosity:	4
Most recent monitoring year:	2021

Figure 7. Site Information and Reference Selection Input Fields in QT Worksheet.

Project Name – This information will auto-populate from the Project Summary worksheet.

Reach ID – This information will auto-populate from the Project Summary worksheet.

Restoration Potential – Restoration potential is determined using the stepwise process described in Section 2.2. This information will auto-populate from the Restoration Potential worksheet.

Ecoregion – The WSQT uses the project's ecoregion to stratify reference curves for riparian vegetation and nutrients parameters. This information will auto-populate from the Project Summary worksheet.

Bioregion – Bioregion is used to select reference curves for percent riffle and both macroinvertebrate metrics. Note: Volcanic Mountains & Valleys (Volcanics) has its own reference curve for percent riffle; if the reach is within this bioregion and stream slope is less than 1.3%, users will be given the option whether to select this curve. This information will auto-populate from the Project Summary worksheet.

River Basin – Wyoming is subdivided into six large river basins. This input is not used in the scoring; it is used to select an appropriate fish species list for the number of native fish species metric. Appendix C contains fish assemblage lists for each river basin. This information will auto-populate from the Project Summary worksheet.

Existing Stream Length (ft) – Project reach stream length extends from the upstream to the downstream end of the project reach. This can be determined by surveying the profile of the stream, stretching a tape in the field, or remotely by tracing the stream centerline pattern from aerial imagery. Stream length is not used for reference curve stratification but is used to calculate functional feet.

Proposed Stream Length (ft) – Project reach stream length extends from the upstream to the downstream end of the project reach. The proposed length can be estimated from project design documents, and later verified using as-built conditions using the approaches described in Existing Stream Length above. Where stream length does not change post-project, the same value can be entered for the Existing and Proposed Stream Length. Stream length is used to calculate the functional feet, so both existing and proposed stream length must be recorded.

Existing Stream Type (drop-down) – This reflects the Rosgen stream type classification (Rosgen 1966) before impact or restoration activity. It is determined using existing condition data, as described in Section 4.2.

Design Stream Type (drop-down) – This is the Rosgen stream type (Rosgen 1996) that will be constructed as part of the project design (i.e., the as-built stream type). It is determined from the design process and other factors described in Section 4.2. This value can be left blank if not applicable to the project reach.

Proposed Stream Type (drop-down) – This reflects the channel dimensions and Rosgen stream type classification (Rosgen 1996) that is expected to form (evolve) by the **end of the monitoring period** (i.e., the restoration target at project closeout). It is informed by factors described in Section 4.2 and should be consistent with the estimated conditions identified in the proposed condition assessment.

Reference Stream Type (drop-down) – This reflects the Rosgen stream type classification (Rosgen 1996) that would naturally occur given the valley morphology and absent from anthropogenic influences. The WSQT relies on the reference stream type to stratify reference curves for the entrenchment ratio and pool spacing ratio metrics. See Section 4.2 for information on characterizing reference stream type.

Valley Type (drop-down) – Valley type is used to stratify reference curves for riparian extent and side channels metrics. The valley type options are unconfined alluvial, confined alluvial or colluvial/V-shaped:

- *Unconfined Alluvial Valleys*: wide, low gradient (typically less than 2% slope) valleys that support meandering or anastomosed stream types (e.g., Rosgen C, E, DA). In alluvial valleys, rivers adjust pattern without intercepting hillslopes. These valleys typically have a valley width ratio greater than 7.0 (Carlson 2009) or a meander width ratio (MWR) greater than 4.0 (Rosgen 2014).
- *Confined Alluvial Valleys*: valleys that support transitional stream types between step-pool and meandering or where meanders intercept hillslopes (e.g., C, Bc). These valley types typically have a valley width ratio less than 7.0 and a MWR between 3.0 and 4.0.
- *Colluvial/V-shaped Valleys*: valleys that are confined and support straighter, step-pool type channels (e.g., A, B, Bc). These valley types typically have a valley width ratio less than 7.0 and a MWR less than 3.0.

Drainage Area (sq. mi.) – The drainage area is the land area (in square miles) draining to the downstream end of a project reach and is delineated using available topographic data (ex. USGS maps, LiDAR or other digital terrain data). The drainage area is not used to stratify reference curves but is important to consider when determining restoration potential.

Stream Slope (%) – The WSQT uses stream slope to select the correct reference curves for percent riffle. The stream slope is a reach average and not the slope of an individual bed feature, e.g., riffle. The slope of the proposed condition is recommended, although the slope most similar to reference condition should be entered.

Bankfull Width (ft) – Bankfull width is used for stratification of the baseflow depth metric and serves as the denominator for the pool spacing ratio metric. The bankfull width can be the width of a stable riffle as described in Section 4.4.

Strahler Stream Order (drop-down) – Stream order as defined by Strahler (1957) is a classification based on stream/tributary relationships. Headwater streams are first order; the

Unless specified otherwise, the input in this section (e.g., slope, bankfull width) should align with values that would naturally occur given the valley morphology and absent from anthropogenic influences. The user can refer to reference stratification to determine critical values that impact scoring.

For example, a project that re-aligns a channel is likely to change the reach slope. The stream slope input is used to stratify percent riffle and there are different reference curves applicable to streams with slope of 3% or greater than for reaches with less than 3% slope. Therefore, there is no difference in scoring the percent riffle for a channel that is 0.5% slope compared to a channel that is 1% slope. However, where the stream slope is near the 3% threshold, it is critical to determine which reference curve represents the undisturbed condition for that reach.

stream becomes second order downstream of the confluence of two first order streams; the stream becomes third order downstream of the confluence of two second order streams; and so on. Stream order is not used for reference curve stratification; it is used for communication purposes.

Flow Type (drop-down) – Select the flow permanence of the project reach as perennial, intermittent, or ephemeral. Flow type is not yet used for reference curve stratification; it is used for communication purposes. Where flow type deviates from reference expectation users are required to contact the Corps to obtain project-specific direction.

Bed Material (drop-down) – The bed material characterization metric in the WSQT is only applicable to gravel or cobble bed streams. The proposed bed material is not used to stratify any reference curves but is important information to include for a project site.

Reference Vegetation Cover (drop-down) – Reference vegetation cover is used to determine whether to apply the woody or herbaceous cover metric. The reference vegetation cover is the community that would occur naturally at the site if the reach were free of anthropogenic alteration. The following classifications are based on the community types described in Carsey et al. (2003):

- *Woody sites* are those whose reference condition is greater than or equal to 20% absolute cover of woody vegetation. This includes scrub/shrub and forested systems.
- *Herbaceous sites* are those whose reference condition is less than 20% absolute woody cover.

The appropriate reference community type can be determined by locating a similar pristine or minimally altered reference site within the catchment area or watershed, researching historical and ecological descriptions of mature and undisturbed vegetation communities in the vicinity, or deduced through understanding the effects of land use practices and management on vegetation communities. For example, many of the unconfined or partially confined alluvial mountain valleys in the southern Rocky Mountains were likely dominated by woody riparian vegetation across the valley floor prior to anthropogenic human activities; therefore these should be classified as having woody reference vegetation cover, even though they are currently dominated by upland grasses. Some plains systems and other E channels may have an herbaceous reference condition with less than 20% woody vegetation cover.

Stream Temperature (drop-down) – The stream temperature tier is used to determine the correct reference curve for baseflow dynamics and temperature parameters (Table 2). Streams in Wyoming are classified by thermal tiers based on the modeled mean August stream temperature (Peterson 2017). Use the mean modeled August stream temperature from the Air, Water, & Aquatic Environments Program (AWAE 2016) to identify the appropriate tier.

Table 2. Stream Temperature Tiers in Wyoming.

Modeled mean August temperature (°C)	Tier	Tier Description
< 15.5	I	Cold
15.5 – 17.7	II	Cold-Cool
17.7 – 19.9	III	Cool
19.9 – 24.4	IV	Cool-Warm
> 24.4	V	Warm

Stream Productivity Rating (drop-down) – Select the stream productivity rating as: Blue Ribbon and non-trout; Red Ribbon; or Yellow or green Ribbon. This input is used to select the correct reference curves for the game species biomass metric. Use the [provided link](#) to identify if the stream is listed as blue, red, or yellow ribbon as determined by WGFD based on trout pounds/mile (Annear et al. 2006).¹⁴ If the stream is not listed, it is assumed to fall under the green-ribbon classification. If the stream supports non-trout game fish such as catfish, sturgeon or sauger, use the blue-ribbon classification.

Percent Riffle Reference Curve Option (drop-down) – Because of a naturally higher proportion of riffles, a separate reference curve for percent riffle exists for streams in the Volcanics bioregion. However, if a project site is in the Volcanics region and the slope is < 1.3%, it may be more appropriate to apply the low gradient reference curve; users will be prompted whether they want to opt out of the Volcanics reference curve for percent riffle: “Yes, opt out”, “No, use Volcanics reference curve for percent riffle” (Example 4). If opting out, the SQT will apply the reference curve for streams with <3% slope.

Downstream Latitude/Longitude – Enter the decimal degree latitude and longitude of the downstream extent of the reach. Latitude and longitude are not used for reference curve stratification and are for communication purposes only.

Existing Sinuosity – Sinuosity is calculated by dividing the stream thalweg distance by the straight-line valley length between the upstream and downstream extent of the project reach. Additional detail on calculating sinuosity can be found in Table 11-14 of Part 654 Stream Restoration Design National Engineering Handbook (NRCS NEH 2007). Sinuosity should be measured using recent aerial imagery and should be assessed over the entire project reach. If recent aerial imagery is not available or the stream channel is not visible on the imagery, then sinuosity should be measured in the field. Sinuosity is not applicable to multi-thread channels and no input is required when the reference stream type is D or D_A. Sinuosity is not used for reference curve stratification and is included for communication purposes only.

¹⁴ [https://wgfd.wyo.gov/Fishing-and-Boating/Stream-Classification#:~:text=Categories%20based%20on%20pounds%20of,\)%20%3C50%20pounds%20per%20mile.](https://wgfd.wyo.gov/Fishing-and-Boating/Stream-Classification#:~:text=Categories%20based%20on%20pounds%20of,)%20%3C50%20pounds%20per%20mile.)

Example 4: Volcanics Reference Curve Selection

Scenario A: The project reach is not located within the Volcanics bioregion – reference curve option is not available.

Reach ID:	Reach 1
Bioregion	Bighorn Basin
Stream Slope (%):	1
Not in Volcanic Mountains & Valleys bioregion. Option not available.	

Scenario B: The project reach is located within the Volcanics bioregion, and the project reach slope is less than 1.3%. The user has the option to apply either the reference curve for the Volcanics bioregion or the reference curve for streams with less than 3% slope.

Reach ID:	Reach 1
Bioregion	Volcanic Mountains & Valleys
Stream Slope (%):	1
Stream slope < 1.3%, opt out of Volcanic reference curve for percent riffle?	Yes, opt out

Scenario C: The project reach is located within the Volcanics bioregion, and the project reach slope is 3% - reference curve option is not available.

Reach ID:	Reach 1
Bioregion	Volcanic Mountains & Valleys
Stream Slope (%):	3
Stream slope \geq 1.3%, must use Volcanic reference curve for percent riffle. Option not available.	

Proposed Sinuosity – The proposed sinuosity can be estimated from project design documents, and later verified using as-built conditions. Where sinuosity does not change post-project, the same value can be entered for the Existing and Proposed Sinuosity. Since channel length affects the functional feet output of the WSQT there is a concern that users may be incentivized to unnaturally increase stream length. However, single-thread channels with high sinuosity are only supported in specific reach-scale settings.

Most recent monitoring year (drop-down) – As monitoring data are entered into the QT worksheet, a drop-down list of monitoring years will populate from the information entered into row 97. Select the most recent year from this drop-down list and the WSQT will display

summary data from that monitoring event in the Functional Change Summary Table, Functional Category Report Card and Condition Assessment Table.

2.3.b. Condition Assessment

After the Site Information and Reference Selection section is complete, the user can input data into the field value column of the existing and proposed condition assessment tables (Figure 8).

Functional Category	Function-based Parameter	Metric	Field Value
Reach Hydrology & Hydraulics	Reach Runoff	Land Use Coefficient	35
		Concentrated Flow Points (#/1000 LF)	0
	Baseflow Dynamics	Average Velocity (fps)	
		Average Depth (ft)	
Bankfull Dynamics	Width/Depth Ratio State (O/E)	1	
Floodplain Connectivity	Bank Height Ratio (ft/ft)	1	
	Entrenchment Ratio (ft/ft)	1.7	
	Percent Side Channels (%)		
Geomorphology	Large Woody Debris	LWD Index	
		LWD Piece Count (#/100m)	0
	Lateral Migration	Greenline Stability Rating	
		Dominant BEHI/NBS	M/H
		Percent Streambank Erosion (%)	14
		Percent Streambank Armoring (%)	3.3
	Bed Material Characterization	Percent Fines (% < 2mm)	
	Bed Form Diversity	Pool Spacing Ratio (ft/ft)	9.7
		Pool Depth Ratio (ft/ft)	2.2
		Percent Riffle (%)	78
Riparian Vegetation	Riparian Extent (%)	13	
	Woody Vegetation Cover (%)	85	
	Herbaceous Vegetation Cover (%)	88	
	Percent Native Cover (%)	95	
Physicochemical	Temperature	MWAT (°C)	
	Nutrients	Chlorophyll α (mg/m²)	
Biology	Macroinvertebrates	WSII	
		RIVPACS	
	Fish	Native Fish Species Richness (% of Expected)	
SGCN Absent Score			
Game Species Biomass (% Change)			

Figure 8. Field Value Data Entry in the Condition Assessment Table.

Users will input field values for all selected metrics (see Section 4.3 for parameter and metric selection). The function-based parameters and metrics are listed by functional category. Tables are color-coded to differentiate between functional categories: blue for reach hydrology and hydraulics, orange for geomorphology, yellow for physicochemical, and green for biology. This table also presents monitoring assessment data, which is auto-populated from data entered into the Monitoring Condition Assessment Table (see Section 2.3.c) based on the most recent monitoring year.

Existing Condition – Existing condition field values are **measured** prior to the implementation of activities (e.g., grading, planting, and installation of wood). Refer to the data collection and analysis methods outlined in Chapter 4 and Appendix A.

- Note: If a field value is entered for a metric in the existing condition assessment, a value **must also be entered** for the same metric in all subsequent condition assessments (proposed, as-built, and every monitoring event). For any field value entered into the WSQT workbook a completed Field Value Documentation form (Appendix B) must be provided to document values and references for field value entries.
- For some metrics, both rapid and more detailed forms of data collection are available; field values can be calculated using data from either rapid or more detailed methods. Coordinate with USACE to determine if rapid data collection methods are acceptable for a project. During site selection the user may want to evaluate potential mitigation or restoration project sites using rapid methods.
- For some metrics multiple years of data are required (i.e., fish metrics).
- For other metrics, where only a single sampling event is required, multiple sampling events will improve the accuracy of the field value used to calculate lift by quantifying inter- or intra-annual variability (e.g., macroinvertebrates and physicochemical metrics).

Proposed Condition – Proposed condition field values represent the expected condition post-activity (restoration or impact) for each selected metric. The proposed condition score is the value that is expected to occur by the end of the monitoring period. For mitigation projects, proposed conditions are based on the **expected condition at the end of the project monitoring period** or at mitigation closeout (e.g., year 5, 7 or 10). Bankfull verification and proposed condition field values should be outlined in the restoration or mitigation plan and documented using the forms in Appendix B. Some stabilization projects may only require an As-Built condition assessment. In this case the proposed condition would reflect the field values expected to be measured during the As-Built condition assessment. More detail on how to determine reasonable values for proposed condition scores are described in relevant metric sections in Chapter 4.

Users should rely on available data to estimate proposed condition field values, including project design studies and calculations, drawings, field investigations, and best available science. For stream restoration projects, the proposed condition field values should be appropriate for the setting, stream type, and watershed conditions within the project area; consistent with the process drivers and restoration potential of the site; and representative of the site conditions likely to occur at the end of an established monitoring period. For a stream restoration project, the proposed condition scores are estimated during the development of the mitigation plan and then verified during the monitoring phase.

2.3.c. Monitoring Condition Assessment Data Entry

Functional change is predicted using the existing and proposed condition assessments and then **verified through monitoring**. Monitoring data are entered in the monitoring condition assessment table in the QT worksheet. For any field value entered into the WSQT workbook a completed Field Value Documentation form (Appendix B) must be provided to document values and references for field value entries.

Starting on row 96 of the worksheet is the monitoring condition assessment table where the user can input the calendar year, monitoring year, and field values for each metric (Figure 9). This table accommodates field values for eleven post-project condition assessments. The first column is the As-Built Condition followed by ten condition assessment columns for monitoring.

- The calendar year is the calendar date of the assessment.
- The monitoring year is the number of years after the as-built survey (as-built is year 0).

The same parameters and metrics assessed in the existing condition assessment must be assessed for all subsequent condition assessments (i.e., proposed, as-built condition and all monitoring events). However, the frequency of monitoring different metrics may vary based on the level of effort and expense of the data collection. To complete a monitoring condition assessment, the user should fill in any field values measured in that assessment year, and for any metrics not assessed, **hold the previously measured field value constant**.

Monitoring requirements may vary between projects, and thus **the monitoring period length, performance standards, and number of monitoring events will be specified by the Corps on a project-specific basis**. Below are general guidelines for applying the WSQT for specific monitoring events.

As-built – As-built condition should document conditions following construction. The proposed condition field values for some metrics (listed below) may be achieved following construction activities. The as-built field values should highlight any changes from the proposed condition.

- Channel plan form should verify pool spacing ratio in meandering streams and the proposed stream length.
- Concentrated flow points, large woody debris index or piece count, percent armoring, and percent side channels metrics should be measured post-construction or documented in record drawings.
- Floodplain grading should verify flood-prone width for the entrenchment ratio and riparian extent metrics.
- Channel dimensions should verify bankfull elevations and metric field values for bank height, entrenchment ratio, width/depth ratio state, and for both baseflow dynamics metrics.
- Channel profile should verify bankfull elevations and pool spacing ratio, pool depth ratio, and percent riffle metric field values.
- The proposed condition field values for the remaining metrics (land use coefficient, other lateral migration metrics, riparian vegetation cover metrics, and all metrics in the physicochemical and biology functional categories) are not likely to be achieved immediately post-construction. Unless values are measured, the existing condition field

value can be entered for the as-built condition and subsequent monitoring events **until post-project data are collected** for a particular metric.

Monitoring Events – Monitoring field values are measured at any given point after project activities have been completed and data collection should be sufficient to **document potential problems in achieving the proposed condition** during the monitoring period.

			Year	2020	2021
			Time since as-built (yr)	As-Built	1
Functional Category	Function-based Parameter	Metric	Field Values		
Reach Hydrology & Hydraulics	Reach Runoff	Land Use Coefficient	35	35	
		Concentrated Flow Points (#/1000 LF)	0	0	
	Baseflow Dynamics	Average Velocity (fps)			
		Average Depth (ft)			
	Bankfull Dynamics	Width/Depth Ratio State (O/E)	1.2	1.2	
	Floodplain Connectivity	Bank Height Ratio (ft/ft)	1	1	
		Entrenchment Ratio (ft/ft)	3.8	3.8	
		Percent Side Channels (%)			
Geomorphology	Large Woody Debris	LWD Index			
		LWD Piece Count (#/100m)	4	4	
	Lateral Migration	Greenline Stability Rating			
		Dominant BEHI/NBS	L/VL	L/VL	
		Percent Streambank Erosion (%)	0	0	
		Percent Streambank Armoring (%)	1	1	
	Bed Material Characterization	Percent Fines (%)			
	Bed Form Diversity	Pool Spacing Ratio (ft/ft)	8.7	8.7	
		Pool Depth Ratio (ft/ft)	3.9	3.9	
		Percent Riffle (%)	38	38	
Riparian Vegetation	Riparian Extent (%)	14.1	14.1		
	Woody Vegetation Cover (%)	20	57		
	Herbaceous Vegetation Cover (%)	20	42		
	Percent Native Cover (%)	97	97		
Physicochemical	Temperature	MWAT (°C)			
	Nutrients	Chlorophyll α (mg/m²)			
Biology	Macroinvertebrates	WSII			
		RIVPACS			
	Fish	Native Fish Species Richness (% of Expected)			
SGCN Absent Score					
Game Species Biomass (% Change)					

Figure 9. Monitoring Condition Assessment Table in QT Worksheet.

Project Closeout – **All metrics should be measured at project closeout.** Note that the user should consult with the Corps for guidance if changes to stressors or catchment scale processes are suspected to affect the post-project monitoring scores or measured condition at project closeout.

2.3.d. Scoring Reach Condition and Functional Change (Lift or Loss)

Scoring occurs automatically as field values are entered into the condition assessments. A field value is a measurement or calculated input for each specific metric and units vary per metric. As field values are entered, the worksheet will calculate an index value ranging from 0.00 to 1.00 for that metric. Where more than one metric quantifies the parameter, these index values are averaged to calculate parameter scores. **The parameter-level scores are the most representative output of condition.** Roll-up scoring continues to generate a single accounting value to calculate lift and loss in the reach. Multiple parameter scores are averaged to calculate functional category scores. Functional category scores are weighted and summed to calculate overall condition scores. Overall condition scores are then multiplied by reach length to generate Functional Feet values.

While the basic suite of parameters and metrics evaluates multiple parameters in lower-level categories, physicochemical and biology functional categories category scores may only reflect the condition of a single parameter. Elements of the scoring process and tips are detailed below.

Index Values – The reference curves used to translate each metric field value into an index value are visible in the Reference Curves worksheet. Documentation on how reference curves were developed is provided in the Scientific Support for the WSQT (WSTT 2023). When a field value is entered for a metric in a condition assessment, these reference curves are used to calculate an index value between 0.00 and 1.00.

As a field value is entered in the condition assessment, the neighboring index value cell should automatically populate with an index value (Example 5a). If the index value cell returns FALSE instead of an index value, the Site Information and Reference Selection section may be missing data (Example 5b).

If the WSQT does not return an index value, the user should check the Site Information and Reference Selection for data entry errors and then check the stratification for the metric in the Reference Curve

worksheet or the Scientific Support for the WSQT (WSTT 2023) to see if there are reference curves applicable to the project. Incorrect information in the Site Information and Reference Selection section may result in applying reference curves that are not suitable for the project.

Example 5: Populating Index Values in WSQT

Scenario A: Index values automatically populate when field values are entered.

Pool Spacing Ratio (ft/ft)	5	1.00
Pool Depth Ratio (ft/ft)		
Percent Riffle (%)	60	1.00

Scenario B: If FALSE, check the Site Information and Reference Selection section of the worksheet.

Pool Spacing Ratio (ft/ft)	5	FALSE
Pool Depth Ratio (ft/ft)		
Percent Riffle (%)	60	FALSE

Roll Up Scoring – Metric index values are averaged to calculate parameter scores; parameter scores are averaged to calculate category scores. The category scores are then weighted and summed to calculate overall condition scores (Table 3). For metrics that are not assessed (i.e., a field value is not entered), the metric is removed from the scoring and no index value is provided; it is NOT counted as a zero. For example, three parameters included in the basic suite assess geomorphology: lateral migration, bed form diversity, and riparian vegetation. Where large woody debris is a natural component of the stream system, the geomorphology category score would be the average four parameter scores instead of three. Additional discussion of scoring is provided in the Scientific Support for the WSQT (WSTT 2023).

Table 3. Functional Category Weights.

Functional Category	Weight
Reach Hydrology and Hydraulics	0.30
Geomorphology	0.30
Physicochemical	0.20
Biology	0.20

Field values, index values, parameter scores and category scores are displayed as follows:

- In the existing and proposed condition assessments, roll-up scoring occurs next to the field value inputs (Figure 10).
- In the post-project monitoring assessment, field values are entered in a table starting at row 100, index values are calculated in a table starting at row 133, and parameter and functional category scores are calculated in tables starting at rows 64 and 80, respectively.

Category scores are additive, so a maximum overall score of 1.00 is only possible when parameters within all categories are evaluated. This procedure will incentivize monitoring physicochemical and biology functional categories because the maximum overall condition score without monitoring these functional categories is 0.60. Overall reach scores are displayed as follows:

- For the existing and proposed condition assessments, overall reach scores are shown in the Functional Change Summary table at the top of the worksheet next to the Site Information and Reference Selection section.
- For the post-project monitoring condition assessments, the overall reach scores are calculated in the Functional Category Summary table starting at row 80.

Functional Category	Function-based Parameter	Metric	Parameter	Category
Reach Hydrology & Hydraulics	Reach Runoff	Land Use Coefficient Concentrated Flow Points (#/1000 LF)	0.58	0.51
	Baseflow Dynamics	Average Velocity (fps) Average Depth (ft)		
	Bankfull Dynamics	Width/Depth Ratio State (O/E)	0.50	
	Floodplain Connectivity	Bank Height Ratio (ft/ft) Entrenchment Ratio (ft/ft) Percent Side Channels (%)	0.44	
Geomorphology	Large Woody Debris	LWD Index LWD Piece Count (#/100m)	0.16	0.49
	Lateral Migration	Greenline Stability Rating Dominant BEHI/NBS Percent Streambank Erosion (%) Percent Streambank Armoring (%)	0.30	
	Bed Material Characterization	Percent Fines (% < 2mm)		
	Bed Form Diversity	Pool Spacing Ratio (ft/ft) Pool Depth Ratio (ft/ft) Percent Riffle (%)	1.00	
	Riparian Vegetation	Riparian Extent (%) Woody Vegetation Cover (%) Herbaceous Vegetation Cover (%) Percent Native Cover (%)	0.50	
Physicochemical	Temperature	MWAT (°C)		0.46
	Nutrients	Chlorophyll (mg/m ²)	0.46	
Biology	Macroinvertebrates	WSII RIVPACS	0.29	0.26
	Fish	Native Fish Species Richness (% of Expected) SGCN Absent Score Game Species Biomass (% Change)	0.22	

Figure 10. Roll Up Scoring Example in QT Worksheet.

Scoring by Rule: Four metrics have rules regarding scoring that will automatically be applied in the WSQT:

- There is no reference curve for the average velocity metric within the baseflow dynamics. **Where velocities are less than 1.0 fps, the baseflow dynamics parameter will score a 0.00**, regardless of the field value for average depth (Figure 11). Where velocities exceed 1.0 fps, the average velocity field value will not influence or inform the parameter score.
- Field values less than 1.0 for the Width/Depth Ratio State metric will only score an index value of less than 1.00 if the stream is also incised (Figure 12).** The width/depth ratio state metric captures problems associated with aggradation (field value is greater than 1.0) and incision (field value is less than 1.0). A W/D that is smaller than the reference W/D

(field value is less than 1.0) is only a problem if the channel is incised. If the bank height ratio is less than or equal to 1.2, the stream is not incised and width/depth ratio state metric field values less than 1.0 will score 1.00 index value.

Function-based Parameter	Metric	Field Value	Index Value	Parameter
Baseflow Dynamics	Average Velocity (fps)	1.2	--	0.59
	Average Depth (ft)	1.6	0.59	

Figure 11a. Baseflow Dynamics Scoring Exception. Parameter score equal to the index value for Average Depth metric.

Function-based Parameter	Metric	Field Value	Index Value	Parameter
Baseflow Dynamics	Average Velocity (fps)	0.9	--	0.00
	Average Depth (ft)	1.6	0.59	

Figure 11b. Baseflow Dynamics Scoring Exception. Parameter score equal to 0.00 because the velocity is less than 1.0 fps.

Function-based Parameter	Metric	Field Value	Index Value
Bankfull Dynamics	Width/Depth Ratio State (O/E)	0.7	1.00
Floodplain Connectivity	Bank Height Ratio (ft/ft)	1.1	0.86
	Entrenchment Ratio (ft/ft)	2.4	0.73
	Percent Side Channels (%)	0	0.00

Figure 12a. Bankfull Dynamics Scoring Exception. Bankfull dynamics field value as less than 1.0 but the index score is equal to 1.00.

Function-based Parameter	Metric	Field Value	Index Value
Bankfull Dynamics	Width/Depth Ratio State (O/E)	0.7	0.63
Floodplain Connectivity	Bank Height Ratio (ft/ft)	1.3	0.58
	Entrenchment Ratio (ft/ft)	2.4	0.73
	Percent Side Channels (%)	0	0.00

Figure 12b. Bankfull Dynamics Scoring Exception. Bankfull dynamics field value as less than 1.0 and index value as less than 1.00 because the BHR field value is greater than 1.2.

- The percent streambank armoring metric captures problems associated with hardened streambank armoring techniques. If present or proposed armoring techniques exceed 50% of the bank length within the project reach, then the lateral migration parameter will score a 0.00 (Figure 13) and the other lateral migration metrics (BEHI/NBS and percent streambank erosion) do not need to be assessed. At this magnitude, the armoring is so pervasive that lateral migration processes would likely have no functional capacity.

Function-based Parameter	Metric	Field Value	Index Value	Parameter
Lateral Migration	Greenline Stability Rating			0.24
	Dominant BEHI/NBS	H/VH	0.00	
	Percent Streambank Erosion (%)	25	0.54	
	Percent Streambank Armoring (%)	25	0.17	

Figure 13a. Lateral Migration Scoring Exception. Parameter score as the average of the three index values.

Function-based Parameter	Metric	Field Value	Index Value	Parameter
Lateral Migration	Greenline Stability Rating			0.00
	Dominant BEHI/NBS	H/VH	0.00	
	Percent Streambank Erosion (%)	25	0.54	
	Percent Streambank Armoring (%)	75	0.00	

Figure 13b. Lateral Migration Scoring Exception. Parameter score equal to 0.00 because the percent streambank armoring is greater than 50%.

- When field values are entered for both macroinvertebrate metrics, the parameter score is an average of index scores. For a small range of values, however, the parameter score will not be an average of the index scores. This exception applies to maintain consistency with how WDEQ applies these models by having a functioning metric score and a functioning-at-risk metric score default to functioning for that parameter. This is accomplished by making 0.70 the minimum parameter score in these cases (Figure 14). Similarly, when one metric has a non-functioning metric score and a functional-at-risk metric score, this will default to non-functioning for that parameter by making 0.29 the maximum parameter score in these cases.

Function-based Parameter	Metric	Field Value	Index Value	Parameter
Macroinvertebrates	WSII	40	0.48	0.70
	RIVPACS	0.9	0.71	

Figure 14. Macroinvertebrates Scoring Exception. Image shows a parameter score of functioning instead of an average of the two index values.

Calculating Functional Change – The WSQT estimates the change in condition at an impact or mitigation site by calculating the difference between pre- and post-project condition. Existing,

proposed and monitoring condition scores are then multiplied by stream length to calculate the change in functional feet (ΔFF). Since the condition score must be 1.00 or less, the functional feet score is always less than or equal to the actual stream length.

The WSQT calculates functional lift and loss in units of functional feet (FF) using stream length and the existing and proposed reach condition scores (ECS and PCS, respectively) as follows:

$$\begin{aligned} \text{Existing FF} &= \text{ECS} * \text{Existing Stream Length} \\ \text{Proposed FF} &= \text{PCS} * \text{Proposed Stream Length} \\ \Delta FF &= \text{Proposed FF} - \text{Existing FF} \end{aligned}$$

Functional lift is generated when the existing condition is more functionally impaired than the proposed condition, and the third equation above yields a positive value. A negative value would represent a functional loss. The change in functional feet can serve as the basis for calculating debits and credits (WSMP v2).

Functional change is summarized in the Functional Change Summary table (Figure 15) and at the functional category level starting at row 88 in the QT worksheet.

Color Coding – When index values are populated in the QT worksheet, cell colors will automatically change to communicate where on the reference curve the field value lies (Figures 10-14). Green represents field values and index scores that represent a functioning range of condition; yellow represents field values and index scores that represent a functioning-at-risk range of condition; and red represents field values and index scores that represent a not functioning range of condition (see Table 1 in Section 1.3 for definitions). This color-coding is provided to illustrate the relative condition of the various metrics and parameters assessed. This is particularly useful when comparing existing to proposed condition, as well as reviewing the summary tables and monitoring data included in the tool. Note that color coding is not provided for the overall condition score, as the overall score is not representative of an overall site condition unless parameters within all categories are evaluated. For example, if only Reach Hydrology & Hydraulics and Geomorphology parameters are evaluated, the maximum overall score will be 0.60. A maximum overall score of 1.00 is possible only when parameters within all four categories are evaluated.

2.3.e. Functional Lift and Loss Summary Tables

The QT worksheet contains five summaries to present scoring results:

- Functional Change Summary,
- Functional Category Report Card,
- Function-based Parameters Summary,
- Functional Categories Score Summary, and
- Functional Categories Functional Foot Summary (FF).

All cells within these summary tables are locked; each is discussed below.

Functional Change Summary – The QT worksheet summarizes the scoring at the top of the sheet, next to the Site Information and Reference Selection section. This summary (Figure 15) provides the overall scores from the existing and proposed condition assessment sections as well as from the most recent monitoring year (when available), calculates change in condition, identifies the number of categories assessed, presents the percent condition change, and

incorporates the length of the project to calculate the existing FF, proposed FF and change in functional feet (ΔFF).

FUNCTIONAL CHANGE SUMMARY	PROPOSED	MONITORED
Existing Condition Score (ECS)	0.43	
Proposed, Monitored Condition Score (PCS, MCS)	0.55	0.52
Change in Condition (PCS - ECS, MCS - ECS)	0.12	0.09
Categories Assessed	2	2
Percent Condition Change	28%	21%
Existing Stream Length (ft)	1300.0	
Proposed Stream Length (ft)	1300.0	
Additional Stream Length (ft)	0.0	
Existing Functional Feet (FF)	559.0	
Proposed, Monitored Functional Feet (FF)	715.0	676.0
Proposed/Monitored FF - Existing FF (ΔFF)	156.0 P3	117.0 P3
Percent Change in FF (%)	28%	21%
Functional Yield ($\Delta FF/LF$)	12%	9%

Figure 15. Functional Change Summary Table. The ΔFF is bolded as the primary output of the WSQT. The number of categories assessed is also bolded to provide context to the condition scores.

The change in condition is the difference between the proposed condition score (PCS) or monitored condition score (MCS) and the existing condition score (ECS). It is a measure of the quality difference between existing and proposed (or monitoring) condition independent of stream length.

The percent condition change is the change in condition divided by the ECS:

$$\text{Percent Proposed Condition Change} = \frac{PCS - ECS}{ECS} * 100$$

$$\text{Percent Monitored Condition Change} = \frac{MCS - ECS}{ECS} * 100$$

The change in functional feet (ΔFF , Proposed FF – Existing FF) is the amount of functional lift or loss resulting from the project. For projects that include multiple reaches, the change in functional feet is summed to calculate the total change in functional feet for an entire project area (Section 2.1).

A scoring qualifier is attached to the change in functional feet (ΔFF) entry in the table. The qualifier relates flow type (perennial, intermittent, and ephemeral) and stream size (Strahler stream order; Strahler 1957) to the overall score to provide context for the ΔFF value generated (e.g., Figure 15 shows a perennial, third order stream indicated by the P3 following the ΔFF). This qualifier helps match impacted stream types to mitigation stream types to support in-kind mitigation. Additional matches can be made by comparing the Site Information and Reference Selection sections between two sites.

In the summary table, functional change is also displayed as functional yield, which shows how many functional feet have been generated for every foot of channel being restored. For example, a value of 0.28 means that 0.28 functional feet are being created for every linear foot of restoration work. When the proposed stream length equals the existing stream length, the Functional Yield equals the change in condition.

$$\text{Proposed Functional Yield} = \frac{\text{Proposed FF} - \text{Existing FF}}{\text{Proposed Stream Length}}$$

$$\text{Monitored Functional Yield} = \frac{\text{Monitoring FF} - \text{Existing FF}}{\text{Proposed Stream Length}}$$

Functional Category Report Card – This summary presents a side-by-side comparison of the functional category scores based on the existing, proposed and monitoring condition assessment scores (Figure 16). This table provides a general overview of the functional changes pre- and post-project to illustrate where the change in condition is anticipated and observed.

FUNCTIONAL CATEGORY REPORT CARD							
Functional Category	ECS	MCS	PCS	Monitored Change in Condition Scores	Monitored ΔFF	Proposed Change in Condition Scores	Proposed ΔFF
Reach Hydrology & Hydraulics	0.90	0.90	0.89	0.00	0.0	-0.01	0.0
Geomorphology	0.40	0.61	0.83	0.21	60.6	0.43	131.3
Physicochemical							
Biology							

Figure 16. Functional Category Report Card.

Function-based Parameters Summary – This summary starts at row 64 in the worksheet and provides a side-by-side comparison of the individual parameter scores for existing, proposed and all monitoring condition assessments (Figure 17). Values are pulled from the condition assessment sections of the worksheet. This table illustrates how the category scores are determined. For example, while the physicochemical functional category score is in the functioning-at-risk range, the parameter summary table illustrates that only nutrients were assessed, and no information was provided on temperature (Figure 17). This table can be used to assess how a project is progressing, as compared with the project's design goals and objectives and specific parameters targeted for improvement. This table is also a useful quality control check to ensure the same parameters were assessed for all condition assessments.

FUNCTION BASED PARAMETER SCORE SUMMARY					
Function-Based Parameter	Existing Parameter	Proposed Parameter	As-Built	1	2
Reach Runoff	1.00	1.00			
Baseflow Dynamics					
Bankfull Dynamics	0.63	0.88			
Floodplain Connectivity	1.00	1.00			
Large Woody Debris	0.00	0.90			
Lateral Migration	0.58	1.00			
Bed Material Characterization					
Bed Form Diversity	0.84	0.95			
Riparian Vegetation	0.45	0.58			
Temperature					
Nutrients	0.25	0.29			
Macroinvertebrates					
Fish					

Figure 17. Function-based Parameters Summary Table.

Functional Category Score Summary – This summary starts at row 80 in the worksheet and provides a side-by-side comparison of the functional category scores for existing, proposed and all monitoring condition assessments (Figure 18). Values are calculated from the condition assessment sections of the worksheet. This table illustrates how each functional category score influences the overall scores.

FUNCTIONAL CATEGORY SCORE SUMMARY for Reach 11-12				
Functional Category	ECS	PCS	As-Built	1
Reach Hydrology & Hydraulics	0.90	0.89		0.90
Geomorphology	0.40	0.83		0.61
Physicochemical				
Biology				
Reach Condition Score *	0.39	0.52		0.45
* Includes multipliers for weighting				

Figure 18. Example Functional Category Score Summary Table.

Functional Categories Summary (functional feet) – This summary starts at row 88 in the worksheet and provides a side-by-side comparison of the functional feet calculated for existing, proposed and all monitoring condition assessments (Figure 19). Values are pulled from the condition assessment sections of the worksheet and multiplied by stream length. This table

illustrates how each functional category contributes to the overall functional feet value for the reach.

FUNCTIONAL CATEGORY FUNCTIONAL FEET SUMMARY (FF) for Reach 11-12				
Functional Category	EFF	PFF	As-Built (FF)	1
Reach Hydrology & Hydraulics *	272.7	272.7		272.7
Geomorphology *	121.2	252.5		181.8
Physicochemical *				
Biology *				
Reach FF	393.9	525.2		454.5
* Includes multiplier for weighting				

Figure 19. Example Functional Category Functional Foot Score Summary Table (FF).

2.4. Flow Alteration Module Worksheet

The Flow Alteration Module (FAM) and metrics are provisional, and use will be at the discretion of the Corps. The FAM worksheet is a supplementary calculator where users enter data describing the existing and proposed hydrologic conditions for an affected stream length.

In the WSQT workbook, the FAM worksheet contains two areas for data entry and one summary table:

- Site Information
- Existing, Proposed, and Monitoring Condition Assessments¹⁵
- Functional Change Summary Table

Cells that allow input are shaded gray and all other cells are locked. Each section of the worksheet is discussed below. The user can duplicate this worksheet when more than one FAM is needed for the project area. This worksheet can be renamed to identify the affected reach ID.

The worksheet title cannot contain spaces. The worksheet title must match the entry provided in the Project Summary worksheet. The text strings must match to populate results in the Flow Alteration Module Summary table.

Site Information – The Site Information section includes the following:

- Project name – automatically populates from the Project Summary worksheet.
- Reach ID(s) – Each Flow Alteration Module should be assigned a reach ID.
- Affected Stream Length – enter the length of stream where the FAM is applied. Affected stream length is defined at the upstream end where impacts or flow protection would

¹⁵ Tables are color-coded to differentiate between functional categories. Blue is for reach hydrology and hydraulics.

initiate, and at the downstream end by the location of the next water rights user, significant tributary junction, or terminus beyond which the flow modification has no material effect on SQT parameters.

- **Strahler Stream Order (drop-down)** – Stream order as defined by Strahler (1957) is a classification based on stream/tributary relationships. Headwater streams are first order; the stream becomes second order downstream of the confluence of two first order streams; the stream becomes third order downstream of the confluence of two second order streams; and so on.
- **Flow Type (drop-down)** – Select the flow permanence of the project reach as perennial, intermittent, or ephemeral.
- **Downstream Latitude/Longitude** – Enter the decimal degree latitude and longitude of the downstream extent of the affected stream reach.
- **Affected Reach Description & Reach Break Criteria** – automatically populates from the Project Summary worksheet.
- **Most recent monitoring year (drop-down)** – As monitoring data are entered into the FAM worksheet, a drop-down list of monitoring years will populate from the information entered into row 43. Select the most recent year from this drop-down list and the WSQT will display summary data from that monitoring event in the Functional Change Summary Table and Condition Assessment Table.

Condition Assessment – Once the Site Information section has been completed, the user can input data into the field value columns of the existing, proposed, or monitoring condition assessment tables. The user will input field values for the applicable metrics within the module (Figure 20). Guidance on metric selection and calculation is provided in Section 4.9. Every metric is a ratio of Observed/Expected (O/E).

There is space to enter data for up to ten monitoring events in the FAM worksheet. Data entry for monitoring events must follow the criteria described in Section 2.3.c. Monitoring years must be entered on this sheet and may not always align with monitoring events for project reaches in the QT worksheet. Monitoring schedule considerations for mitigation projects are described in Section 2.3.c. Tables that contain monitoring data have alternating columns with and without stipple formatting for vertical tracking of data in the columns.

	EXISTING CONDITION ASSESSMENT		
Metric	Field Value	Index Value	Module
Mean Annual Q (O/E)	0.52	0.58	0.70
Mean Aug Q (O/E)	0.65	0.72	
Mean Sept Q (O/E)	0.88	0.98	
Mean Jan Q (O/E)	0.71	0.79	
Mean Annual Peak Daily Q (O/E)	0.56	0.62	
7-Day Minimum (O/E)	0.48	0.53	

Figure 20. Example Flow Alteration Module Condition Assessment.

Functional Change Summary Table – The FAM worksheet summarizes the scoring at the top of the sheet. This summary (Figure 21) provides the module scores from the existing, proposed, and monitoring condition assessment sections, calculates change in condition (mPCS-mECS), identifies the affected stream length, calculates the existing (FF), proposed (FF) and monitored functional feet values, calculates a weighted change in functional feet (ΔFF) and percent change in FF for both proposed and monitored condition.

Roll-up scoring in the FAM occurs automatically as field values are entered into the condition assessment tables. Metric index values are averaged to calculate a module score. Functional lift is generated when the proposed scores are higher than the existing scores; functional loss is generated when proposed scores are lower than existing, resulting in a negative value. Existing, proposed and monitoring scores are multiplied by the affected stream length and weighted by 20% (WSTT 2023) to calculate FF. The weighted existing FF, proposed FF and ΔFF are displayed in the Functional Change Summary Table as well as the Project Summary worksheet (m ΔFF). The m ΔFF is added to the ΔFF for each project reach and included in the Project Total ΔFF .

FUNCTIONAL CHANGE SUMMARY	PROPOSED	MONITORED
Module Existing Condition Score (mECS)	0.78	
Module Proposed, Monitored Condition Score (mPCS, mMCS)	0.83	
Change in Condition (mPCS - mECS, mMCS - mECS)	0.05	
Affected Stream Length (ft)	55213.0	
Existing Functional Feet (FF)	8834.1	
Proposed, Monitored Functional Feet (FF)	9386.2	
Proposed FF - Existing FF (ΔFF)	552.1 P3	
Percent Change in FF (%)	6%	

Figure 21. Example Flow Alteration Module Functional Change Summary Table.

2.5. Reference Curves Worksheet

The Reference Curves worksheet contains the reference curves used to convert field values into index values. *This worksheet is included for information purposes and does not require any data entry.*

The numeric index value range (0.00 to 1.00) is standardized across metrics using the definitions of functional capacity, i.e., functioning, functioning-at-risk and not functioning condition provided in Table 1 in Section 1.3. Reference curves are tied to specific benchmarks (thresholds) that represent the degree to which condition departs from reference condition as described in Section 1.3.

On this worksheet, reference curves are organized into columns based on functional category and appear in the order they are listed in the condition assessments. One metric can have multiple curves depending on how the reference curves were stratified. For example, the woody

vegetation cover metric is stratified by ecoregion. All reference curves and their stratification are described in the Scientific Support for the WSQT (WSTT 2023).

There may be instances where better data are available for a particular project, and the Corps can approve an exception to using the reference curves within the WSQT. Examples of factors that may indicate the need for alternative reference curves include geographic or ecoregion differences, differences in stream type or flow permanence, local reference reach data, or better modeling, depending on the parameter and metric.

Chapter 3. Wyoming Stream Impact Tool Workbook

The Wyoming Stream Impact Tool (WSIT) workbook (WSQT v2.0_Stream Impact Tool.xlsx) is a Microsoft Excel workbook comprised of six visible worksheets and one hidden worksheet. **This workbook provides a simplified approach to estimating functional loss for a project that is impacting stream functions.** There are no macros in the workbook and all formulas are visible, though locked worksheets prevent editing. The WSIT workbook is a project- or stream-based workbook, with space on each worksheet to input data for up to 10 reaches in a project area. The WSIT worksheets include:

- Project Summary
- Functional Loss
- Existing Conditions
- Proposed Conditions
- Flow Alteration Module
- Reference Curves
- Pull Down Notes – This hidden worksheet contains all the inputs for drop-down menus throughout the workbook.

Each of the worksheets are described in the following sections.

3.1. Project Summary Worksheet

The purpose of the Project Summary worksheet is to describe the proposed project and provide a summary of the project reaches within the project area. This worksheet should be completed for all projects. Users input values into the gray cells and select inputs from the drop-down menus in the blue cells; white cells are locked and will auto-populate with input provided on another worksheet.

WSQT Stream Impact Tool						
Project Name:		First Creek			Total Functional Loss -660.0	
Applicant:		Example Firm				
Project ID/Permit Applicant Number(s) (optional):		12345				
Date:		6/9/2023				
Project Description:		Expand current highway corridor around XYZ City.				
Reach Summary						
Stream ID By Reach	Flow Type	Strahler Stream Order	Impact Description & Reach Break Criteria	Priority Category	Downstream Latitude (decimal degrees)	Downstream Longitude (decimal degrees)
STR-1	Perennial	4+	Extend bridge and installing piers in-channel	Outstanding Water		
STR-2	Intermittent	2	Extend culvert	Standard		
STR-3	Ephemeral	1	Extend culvert	Exception		

Figure 22. WSIT Workbook Project Summary Example.

Reach Summary (Figure 22)– Include the following information for each project reach in the workbook:

- Stream ID by reach - Each project reach within a project area should be assigned a unique identifier. See Section 4.1 for guidance on delineating project reaches.
- Flow Type (drop-down) – Select the flow permanence of the project reach as perennial, intermittent, or ephemeral.
- Strahler Stream Order (drop-down) – Stream order as defined by Strahler (1957) is a classification based on stream/tributary relationships. Headwater streams are first order; the stream becomes second order downstream of the confluence of two first order streams; the stream becomes third order downstream of the confluence of two second order streams; and so on.
- Impact Description & Reach Break Criteria – briefly describe proposed impact for each reach and the characteristics that separate the reach from the other reaches in the project (see Section 4.1 for guidance on identifying project reaches). Activities can range from culvert installations to bank armoring or full channel fill and replacement.
- Priority Category (drop-down) – This is used to determine the default scores in the Functional Loss worksheet. These include outstanding water, standard and exception. Outstanding water are WDEQ Class 1 waters and other special resource waters, as outlined in the WSMP v2. Exception should only be selected on a case-specific basis following consultation with the Corps. Users should select 'standard' unless criteria are met for the other categories.
- Latitude and Longitude of the downstream limit of project reach.

Flow Alteration Module Summary – Include the following information for each FAM:

- Affected Reach ID - Each Flow Alteration Module should be assigned a reach ID.
- Flow Type (drop-down) – Select the flow permanence of the project reach as perennial, intermittent, or ephemeral.
- Strahler Stream Order (drop-down) – Stream order as defined by Strahler (1957) is a classification based on stream/tributary relationships. Headwater streams are first order; the stream becomes second order downstream of the confluence of two first order streams; the stream becomes third order downstream of the confluence of two second order streams; and so on.
- Affected Reach Description & Reach Break Criteria – describe how affected stream length was determined, including the criteria for the beginning and end terminus of the affected stream length (see Section 4.9 for guidance on how to determine the affected stream length).
- Latitude and Longitude of the downstream limit of project reach.

3.2. Functional Loss Worksheet

This worksheet is only present in the WSIT workbook, and not in the WSQT workbook. The Functional Loss worksheet is where users enter data describing the impacts to each reach, select an impact severity tier, and where functional change is calculated. The worksheet consists of an input table, explanatory information on the proposed impact factors and activity modeling, and a summary of the results from the Existing and Proposed Conditions worksheets within the WSIT workbook. Users can assess up to 10 reaches within each WSIT workbook. If a project includes more than 10 reaches, additional WSIT workbooks will be needed.

Cells that allow input are shaded grey, users select inputs from the drop-down menus in the blue cells and other cells are locked. Each section of the Functional Loss worksheet is discussed below.

Calculating Functional Change – The WSIT workbook estimates the change in condition at an impact site by calculating the difference between pre- and post-project condition. Existing and proposed condition scores are then multiplied by stream length to calculate the change in functional feet (ΔFF). Since the condition score must be 1.00 or less, the functional feet score is always less than or equal to the actual stream length.

The WSIT workbook calculates functional loss in units of functional feet (FF) using stream length and the existing and proposed reach condition scores (ECS and PCS, respectively) as follows:

$$\begin{aligned} \text{Existing FF} &= \text{ECS} * \text{Existing Stream Length} \\ \text{Proposed FF} &= \text{PCS} * \text{Proposed Stream Length} \\ \Delta FF &= \text{Proposed FF} - \text{Existing FF} \end{aligned}$$

Functional loss is generated when the proposed condition is more functionally impaired than the existing condition, and the third equation above yields a negative value. The change in functional feet can serve as the basis for calculating debits (WSMP v2). Note: The functional loss calculation does not consider temporal loss, the proximity of the mitigation to the impact, or other factors that may be addressed in the WSMP v2. Guidance on how functional loss calculations inform compensatory mitigation requirements, or what permits may be required for specific activities is not included here; users should coordinate with the Corps and review the WSMP v2 for this guidance.

In the Functional Loss worksheet, functional feet are summarized in the Functional Loss Summary table.

A scoring qualifier is attached to the change in functional feet (ΔFF) entry in the table. The qualifier relates flow type (perennial, intermittent, and ephemeral) and stream size (Strahler stream order; Strahler 1957) to the overall score to provide context for the ΔFF value generated. This qualifier helps match impacted stream types to mitigation stream types to support in-kind mitigation. Additional matches can be made by comparing the Site Information and Reference Selection sections between two sites.

3.2.a. Components of the Functional Loss worksheet

Project Name, Date, Applicant and Project ID/Permit Number – This information will automatically populate from the Project Summary worksheet.

Functional Loss Summary Table – This is the calculator that summarizes information for all reaches (Figure 23). For each reach, users should select the impact assessment option, existing stream length, proposed stream length and impact severity tier, as described below. Stream ID, Priority Category, Flow Type and Stream Order will automatically populate from the Project Summary worksheet; existing and proposed condition scores will auto-populate from their respective worksheets if relevant Impact Assessment Options are selected. The table will calculate change in functional feet for each reach and total functional loss across all reaches.

FUNCTIONAL LOSS SUMMARY									
Stream ID by Reach	Priority Category	Impact Assessment Option	Existing Stream Length	Existing Condition Score	Proposed Stream Length	Impact Severity Tier	Proposed Condition Score	Change in FF (ΔFF)	Flow Type and Stream Order
STR1 R1	Standard	2	1000	0.67	800	Tier 3	0.34	-398.0	P2
STR1 R2	Standard	2	1000	0.64	1000	Tier 2	0.45	-190.0	P2
STR3 R3	Standard	2	1000	0.69	1000	Tier 2	0.48	-210.0	P2
UT1 R1	Exception	3	300	0.70	300	Tier 4	0.18	-156.0	E1
				0.90					
				0.90					
				0.90					
				0.90					
				0.90					
				0.90					
Total Functional Loss (ΔFF):								-954.0	

Figure 23. Functional Loss Summary Table Example.

Impact Assessment Option (drop-down) – For permitted impacts, data to inform proposed condition scores may not be available for various reasons. There are three options to calculate functional loss at an impact site. The three impact assessment options require varying levels of information and effort to calculate functional loss. In general, impact assessment option 1 requires the most information and effort, while impact assessment option 3 requires the least. These options are described below and summarized in Table 4. Users should consult the WSMP v2 for guidance on determining debits and compensation requirements.

Option 1 calculates functional loss using data entered in the Existing Condition and Proposed Condition worksheets (Section 3.3). For this option, the user must conduct an existing condition assessment within the project reach and be able to reasonably predict proposed condition metrics using project design reports, drawings, field investigations, etc.

The following steps are necessary to complete impact assessment option 1:

1. Complete the Project Summary worksheet (see Section 3.1).
2. Complete the Functional Loss worksheet (described in this section).

3. Determine the parameters and metrics that will be used to assess the reach (see Section 4.3). Note: parameters and metrics from all four functional categories should be selected.
4. Collect data (Chapter 4) and complete the Existing Condition worksheet (see Section 3.3).
5. Complete the Proposed Condition worksheet (see Section 3.3). For all Proposed Condition field values, the user must explain in a narrative, cite resources, and provide justification.
6. Impact severity tier selection is not required with the use of debit option 1.

Table 4. Summary of Impact Assessment Options.

Impact Assessment Option	Existing Condition Score (ECS)	Proposed Condition Score (PCS)
1 "Assess everything"	Assess existing condition for required parameters using Existing Condition worksheet.	Estimate proposed condition for required parameters using Proposed Condition worksheet.
2 "Assess some things"	Assess existing condition using Existing Condition worksheet for selected parameters and rely on default scores* for all other parameters.	Estimate proposed condition based on impact severity tier.
3 "Assess nothing"	No assessment; rely on default scores* for all parameters.	Estimate proposed condition based on impact severity tier.
*Default scores are 0.90 for outstanding waters, 0.80 for most other waters (standard), and 0.70 on a case-specific basis following Corps approval (exception).		

For the proposed condition assessment, the user should rely on available data to reasonably predict proposed condition field values (Example 6). The same parameters used to derive the existing condition score must also be used to determine the proposed, post-impact, condition score. Therefore, proposed condition field values must be determined for all metrics used to assess the existing stream reach (Note: field value here refers to where data are entered into

Example 6: Determining Proposed (Post-Impact) Condition Score

Impacts that result in relocating or straightening a channel could use construction documents to determine the cross-section and profile of the proposed channel. These data can be used to estimate the proposed floodplain connectivity and bankfull dynamics field values. Bedform diversity metrics could also be estimated from the project design plans. The proposed development plans should indicate the extent of impervious surfaces to be added to the lateral drainage and the number of concentrated flow points that would be added. This information can be translated into reach runoff field values.

For physicochemical and biology parameters, the degradation of the parameters outlined above would be used to estimate or model the extent of degradation expected for parameters in physicochemical and biology categories.

the worksheet and not the actual collection of field data to yield a field value). Proposed field values that describe the physical post-impact condition of the stream reach should be based on project design reports, drawings, field investigations, etc.

Option 2 calculates functional loss using a combination of existing condition assessment data from the Existing Condition worksheet (Section 3.3) and the formulas in the Functional Loss worksheet to calculate functional loss.

The following steps are necessary to complete impact assessment option 2:

1. Complete the Project Summary worksheet (see Section 3.1).
2. Complete the Functional Loss worksheet (described in this section)
3. Determine the parameters and metrics that will be used to assess the reach (see Section 4.3). Note: any required parameters not evaluated will be assigned default scores (Table 4). Users should consult with the Corps to determine appropriate parameter selection.
4. Collect data (Chapter 4) and complete the Existing Condition worksheet (see Section 3.3) for all evaluated metrics.

The Functional Loss worksheet will automatically populate existing condition information entered in the Existing Condition worksheet and apply default scores to the physicochemical parameters, biology parameters and parameters in the basic suite (Section 4.3) that are not evaluated. The Functional Loss worksheet will generate a PCS and summary information including the change in functional feet based on the information provided.

Option 3 is identical to option 2, except users would not perform any existing condition assessment. In this case, the user simply relies on default existing condition scores (Table 4). Just as with option 2, the Functional Loss worksheet is used to estimate the proposed (post-impact) condition score and calculate functional loss. This option is the fastest and easiest method for determining functional loss.

The following steps are needed to complete impact assessment option 3:

1. Complete the Project Summary worksheet (see Section 3.1)
2. Complete the Functional Loss worksheet (described in this section)

Existing Stream Length – Calculate the length of the stream that will be directly impacted by the permitted activity. For example, measuring the channel length before a culvert is installed. Stream length should be measured along the centerline of the channel.

Proposed Stream Length – Estimate the length of stream channel after impact. For pipes, the proposed length is the length of the pipe, at a minimum. If the stream will be straightened by the permitted activity, the proposed stream length will be less than the existing stream length. Proposed stream lengths should not be longer than the impact length. Streams cannot be lengthened by pipes. Therefore, a 300-foot pipe along 275 feet of stream will only impact 275 linear feet of stream. The cell will highlight in red if the existing stream length is shorter than the proposed stream length.

Impact Severity Tier (drop-down) – Users need to select an impact severity tier to calculate a proposed condition score. The impact severity tier is a categorical determination of the adverse impact to stream functions, ranging from no loss to total loss. Impact severity tier categories

were developed by comparing the habitat conditions that would likely exist at an impact site in the altered reach versus the conditions existing in a non-impacted stream. These factors were based on projected functional loss and grouped by common impact activities with similar functional loss.

The Impact Severity Tier section includes a drop-down menu to select an impact severity tier from 0 to 5. Once the impact severity tier has been selected, the PCS and proposed change in functional feet will automatically calculate in the WSIT workbook. Tier 0 represents no permanent loss of stream functions and therefore no mitigation would be needed. Tiers 1 – 4 represent a range of impacts resulting from proposed activities; information to select between these tiers can come from project plans and documents, permit applications, discussions between the permit applicant and the Corps, etc. Tier 5 is exclusive to projects that completely fill the stream channel, and either pipe or relocate the original channel. Table 5 lists the impact severity tiers along with a description of impacts to key function-based parameters and example activities that may lead to those impacts. Note that some activities could be in multiple tiers depending on the magnitude of the impact and efforts taken to minimize impacts using bioengineering techniques or other low-impact practices. This can include the type of structure, how it is installed, or the extent of the project and how it is constructed. Selection of the appropriate impact severity tier must be coordinated with the Corps.

Table 5. Impact Severity Tiers and Example Activities.

Tier	Description (Impacts to function-based parameters)	Example Activities
0	No permanent impacts on any of the key function-based parameters.	Bio-engineering of streambanks
1	Minor impacts primarily to riparian vegetation and/or lateral migration.	Bank stabilization and utility crossings.
2	Moderate impacts to riparian vegetation, lateral migration, bed form diversity, and/or flow dynamics. Potential for minor impacts to some physicochemical and biology functions.	Armoring, utility crossings, bridges, bottomless arch culverts
3	Moderate to severe impacts to riparian vegetation, lateral migration, bed form diversity, flow dynamics, and/or floodplain connectivity. Minor to moderate impacts to some physicochemical and biology functions.	Bottomless arch culverts and small channelization/grading projects
4	Moderate to severe impacts to most hydraulic and geomorphic functions that are likely to result in moderate to severe impacts to physicochemical and biology functions.	Channelization (e.g., straightening, widening, deepening, removing natural obstructions/roughness); countersunk enlarged and bottomless arch culverts; weirs/impoundments
5	Removal of all aquatic functions.	Culverts, pipes, relocation, fill of small channels from mining or development

Tiers 1-4 – The existing condition score and the impact severity tier are used to calculate the proposed condition using the multipliers shown in Table 6. For example, a Tier 3 impact on a reach with an ECS of 0.52 would result in a proposed condition score of 0.26 ($0.5 * 0.52 = 0.26$). This means that the proposed condition score is 50% of the existing condition score. The inverse is also true, meaning that there was a corresponding 50% loss of stream function.

Multipliers for each impact tier were developed from linear regression equations of modeled impact scenarios using a simplified version of the WSQT; additional detail on how the multipliers were developed is provided in a white paper on the original debit tool (Harman and Jones 2017).

Tier 5 – Activities that completely fill the channel, removing all aquatic functions, are assigned to tier 5. Their PCS is an automatic 0, meaning that all aquatic functions have been lost. Streams enclosed in pipes are included in this tier because it is assumed that no hydraulic, geomorphology, physicochemical, and biology functions are present in this reach. While hydrology is still present, it is simply being conveyed through the reach and not supporting any other functions.

Table 6. Impact Severity Tiers and PCS Calculation.

Impact Severity Tier	PCS Equation	Percent Loss
1	$PCS = 0.9 * ECS$	10%
2	$PCS = 0.7 * ECS$	30%
3	$PCS = 0.5 * ECS$	50%
4	$PCS = 0.25 * ECS$	75%
5	$PCS = 0$	100%

ECS and PCS Summary Table – The overall ECSs and overall PCSs of all stream reaches from the Existing Conditions and Proposed Conditions worksheets are summarized in a table located below the Functional Loss table.

Calculating Functional Loss – Once the PCS is calculated, the Functional Loss worksheet uses the existing and proposed stream lengths to calculate the ΔFF using the equation described in at the beginning of Section 3.2. The WSIT workbook can only calculate loss and therefore, the change in functional feet can only be less than or equal to 0.0. The Functional Loss Summary table summarizes all the necessary information for each impact reach (Figure 22). The worksheet will automatically total the ΔFF when data are entered for multiple project reaches.

3.3. Existing Conditions and Proposed Conditions Worksheets

The Existing Conditions and Proposed Conditions worksheets are used to input existing and proposed field values for a project reach, with changes in condition calculated in the Functional Loss worksheet. There are two areas for data entry:

- Site Information and Reference Selection,
- Condition assessment field values,

The Existing Conditions and Proposed Conditions worksheets will accommodate existing and proposed condition scores for up to ten reaches. The user provides site information for each reach in the Site Information and Reference Selection table above each condition assessment.

Users input values into the gray cells and select inputs from the drop-down menus in the blue cells; white cells are locked and will auto-populate with input provided on another worksheet.

3.3.a. Site Information and Reference Selection

The Site Information and Reference Selection section consists of general site information and classifications to determine which reference curve(s) to apply in calculating index values for relevant metrics (Figure 24). For some metrics, reference curves are stratified by physical stream characteristics like stream type, temperature, and ecoregion. Information on each and guidance on how to select values is described below. While it may not be necessary to complete all fields (depending on parameter selection), some metrics will not be scored or may be scored incorrectly if data are not provided in this section.

For each reach, data are entered on the Existing Conditions worksheet and these data are auto-populated onto the Proposed Conditions worksheet.

The user should ensure entries in this section are accurate, **incorrect information in the Site Information and Reference Selection section may result in applying reference curves that are not suitable for the project.**

Users input values into the gray cells and select inputs from the drop-down menus in the blue cells; white cells are locked and will auto-populate with input provided on another worksheet. For fields with drop-down menus, if the correct selection is not included in the drop-down menus, then data to inform relevant metric index values for that variable are not available and users should review the Parameter and Metric Selection (Section 4.3) to determine if it is appropriate to assess relevant metrics at the project site. Additional information on how reference curves are stratified is included in the Scientific Support for the WSQT (WSTT 2023).

Reach ID – Each project reach within a project area is assigned a unique identifier in the Project Summary worksheet and each Reach ID is auto-populated on the Existing Conditions and Proposed Conditions worksheets.

Reference Stream Type (drop-down) – Select reference stream type for each reach. This reflects the Rosgen stream type classification that would naturally occur given the valley morphology and absent from anthropogenic influences. The WSQT relies on the reference stream type to stratify reference curves for the entrenchment ratio and pool spacing ratio metrics. See Section 4.2 for information on characterizing reference stream type in Wyoming.

Site Information and Reference Selection							
Reach ID:	STR1 R1	Stream Slope (%):	0.8	Stream Temperature:	Tier II (Cold-Cool)	Downstream Latitude (decimal degrees):	
Reference Stream Type:	C	Proposed Bankfull Width (ft):	15	Bioregion:	Granitic Mountains	Downstream Longitude (decimal degrees):	
Flow Type:	Perennial	Valley Type:	Unconfined Alluvial	Ecoregion:	Mountains	Not in Volcanic Mountains & Valleys bioregion. Option not available.	
Strahler Stream Order:	Second	Reference Vegetation Cover:	Woody	River Basin:	Snake/ Salt River		
Priority Category:	Standard	Bed Material:	Gravel	Stream Productivity Rating:	Blue Ribbon and non-trout		

Figure 24. Site Information and Reference Stratification Input Fields in Existing Conditions Worksheet.

Flow Type – Flow type is reported in the Project Summary worksheet and auto-populated on the Existing and Proposed Conditions worksheets. Flow type is not yet used for reference curve stratification; it is used for communication purposes.

Strahler Stream Order – Stream order is reported in the Project Summary worksheet and auto-populated on the Existing and Proposed Conditions worksheets. Stream order is not used for reference curve stratification; it is used for communication purposes.

Priority Category – The priority category is reported in the Project Summary worksheet and auto-populated on the Existing and Proposed Conditions worksheets. This input is used to determine the default parameter scores for existing conditions.

Stream Slope (%) – The WSIT uses stream slope to select the correct reference curves for percent riffle. The stream slope is a reach average and not the slope of an individual bed feature, e.g., riffle. The slope most similar to reference condition should be entered.

Bankfull Width (ft) – Bankfull width is used for stratification of the baseflow depth metric and serves as the denominator for the pool spacing ratio metric. The proposed bankfull width is the width of a stable riffle (Section 4.4) or calculated from regional curves applicable to the project area.

Valley Type (drop-down) – Valley type is used to stratify reference curves for riparian extent and side channels metrics. The valley type options are unconfined alluvial, confined alluvial or colluvial/V-shaped:

- *Unconfined Alluvial Valleys*: wide, low gradient (typically less than 2% slope) valleys that support meandering or anastomosed stream types (e.g., Rosgen C, E, DA). In alluvial valleys, rivers adjust pattern without intercepting hillslopes. These valleys typically have a valley width ratio greater than 7.0 (Carlson 2009) or a meander width ratio (MWR) greater than 4.0 (Rosgen 2014).
- *Confined Alluvial Valleys*: valleys that support transitional stream types between step-pool and meandering or where meanders intercept hillslopes (e.g., C, Bc). These valley types typically have a valley width ratio of less than 7.0 and a MWR between 3.0 and 4.0.
- *Colluvial/V-shaped Valleys*: valleys that are confined and support straighter, step-pool type channels (e.g., A, B, Bc). These valley types typically have a valley width ratio less than 7.0 and a MWR less than 3.0.

Reference Vegetation Cover (drop-down) – Reference vegetation cover is used to determine whether to apply the woody or herbaceous cover metric. The reference vegetation cover is the community that would occur naturally at the site if the reach were free of anthropogenic alteration. The following classifications are based on the community types described in Carsey et al. (2003):

- *Woody sites* are those whose reference condition is greater than or equal to 20% absolute cover of woody vegetation. This includes scrub/shrub and forested systems.
- *Herbaceous sites* are those whose reference condition is less than 20% absolute woody cover.

The appropriate reference community type can be determined by locating a similar pristine or minimally altered reference site within the catchment area or watershed, researching historical and ecological descriptions of mature and undisturbed vegetation communities in the vicinity, or deduced through understanding the effects of land use practices and management on vegetation communities. For example, many of the unconfined or partially confined alluvial mountain valleys in the southern Rocky Mountains were likely dominated by woody riparian vegetation across the valley floor prior to anthropogenic human activities and should be classified as having woody reference vegetation cover, even though they are currently dominated by upland grasses. Some plains systems and other E channels may have an herbaceous reference condition with less than 20% woody vegetation cover.

Bed Material (drop-down) – The bed material characterization metric in the WSIT is only applicable to gravel or cobble bed streams. The proposed bed material is not used to stratify any reference curves but is important information to include for a project site.

Stream Temperature (drop-down) – The stream temperature tier is used to determine the correct reference curve for baseflow dynamics and temperature parameters (Table 2 in Section 2.1). Streams in Wyoming are classified by thermal tiers based on the modeled mean August stream temperature (Peterson 2017). Use the mean modeled August stream temperature from the Air, Water, & Aquatic Environments Program (AWAE 2016) to identify the appropriate tier.

Bioregion (drop-down) – Bioregions are defined by WDEQ to classify groups of streams with similar physical, chemical, and biological traits (Figure 4 in Section 2.1; Hargett and Zumberge

2011). Bioregions are delineated using a hybrid classification approach that uses integrated cluster analyses of reference site macroinvertebrate data, GIS, nonmetric multidimensional scaling (NMS), and best professional judgment. The boundaries of the eleven bioregions were constructed using USEPA Level IV Ecoregions, elevation contours, watershed boundaries, bedrock geology, and stream origins and should not be considered precise boundaries. When a site falls on the edge of two bioregions, professional judgment may be needed to determine the appropriate bioregion. Bioregion is used to select reference curves for percent riffle and both macroinvertebrate metrics. Note: Volcanic Mountains & Valleys (Volcanics) has its own reference curve for percent riffle; if the reach is within this bioregion and stream slope is less than 1.3%, users will be given the option whether to select this curve.

Ecoregion (drop-down) – The WSQT uses the project’s ecoregion to stratify reference curves for riparian vegetation and nutrients parameters. The ecoregion is based on the Level I Ecoregion descriptions from the USEPA: Great Plains, North American Deserts, and Northwestern Forested Mountains. In Wyoming, the North American Desert Ecoregion consists of the Wyoming Basin and is referred to as the ‘Basins’ ecoregion in the WSQT. The Great Plains ecoregion is referred to as the ‘Plains’; and the Northwestern Forested Mountains is referred to as ‘Mountains’ in the WSIT.

River Basin (drop-down) – Wyoming is subdivided into six large river basins (WGFD 2017): Bear River, Green River, NE Missouri Basin, Platte River, Snake/Salt River, and Yellowstone River. Select the river basin that the project reach falls within. This input is not used in the scoring; it is used to select an appropriate fish species list for the number of native fish species metric. Appendix C contains fish assemblage lists for each river basin.

Stream Productivity Rating (drop-down) – Select the stream productivity rating as: Blue Ribbon and non-trout; Red Ribbon; or Yellow or green Ribbon. This input is used to select the correct reference curves for the game species biomass metric. Use the [provided link](#) to identify if the stream is listed as blue, red, or yellow ribbon as determined by WGFD based on trout pounds/mile (Annear et al. 2006).¹⁶ If the stream is not listed, it is assumed to fall under the green-ribbon classification. If the stream supports non-trout game fish such as catfish, sturgeon or sauger, use the blue-ribbon classification.

Latitude/Longitude –The decimal degree latitude and longitude of the downstream extent of the reach is reported in the Project Summary worksheet and auto-populated on the Existing and Proposed Conditions worksheets.

Percent Riffle Reference Curve Option (drop-down) – Because of a naturally higher proportion of riffles, a separate reference curve for percent riffle exists for all streams in the Volcanics bioregion. However, if a project site is in the Volcanics region and the slope is < 1.3%, it may be more appropriate to not apply the Volcanics reference curve; users will be prompted whether they want to opt out of the Volcanics reference curve for percent riffle: “Yes, opt out”, “No, use Volcanics reference curve for percent riffle” (Example 4 in Section 2.3.a). If opting out, the SQT will apply the reference curve for streams with <3% slope.

¹⁶ [https://wgfd.wyo.gov/Fishing-and-Boating/Stream-Classification#:~:text=Categories%20based%20on%20pounds%20of,\)%20%3C50%20pounds%20per%20mile](https://wgfd.wyo.gov/Fishing-and-Boating/Stream-Classification#:~:text=Categories%20based%20on%20pounds%20of,)%20%3C50%20pounds%20per%20mile).

3.3.b. Existing and Proposed Condition Assessment Data Entry

Once the Site Information and Reference Selection section has been completed, the user can input data into the field value column of the existing and proposed condition assessment tables (Figure 8 in Section 2.3).

Users will input field values for all selected metrics (see Section 4.3 for parameter and metric selection). The function-based parameters and metrics are listed by functional category. Tables are color-coded to differentiate between functional categories: blue for reach hydrology and hydraulics, orange for geomorphology, yellow for physicochemical, and green for biology.

Existing Condition – Existing condition field values are measured prior to the implementation of activities (e.g., grading, culvert installation). Refer to the data collection and analysis methods outlined in Chapter 4 and Appendix A.

- Note for impact assessment option 1: If a field value is entered for a metric in the existing condition assessment, a value **must also be entered** for the same metric in the proposed condition assessment. For any field value entered into the WSIT workbook a completed Field Value Documentation form (Appendix B) must be provided to document values and references for field value entries.
- For some metrics, methods include both rapid and more detailed forms of data collection; field values can be calculated using data from either rapid or more detailed methods. Coordinate with USACE to determine if rapid data collection methods are acceptable for a project. Rapid field data collection alternatives are acceptable to assess the existing condition at impact sites.
- For some metrics multiple years of data are required (i.e., fish metrics).
- For metrics where only a single sampling event is required (e.g., macroinvertebrates), multiple sampling events will improve the accuracy of the field value by accounting for inter- or intra-annual variability.

Proposed Condition – Only applicable for impact assessment option 1. More information on impact assessment options is provided in Section 3.2. Proposed condition field values represent the expected condition post-impact for each selected metric. More detail on how to determine reasonable values for proposed condition scores are described in relevant metric sections in Chapter 4.

3.3.c. Scoring Reach Condition

Scoring occurs automatically as field values are entered into the condition assessments. A field value is a measurement or calculated input for each specific metric and units vary per metric. As field values are entered, the worksheet will calculate an index value ranging from 0.00 to 1.00 for that metric. Where more than one metric is used per parameter, these index values are averaged to calculate parameter scores. **The parameter-level scores are the most representative output of condition.** Roll-up scoring continues to generate a single accounting value to calculate lift and loss in the reach. Multiple parameter scores are averaged to calculate functional category scores. Functional category scores are weighted and summed to calculate overall condition scores. Overall condition scores are then multiplied by reach length to generate Functional Feet values. Elements of the scoring process and tips are detailed below.

Index Values – The reference curves used to translate each metric field value into an index value are visible in the Reference Curves worksheet. Documentation on how reference curves were developed is provided in the Scientific Support for the WSQT (WSTT 2023). When a field value is entered for a metric in a condition assessment, these reference curves are used to calculate an index value between 0.00 and 1.00.

As a field value is entered in the condition assessment, the neighboring index value cell should automatically populate with an index value (Example 5a in Section 2.3). If the index value cell returns FALSE instead of an index value, the Site Information and Reference Selection section may be missing data (Example 5b).

If the WSQT does not return an index value, the user should check the Site Information and Reference Selection for data entry errors and then check the stratification for the metric in the Reference Curve worksheet or the Scientific Support for the WSQT (WSTT 2023) to see if there are reference curves applicable to the project. Incorrect information in the Site Information and Reference Selection section may result in applying reference curves that are not suitable for the project.

Roll Up Scoring – Metric index values are averaged to calculate parameter scores; parameter scores are averaged to calculate category scores. The category scores are then weighted and summed to calculate overall condition scores (Table 3 in Section 2.3). For metrics that are not assessed (i.e., a field value is not entered), the metric is removed from the scoring and no index value is provided; it is NOT counted as a zero. For example, three parameters included in the basic suite assess geomorphology: lateral migration, bed form diversity, and riparian vegetation. Where large woody debris is a natural component of the stream system, the geomorphology category score would be the average four parameter scores instead of three. Additional discussion of scoring is provided in the Scientific Support for the WSQT (WSTT 2023).

Field values, index values, parameter scores and category scores are displayed in Figure 24. In the existing and proposed condition assessments, roll-up scoring occurs next to the field value inputs.

Category scores are additive, so a maximum overall score of 1.00 is only possible when parameters within all categories are evaluated. Therefore, the maximum overall condition score without evaluating physicochemical and biology functional categories is 0.60. Overall reach scores are shown to the right of the category scores for each assessment.

Default Scores – In the Existing Conditions worksheet, when field values are not measured, default scores are applied at the parameter level and are based on the Priority Category selected in the Project Summary worksheet. The following default scores will be used: 0.90 for outstanding waters, 0.80 for most other waters (standard), and 0.70 on a case-by-case basis (exception). USACE will make a case-specific decision when a 0.70 default score is applicable. Default scores do not assume a pristine condition (i.e., 1.00 index value); this approach acknowledges that some metrics can and often score high where other metrics may reflect a lower capacity.

Functional Category	Function-Based Parameters	Parameter	Category	Category	ECS
Reach Hydrology & Hydraulics	Reach Runoff	0.56	0.61	Functioning At Risk	0.67
	Baseflow Dynamics				
	Bankfull Dynamics	0.75			
	Floodplain Connectivity	0.51			
Geomorphology	Large Woody Debris	0.00	0.55	Functioning At Risk	
	Lateral Migration	0.80			
	Bed Material Characterization				
	Bed Form Diversity	0.58			
	Riparian Vegetation	0.80			
Physicochemical	Temperature	0.80	0.80	Functioning	
	Nutrients	0.80			
Biology	Macroinvertebrates	0.80	0.80	Functioning	
	Fish	0.80			

Figure 25. Roll Up Scoring Example in Existing and Proposed Condition Worksheets.

Scoring by Rule: Four metrics have rules regarding scoring that will automatically be applied in the WSIT:

- There is no reference curve for the average velocity metric within the baseflow dynamics. **Where velocities are less than 1.0 fps, the baseflow dynamics parameter will score a 0.00**, regardless of the field value for average depth (Figure 11 in Section 2.3.d). Where velocities exceed 1.0 fps, the average velocity field value will not influence or inform the parameter score.
- **Field values less than 1.0 for the Width/Depth Ratio State metric will only score an index value of less than 1.00 if the stream is also incised** (Figure 12 in Section 2.3.d). The width/depth ratio state metric captures problems associated with aggradation (field value is greater than 1.0) and incision (field value is less than 1.0). A W/D that is smaller than the reference W/D (field value is less than 1.0) is only a problem if the channel is incised. If the bank height ratio is less than or equal to 1.2, the stream is not incised and width/depth ratio state metric field values less than 1.0 will score an index value of 1.00 .
- The percent streambank armoring metric captures problems associated with hardened streambank armoring techniques. If present or proposed armoring techniques exceed 50% of the bank length within the project reach, then the lateral migration parameter will score a 0.00 (Figure 13 in Section 2.3.d) and the other lateral migration metrics (BEHI/NBS and percent streambank erosion) do not need to be assessed. At this magnitude, the armoring is so pervasive that lateral migration processes would likely have no functional capacity.
- When field values are entered for both macroinvertebrate metrics, the parameter score is an average of index scores. For a small range of values, however, the parameter score will not be an average of the index scores. This exception applies to maintain consistency with how WDEQ applies these models by having a functioning metric score and a functioning-at-risk metric score default to functioning for that parameter. This is accomplished by making 0.70 the minimum parameter score in these cases (Figure 14 in Section 2.3.d). Similarly, when one metric has a non-functioning metric score and a functional-at-risk metric score, this will default to non-functioning for that parameter by making 0.29 the maximum parameter score in these cases.

Color Coding – When index values are populated in the Existing or Proposed Conditions worksheets, cell colors will automatically change to communicate where on the reference curve the field value lies. Green represents field values and index scores that represent a functioning range of condition; yellow represents field values and index scores that represent a functioning-at-risk (FAR) range of condition; and red represents field values and index scores that represent a not functioning range of condition (see Table 1 in Section 1.3 for definitions). This color-coding is provided to illustrate the relative condition of the various metrics and parameters assessed. Note that color coding is not provided for the overall condition score, as the overall score is not representative of an overall site condition unless parameters within all categories are evaluated.

3.4. Flow Alteration Module Worksheet

The Flow Alteration Module (FAM) and metrics are provisional, and use will be at the discretion of the Corps. The FAM worksheet is a supplementary calculator where users enter data describing the existing and proposed hydrologic conditions for an affected stream length.

In the WSIT workbook, the FAM worksheet contains two areas for data entry and one summary table:

- Functional Change Summary Table
- Site Information
- Existing and Proposed Condition Assessments¹⁷

Cells that allow input are shaded gray and all other cells are locked. Each section of the worksheet is discussed below. The worksheet can hold up to three reaches.

Site Information – The Site Information section includes the following:

- Reach ID – automatically populates from the Project Summary worksheet.
- Affected Stream Length – enter the length of stream where the FAM is applied. Affected stream length is defined at the upstream end where impacts or flow protection would initiate, and at the downstream end by the location of the next water rights user, significant tributary junction, or terminus beyond which the flow modification has no material effect on SQT parameters.
- Flow Type – automatically populates from the Project Summary worksheet.
- Strahler Stream Order – automatically populates from the Project Summary worksheet.
- Downstream Latitude and Longitude – automatically populates from the Project Summary worksheet.

Condition Assessment– Once the Site Information section has been completed, the user can input data into the field value columns of the existing and proposed condition assessments. The user will input field values for the applicable metrics within the module (Figure 26). Guidance on metric selection and calculation is provided in Section 4.9. Every metric is a ratio of Observed/Expected (O/E).

Functional Change Summary Table – The FAM worksheet summarizes the scoring at the top of the sheet. This summary (Figure 27) provides the module scores from the existing and proposed condition assessment sections, calculates change in condition (mPCS-mECS), identifies the affected stream length, calculates the existing (FF) and proposed (FF) functional feet values, calculates a weighted change in functional feet (ΔFF) and percent change in FF.

Roll-up scoring in the FAM occurs automatically as field values are entered into the condition assessment tables. Metric index values are averaged to calculate a module score. Functional loss is generated when proposed scores are lower than existing, resulting in a negative value. Existing and proposed scores are multiplied by the affected stream length and weighted by 20% (WSTT 2023) to calculate FF. The weighted existing FF, proposed FF and ΔFF are displayed in the Functional Change Summary Table. On the Project Summary worksheet, the ΔFF for each

¹⁷ Tables are color-coded to differentiate between functional categories. Blue is for reach hydrology and hydraulics.

of the three affected reaches is added to the ΔFF for all project reaches in the Functional Loss worksheet to calculate the total functional loss.

EXISTING CONDITION for Reach STR1 AR1			
Metric	Field Value	Index Value	Module
Mean Annual Q (O/E)	0.52	0.58	0.70
Mean Aug Q (O/E)	0.65	0.72	
Mean Sept Q (O/E)	0.88	0.98	
Mean Jan Q (O/E)	0.71	0.79	
Mean Annual Peak Daily Q (O/E)	0.56	0.62	
7-Day Minimum (O/E)	0.48	0.53	

Figure 26. Example WSIT Flow Alteration Module Condition Assessment.

FUNCTIONAL CHANGE SUMMARY			
Reach ID	STR1 AR1	STR1 AR2	STR2
Module Existing Condition Score (mECS)	0.70		
Module Proposed Condition Score (mPCS)	0.89		
Change in Functional Condition (mPCS - mECS) *	0.04		
Affected Stream Length (ft)	5200.0		
Existing Functional Feet (FF) *	728.0		
Proposed Functional Feet (FF) *	936.0		
Proposed FF - Existing FF (ΔFF) *	208.0	0.0	0.0
Percent Change in FF (%)	29%		
* Includes 20% multiplier for weighting			

Figure 27. Example WSIT Flow Alteration Module Functional Change Summary Table.

3.5. Reference Curves Worksheet

The Reference Curves worksheet contains the reference curves used to convert field values into index values. *This worksheet is included for information purposes and does not require any data entry.*

The numeric index value range (0.00 to 1.00) is standardized across metrics using the definitions of functional capacity, i.e., functioning, functioning-at-risk and not functioning condition provided in Table 1 in Section 1.3. Reference curves are tied to specific benchmarks (thresholds) that represent the degree to which condition departs from reference condition as described in Section 1.3.

On this worksheet, reference curves are organized into columns based on functional category and appear in the order they are listed in the condition assessments. One metric can have multiple curves depending on how the reference curves were stratified. For example, the woody vegetation cover metric is stratified by ecoregion. All reference curves and their stratification are described in the Scientific Support for the WSQT (WSTT 2023).

Chapter 4. Data Collection and Analysis

This chapter provides instructions on how to collect and analyze data used in the WSQT and WSIT workbooks (Figure 28). For the WSIT workbook, the instructions in this chapter are only applicable to reaches implementing Impact Assessment Option 1 or 2 (refer to Section 3.2).

Teams collecting and analyzing these data should have experience and expertise in botany, ecology, hydrology, and geomorphology, as well as expertise and experience in applying the assessment methods used to calculate the metrics included in the SQT. Interdisciplinary teams of at least two people with a combination of these skills are necessary to ensure consistent and accurate data collection and analysis.

This chapter includes experience requirements for each parameter, steps for calculating metric field values, advice for estimating proposed condition field values, and describes supporting documentation and field forms. Field procedures are summarized in Appendix A. For some metrics, multiple field methods are available to allow for either rapid or detailed assessment methods. Few metrics are unique to the WSQT, and data collection procedures are often consistent with other instruction manuals or literature. Where appropriate, this chapter and Appendix A will reference the original methodology to provide technical explanations and make clear any differences in data collection or calculation methods needed for the WSQT.

4.1. Reach Delineation and Representative Sub-Reach Selection

The WSQT is a reach-based assessment, and each reach is evaluated separately. A large project may extend several miles or include both mainstem channels and tributaries. As stream condition or character can vary widely from the upstream end of a project to the downstream end a large project would need to be subdivided into multiple project reaches. In addition to metrics that assess in-channel conditions for each project reach, metrics also assess the floodplain, riparian area, and runoff from adjacent land.

Delineating stream reaches within a project area occurs in two steps. The first step is to identify whether there is a need to separate the project area into multiple reaches based on variations in stream physical characteristics and/or differences in project designs or magnitude of impacts. Once project reaches are determined, the user selects a representative sub-reach within each project reach to assess various metrics. The processes to define project reaches and representative sub-reaches are described in detail below in Sections 4.1.a and 4.1.b respectively.

The WSQT also includes a Flow Alteration Module (FAM) that assesses the length of stream affected by a proposed change in flow regime, which may include multiple project reaches or extend beyond the project area. More detail on the FAM affected stream length is provided in Section 4.9.

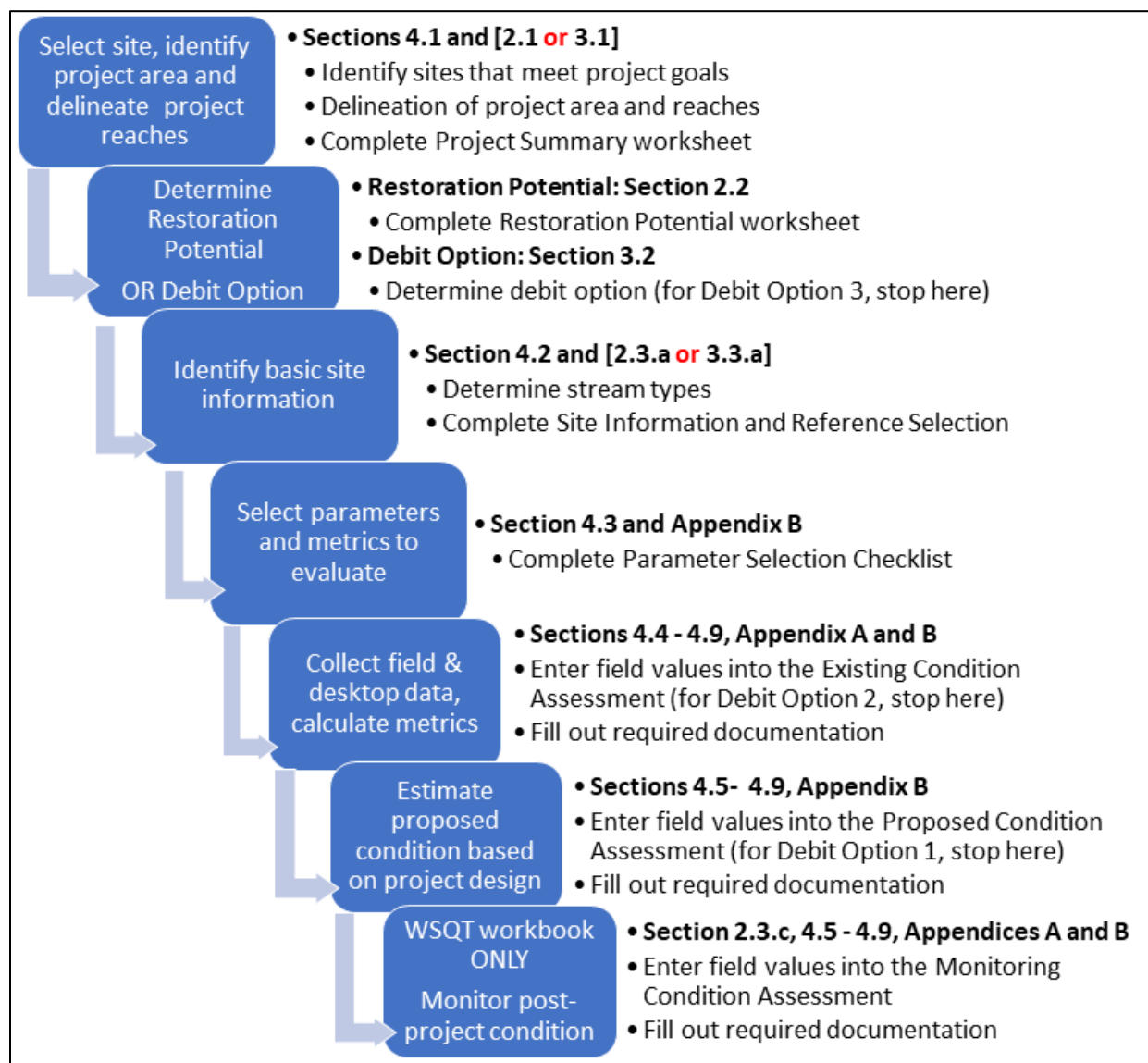


Figure 28. WSQT and WSIT Process Flow Chart.

4.1.a. Delineation of Project Reach(es)

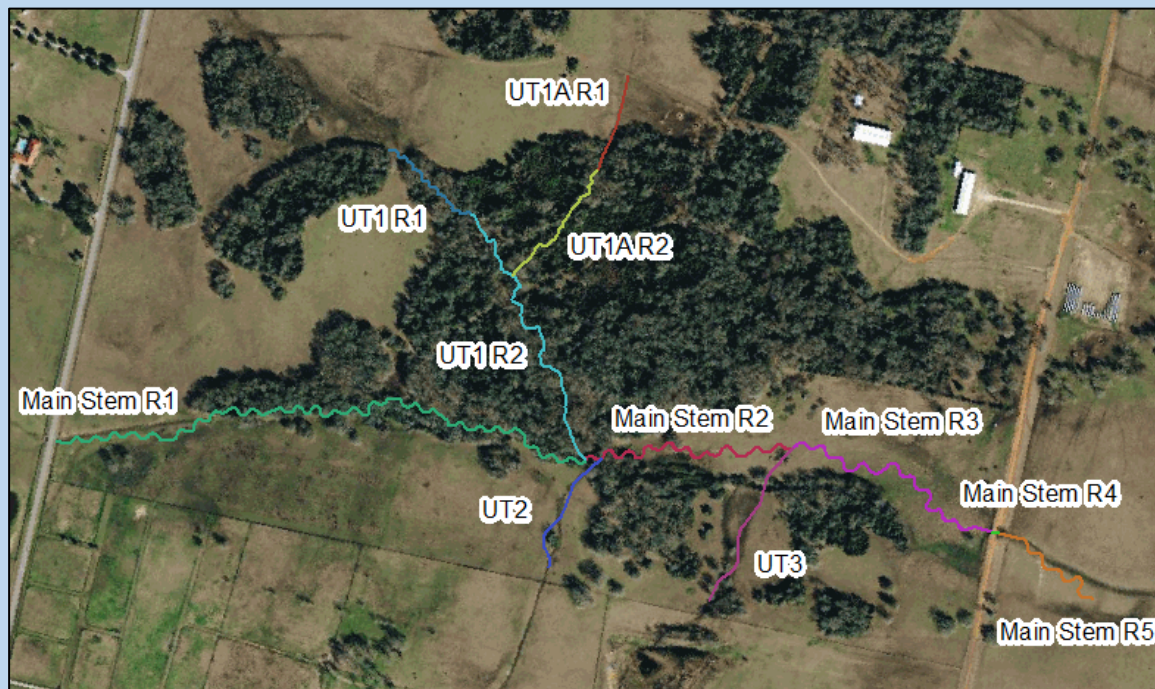
The user should determine whether their project area encompasses a single homogeneous reach or multiple potential reaches. For this purpose, a reach is defined as a stream segment with similar processes and morphology, including characteristics such as stream type (Rosgen 1996), stability condition, riparian vegetation type, and bed material composition. Reaches within a project area may be short or long depending on the variability of the physical stream characteristics within the project area (see Example 7).

Professional judgement is required to delineate project reaches. Users can review aerial imagery, National Hydrography Dataset, and other desktop tools to preliminarily determine reach breaks; these determinations should be verified in the field. Users should provide justification for the final reach breaks in the Project Summary worksheet. Specific guidance is provided below to assist in making consistent reach identifications:

- Separate streams, i.e., tributaries vs. main stem, are considered separate project reaches.
- A tributary confluence should lead to a reach break. Where a tributary enters the main stem, the main stem should be split into two project reaches - one upstream and one downstream of the confluence. Small tributaries, as compared to the drainage area of the main stem channel, may not require a reach break.
- Reach breaks should occur where there are changes to geologic, hydrologic or biological process drivers (Castro and Thorne 2019); valley morphology; stream type (Rosgen 1996); or bed material composition.
- Reach breaks should occur where there are diversion dams or other flow modification structures on the stream, with one project reach upstream of the structure and one downstream of the structure. In some cases, the structure would also be its own reach (see Example 8). Discrete structures that don't measurably alter stream conditions can be included within a larger reach.
- Reach breaks should occur where there are distinct changes in the level of anthropogenic modifications, such as narrowed riparian width from road embankments, concrete lined channels, or culverts/pipes. For example, a culvert's footprint would be evaluated as a separate project reach from the reaches immediately up and downstream of the culvert.
- Multiple project reaches are needed where there are differences in the magnitude of impact or mitigation approach (e.g., enhancement vs. restoration) within the project area. For example, restoration approaches that reconnect stream channels to their original floodplain would be evaluated in a separate reach from portions of a project that only include bank stabilization activities.

Example 7: Project Reach Delineation

The following is an example showing how project reaches are identified based on physical observations. Work was proposed on five streams. The main-stem channel was delineated into five reaches, two unnamed tributaries (UT) were delineated into two reaches each, and the remaining two UTs as individual project reaches. Because up to 10 reaches can be evaluated per workbook, two Excel Workbooks would be needed for the 11 project reaches.



Reach	Reach Break Description
Main Stem R1	Beginning of project to UT1 confluence where drainage area increases by 25%.
Main Stem R2	To UT3 confluence where there is a change in slope and in-channel conditions.
Main Stem R3	To culvert. Bed material is finer and bedform diversity is impaired below culvert.
Main Stem R4	40 feet through the culvert.
Main Stem R5	From culvert to end of project.
UT1 R1	Property boundary to the last of a series of headcuts caused by diffuse drainage off the surrounding agricultural fields.
UT1 R2	To confluence with main stem. Restoration approach differs between UT1 R1 where restoration is proposed to address headcuts and this reach where enhancement is proposed.
UT1A R1	Property boundary to edge of riparian vegetation. Reach is more impaired than UT1A R2, restoration is proposed.
UT1A R2	To confluence with UT1. Enhancement is proposed to preserve riparian buffer.
UT2 & UT3	Beginning of project to confluences with main stem. Reaches are actively downcutting and supplying sediment to the main stem.

Example 8: Existing Versus Proposed Reach Breaks

The physical observations of condition are not necessarily the same between existing and proposed conditions. In other words, reach breaks during monitoring may not correspond to pre-project (existing condition) reach breaks. Consider the mainstem reaches from Example 7. Mainstem reaches 3, 4, and 5 have similar proposed conditions in the project design. The road and culvert (R4) will be removed, and the measurable proposed conditions are expected to be similar. In this case, the proposed conditions can have a single reach encompassing the three existing condition reaches.

Reach	Existing Stream Length (ft)	ECS	Proposed Stream Length (ft)	PCS	ΔFF
Main Stem R3	1,600	0.50	2,000	0.65	500
Main Stem R4	40	0.00	40	0.65	26
Main Stem R5	1,200	0.40	1,500	0.65	495

For the existing conditions, three reaches are present and condition assessments are performed. As a culvert, Reach 4 field values are measured as having no function. Once the project is constructed, monitoring events will confirm reach breaks represent constructed and current conditions before collecting data. Then data can be collected and field values calculated for the proposed condition reaches which lump R3, R4 and R5 together

4.1.b. Representative Sub-Reach Determination

Some metrics, such as armoring and concentrated flow points, will be evaluated along the entire project reach, but other metrics will only be evaluated within a representative sub-reach (Figure 29). Selecting a representative sub-reach is necessary to avoid having to quantitatively assess very long reaches with similar physical conditions. The representative sub-reach should be at least 20 times the bankfull width or two meander wavelengths (Leopold 1994), whichever is longer. If the entire reach is shorter than this length, then the entire project reach should be assessed. The location of the representative sub-reach should be selected where measured values will be representative of the reach conditions. Assessment length and sampling locations are described below for each metric and parameter.

The representative sub-reach shall begin and end at the head (beginning) of the same type of bedform feature. Typically, a sampling reach begins and ends at the head of a riffle feature, although it can begin and end at the head of the same type of feature (i.e., riffle or pool). This is important for measuring the slope and percent riffle metric as there should be an equal number of riffle and pool features.

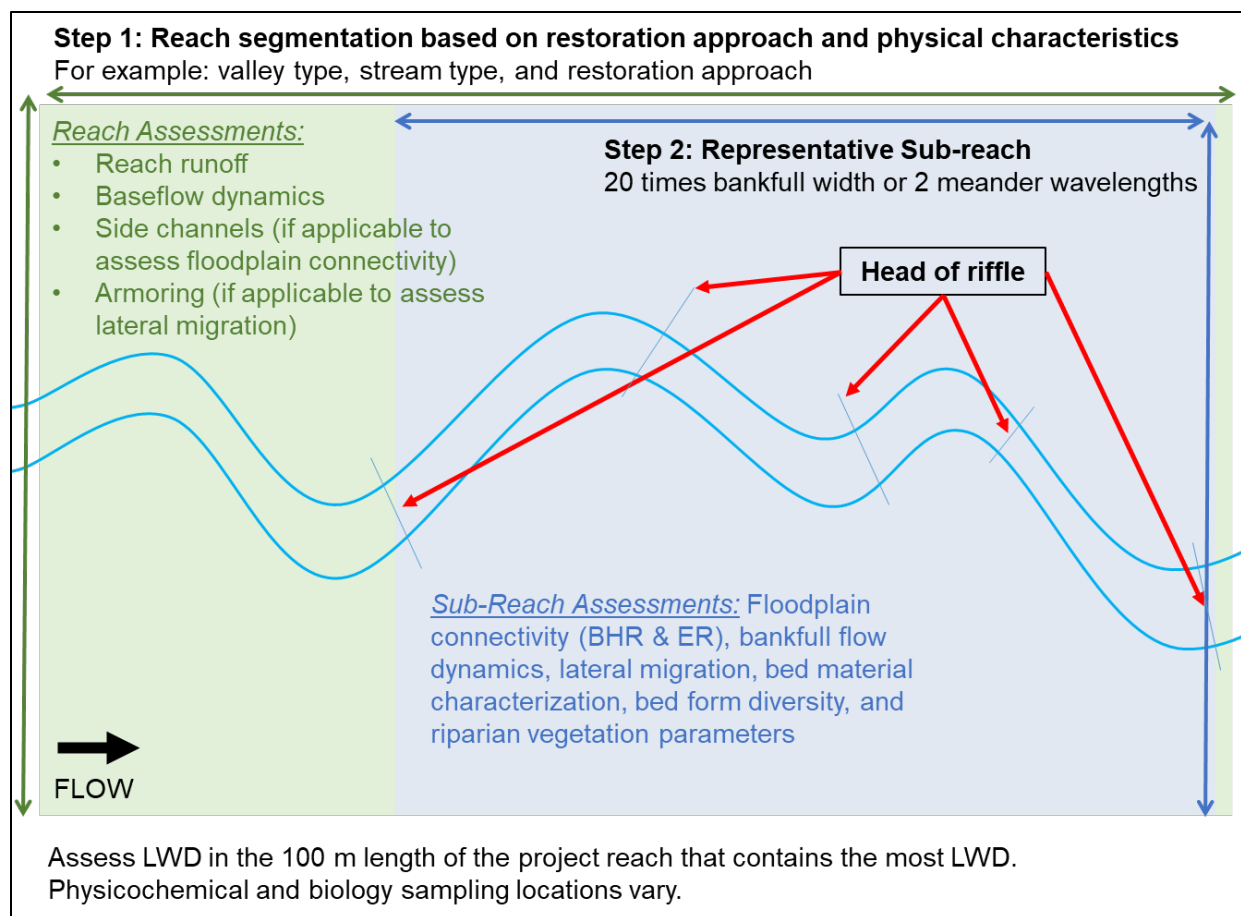


Figure 29. Reach and Sub-Reach Segmentation.

Reach Hydrology & Hydraulics Functional Category:

- Reach runoff metrics and the percent side channel metric (floodplain connectivity) are evaluated within the entire project reach.
- Baseflow dynamics metrics are evaluated at three riffles within the project reach.
- Bank height ratio and entrenchment ratio metrics (floodplain connectivity) and the bankfull dynamics parameter are assessed within the representative sub-reach.

Geomorphology Functional Category:

- Percent armoring (lateral migration) is assessed along the entire project reach.
- Riparian vegetation, lateral migration (dominant BEHI/NBS, percent erosion and greenline stability rating), bed material characterization, and bed form diversity are assessed within the representative sub-reach.
- Large woody debris (LWD) is assessed within a 328-foot (100 meter) segment located, whenever possible, within the representative sub-reach. If the project reach is less than 328 feet, assess LWD throughout the project reach and scale the resulting value to 100m length.

Physicochemical and Biology Functional Categories:

- Sampling should occur within the project reach, but specific locations will vary by metric, and are described in the metric sections in this chapter.

Note: Use of a reference or control reach is required for the game species biomass metric. The user may choose to assess other parameters at a reference reach in addition to the project reach to compare the project site with an upstream or nearby condition. If a reference reach is located at the upstream end of the project reach, this would provide an upstream to downstream comparison in addition to showing changes pre- and post-project at a site.

4.2. Determining Stream Types

The Site Information and Reference Selection sections require identification of the reference stream type for each project reach using the Rosgen (1996) method. Reference stream type is used to stratify reference curves for the entrenchment ratio and pool spacing ratio metrics. The WSQT workbook also has space to identify the existing, proposed and design stream types. Each of these stream type characterizations provides information on the project reach and could inform the restoration potential determination, project goals and objectives, and reach-specific performance standards.

Stream types are based on the Rosgen stream type classification system and the basic fluvial landscapes where they typically occur, which are described in detail in Applied River Morphology (Rosgen 1996) and in Part 654 Stream Restoration Design National Engineering Handbook (NRCS 2007). The broad-level stream type is determined using valley type, entrenchment ratio, width depth ratio, sinuosity, and slope (Figure 30).

Quick Rosgen Stream Classification Guide (Rosgen 1996)					
ER < 1.4		1.4 < ER < 2.2		ER > 2.2	
WDR < 12	WDR > 12	WDR > 12		WDR < 12	WDR > 12
K < 1.2	K > 1.2	F	B	E	C
A	G	ER = Entrenchment Ratio; WDR = Width Depth Ratio; K = Sinuosity			

Figure 30. Rosgen Stream Classification Summary (Rosgen 1996).

Existing Stream Type – Existing stream type reflects the Rosgen stream type before impact or restoration activities. Existing stream type is not used to select the appropriate reference curve or determine index values but is provided for communication and can be used to inform restoration potential. The existing stream type is determined through a field survey of the project reach.

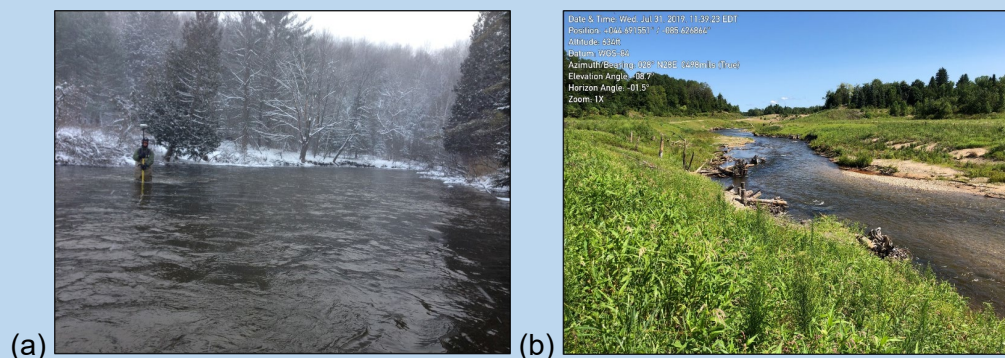
Example 9a: Determining Stream Types

Existing Stream Type = G5c (Figure a). The stream is incised and entrenched with a low bankfull width/depth ratio, slope less than 2%, and a sand bed.

Reference Stream Type = C5 (Figure b). The reference reach is immediately upstream of the project reach. It is a single-thread, stream-wetland complex in a forested watershed that has not been disturbed in many decades. There was no evidence that the stream had ever been channelized or altered.

Design Stream Type = C5 (Figure c). The design (and as-built) stream type is a C. The entrenchment ratio is very large (>10), the bankfull width/depth ratio is >12 to encourage wetland development on the floodplain similar to the reference reach (a higher width/depth ratio can yield a shallower depth to the water table in this landscape and produce a stream-wetland complex). The upstream watershed is forested with low sediment supply. Stream power is low, erosion resistance is low, and the biotic interaction with riparian vegetation is high. These factors contribute to the decision to design a higher width/depth ratio than an E stream type, which would be more effective at transporting sediment in a low slope valley.

Proposed Stream Type (Figure d) = C5. Based on the design and an understanding of channel evolution in an unconfined alluvial valley in this landscape, it is anticipated that the proposed stream type at the end of five years of monitoring will remain a C5. This decision was also informed by the reference reach immediately upstream of the project reach.

Example 9b: Determining Stream Types

Existing Stream Type = Does not apply. Existing condition is a lake.

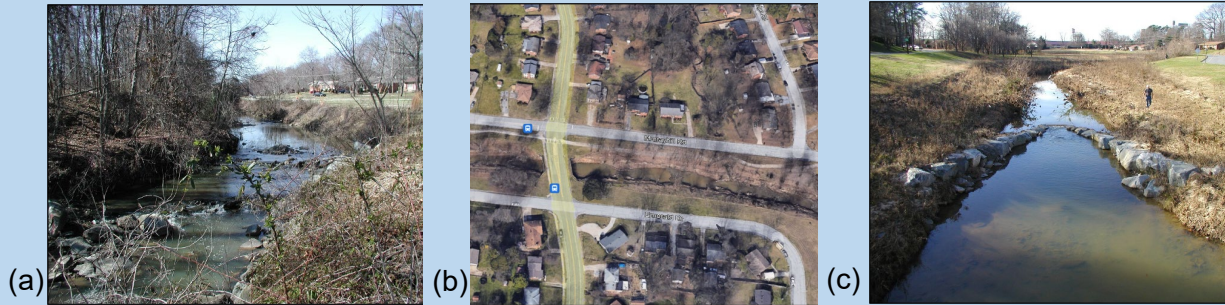
Reference Stream Type = C4 (Figure a). This river is in an unconfined alluvial valley with slopes <1%. Many reaches in undisturbed portions of the watershed classify as a C4.

Design/Proposed Stream Type = B4c (Figure b). The design goal is to remove the downstream dam and restore the stream channel in its former location. However, there is not enough funding to excavate the floodplain and remove the accumulated sediment in the lake bottom. Instead, floodplain (bankfull) benches will be constructed to provide a moderate entrenchment ratio (1.4 - 2.2). A Bc was selected as the design stream type due to reach-scale constraints. For the stream to evolve into a C stream type, significant floodplain erosion would have to occur. The stream type is expected to remain stable over the duration of the monitoring period, thus the proposed stream type is also a Bc.

Design Stream Type – Design stream type reflects the channel dimension, pattern, and profile that will be constructed as part of the project design and is also referred to as the as-built stream type. This stream type may or may not be the same as the proposed or reference stream types.

Proposed Stream Type – The proposed stream type reflects the dimension, pattern, and profile that is expected to form (evolve) by the end of the monitoring period. The proposed stream type is the restoration target **at project closeout** informed by the design and an understanding of channel/stream evolution processes (Example 9) and should be consistent with the expected conditions within the proposed condition assessment. This stream type may or may not be the same as design or reference stream type. For example, in alluvial valleys, it is common for practitioners to design a C, with the expectation it will evolve into an E over the course of the monitoring period. The proposed stream type is provided for communication and to inform the development of performance standards, for example, to account for any anticipated changes between as-built conditions and conditions at the end of the monitoring period.

Reference Stream Type – The reference stream type reflects the channel dimension, pattern, and profile that would naturally occur in a given valley absent from human influences. The reference stream type is used to stratify reference curves for the entrenchment ratio and pool spacing ratio metrics and can also inform restoration potential. This stream type may or may not be the same as design and proposed stream types.

Example 9c: Determining Stream Types

Existing Stream Type = F4 (Figure a). This stream is in an urban setting, and is incised and entrenched but with a higher bankfull width/depth ratio than the Gc from Scenario A.

Reference Stream Type = E4 (Figure b). The reach is in an unconfined alluvial valley that is currently developed with homes and roads. The stream has been confined and channelized; however, it is still classified as an unconfined alluvial valley for reference stream type purposes. Therefore, the reference stream type is a C or an E. Other reference reach streams in this region are E's due to the dense, woody vegetation along the streambanks and lack of cobble in the streambeds.

Design/Proposed Stream Type = B4c (Figure c). The design stream type is a Bc due to reach-scale constraints, including a sewer line along one bank and a road near the other. A bankfull bench will be constructed and the banks sloped to provide a moderate entrenchment ratio. In-stream structures will be used to create a step-pool sequence. Because no change in stream type is expected between the as-built condition and year five monitoring, proposed stream type is also a Bc. Maintaining channel stability is important due to the urban landscape.

Reference stream type is the stream type that should occur in a given landscape setting and the hydrogeomorphic processes occurring at the watershed and reach scales (Example 9). To determine reference stream type, users should have experience and knowledge about channel evolution, process drivers and the Rosgen stream classification system. For the WSQT, the reference stream type would be a C, E, or DA in unconfined alluvial valleys and a B for colluvial valleys. In confined alluvial valleys, the reference stream type would be a C or Bc depending on historic evidence of a meandering stream or step-pool stream.

While existing stream type is calculated from field data, determining the design, proposed and reference stream types will require additional sources of information. The Rosgen Channel Succession Scenarios (Rosgen 2006) or other channel or stream evolution models (e.g., Schumm et al. 1984; Cluer and Thorne 2013; Castro and Thorne 2019) can be used as a guide for determining potential trajectories. Where available this information can be further supported with information from the design process (e.g., fluvial landscape, historic channel conditions, watershed hydrology, sediment transport, and/or anthropogenic constraints); historic, geomorphic, and stratigraphic evidence; and an evaluation of process drivers.

The Stream Evolution Triangle can be employed to identify the dominant process drivers for the project reach following the guidance from Castro and Thorne (2019). Castro and Thorne (2019)

identify three primary stream process drivers: geology (erosion resistance), hydrology (stream power), and biology (biotic interactions). Determine if **erosion resistance** for a reach is high, moderate or low by considering valley confinement, valley material source (alluvial, colluvial or bedrock) and sediment transport capability (source, transport, or response). Determine whether the **stream power** for a reach is high, moderate, or low by considering whether the watershed is permeable or impermeable, whether flow is regulated, and whether the hydrologic regime is driven by baseflow, snow, rain, rain-on-snow, or storms. Determine whether the **biotic interaction** for a reach is high, moderate, or low by considering the influence of wetland vegetation, beaver, LWD, and biologically induced bed stability or instability. Using these evaluations, the user can refer to Figures 6a and 6b from Castro and Thorne (2019) to determine the typical Rosgen stream type(s) that might be expected given an assessment of the dominant process drivers.

4.3. Parameter and Metric Selection

The WSQT condition assessments include 29 metrics to quantify 13 parameters. There is also a Flow Alteration Module (FAM) that adds (or subtracts) from the functional feet score based on the magnitude of flow alteration within a potentially larger, hydrologically affected reach. Not all metrics and parameters will need to be evaluated at each site.¹⁸ The user should consider landscape setting, process drivers, function-based goals/objectives, and restoration potential when selecting parameters. A parameter selection checklist is included in Appendix B and should be completed for each project (Figure 31).

The condition assessments within the WSQT workbook and WSIT workbook have the same 13 parameters and 29 metrics. However, the existing condition worksheet in the WSIT workbook provides default parameter scores to be used with Impact Assessment Option 2. Default scores are provided for the basic suite and follow parameter selection guidance in this section (i.e., if field values are entered for baseflow dynamics, then the default score for bankfull dynamics is removed from scoring). Default scores are also provided for physicochemical and biology parameters to ensure that authorized stream impacts are adequately mitigated. Refer to Section 3.2 for more information on how functional loss is calculated using impact severity tiers.

¹⁸ Under CWA §404, the level of analysis and documentation should be commensurate with the scale and scope of the project (USACE 2008a). The Corps routinely evaluates projects where stream impacts range from minor, localized impacts to projects with direct and secondary impacts spanning broad geographic scales. As such, approaches that have flexibility in their application are beneficial within the CWA §404 program (Somerville and Pruitt 2004).

Function-based Parameter		Metric(s)		Applicability
<input checked="" type="checkbox"/>	Reach Runoff*	<input checked="" type="checkbox"/>	Land Use Coefficient* (D) AND Concentrated Flow Points* (F)	All streams and flow types.
<input type="checkbox"/>	Baseflow Dynamics	<input type="checkbox"/>	Average Velocity AND Average Depth (D/F)	Use INSTEAD OF Bankfull Dynamics where hydraulic conditions during summer/fall baseflow periods should support trout assemblages (coldwater perennial or intermittent streams).
<input checked="" type="checkbox"/>	Bankfull Dynamics*	<input checked="" type="checkbox"/>	Width/Depth Ratio State* (D/F)	Use in single-thread channels.
<input checked="" type="checkbox"/>	Floodplain Connectivity*	<input checked="" type="checkbox"/>	Bank Height Ratio* AND Entrenchment Ratio (F)	Omit ER in multi-thread channels.
		<input type="checkbox"/>	Percent Side Channels (F)	Metric applicable in alluvial valleys with single-thread channels that support side-channels.
<input type="checkbox"/>	Large Woody Debris (LWD)	<input type="checkbox"/>	LWD Index (F)	Use in systems with forested catchments, riparian gallery forests, or that otherwise naturally have a supply of LWD. This parameter can also be used where LWD is an appropriate element in restoration.
		or		
		<input type="checkbox"/>	No. of LWD Pieces/ 100 meters (F)	
<input checked="" type="checkbox"/>	Lateral Migration*	<input checked="" type="checkbox"/>	Dominant BEHI/NBS AND Percent Streambank Erosion (F)	Use in single-thread channels.
		or		
		<input type="checkbox"/>	Greenline Stability Rating (F)	Likely more applicable in streams naturally unstable.
		<input type="checkbox"/>	Percent Armoring (F)	Use in addition to the other metric(s) when man-made armoring is present or proposed in the project reach.
<input type="checkbox"/>	Bed Material Characterization	<input type="checkbox"/>	Percent Fines (F)	Applicable where reach wide d50 > 2mm and fine sediment deposition over coarse bed material is occurring or expected.
<input checked="" type="checkbox"/>	Bed Form Diversity*	<input checked="" type="checkbox"/>	Pool Spacing Ratio AND Pool Depth Ratio* AND Percent Riffle* (F)	Applicable in perennial and intermittent single-thread channels. Omit pool spacing ratio in bedrock dominated systems.
<input checked="" type="checkbox"/>	Riparian Vegetation*	<input checked="" type="checkbox"/>	Riparian Extent (D/F) AND Woody Vegetation Cover (F) AND Percent Native Cover (F) AND for CWA 404 projects Herbaceous Cover (F).	Where absolute woody vegetation cover is/should be >20%.
		<input type="checkbox"/>	Riparian Extent (D/F) AND Herbaceous Vegetation Cover (F) AND Percent Native Cover (F)	Where absolute woody vegetation cover is/should be <20%.
<input type="checkbox"/>	Temperature	<input type="checkbox"/>	Maximum Weekly Average Temperature (F)	Use these parameters and metrics for impacts or for projects with goals related to water quality improvements.
<input type="checkbox"/>	Nutrients	<input type="checkbox"/>	Chlorophyll (F)	
<input type="checkbox"/>	Macroinvertebrates	<input type="checkbox"/>	WSII AND RIVPACs (F)	Use for impacts, for projects with goals related to biological improvements or where project may impact conservation areas or other valuable fish habitats.
<input type="checkbox"/>	Fish	<input type="checkbox"/>	Native Fish Species Richness AND SGCN Absent (F)	
		<input type="checkbox"/>	Game Species Biomass (F)	
* Include in all assessments				
(D) indicates metrics are calculated using desktop methods				
(F) indicates metrics are calculated or verified using field methods				

Figure 31. Parameter Selection Checklist.

A basic suite of metrics within six parameters are recommended at all project sites evaluated for CWA §404 purposes to provide consistency between impacts and compensatory mitigation and allow for more consistent accounting of functional change (Figure 32). The basic suite includes metrics within the **reach runoff, floodplain connectivity, baseflow or bankfull dynamics, lateral migration, bed form diversity, and riparian vegetation parameters**. (Note: some of these parameters are not applicable in ephemeral and/or multi-thread sites, see Table 7). Application of the basic suite of metrics is considered rapid, as field data can be collected by a team of two in less than a day. Additional metrics may require more time in the field and/or additional data processing.

Basic Suite of Parameters		
Reach Runoff	Flow Dynamics (typically bankfull)	Floodplain Connectivity
Lateral Migration	Bed Form Diversity	Riparian Vegetation

Figure 32. Basic Suite of Parameters Included in All Assessments.

Table 7. Applicability of Parameters Across Flow Type and in Multi-thread Systems. An 'x' denotes that one or more metrics within a parameter is applicable within these stream types.

Applicable Parameters*	Perennial	Intermittent	Ephemeral	Multi-thread Channels
Reach Runoff	x	x	x	x
Baseflow Dynamics	x	x		x
Bankfull Dynamics	x	x	x	
Floodplain	x	x	x	x (BHR only)
Large Wood	x	x	x	x
Lateral Migration	x	x	x	x (GSR and armoring)
Bed Material Characterization	x	x	x	x
Bed Form Diversity	x	x		
Riparian Vegetation	x	x	x	x
Temperature	x	Where baseflows extend through sampling period		x
Nutrients	x			x
Macroinvertebrates	x			x
Fish	x	x		x

*Some parameters have applicability limitations other than flow type and number of threads.

The WSQT can be tailored to a specific project through selection of additional parameters that tie to the project's landscape setting, function-based goals, objectives, and restoration potential. For projects proposed under CWA §404, early consultation with the Corps is required to identify any additional parameters or metrics that may be needed for a specific project.

Important notes on parameter and metric selection:

- **For CWA §404 projects, the Corps has discretion** over which field methods, metrics, and parameters are used for a project. Users should complete the Parameter Selection Checklist (Figure 31 and Appendix B) and consult with the Corps prior to data collection on a project.
- The same parameters and metrics must be used in the existing condition and all subsequent condition assessments (e.g., proposed, as-built, and monitoring) within a project reach, otherwise the relative weighting between metrics and parameters changes and the WSQT output is not comparable over time.
- For metrics that are not assessed (i.e., a field value is not entered), the metric is not included in the scoring. **Users should not enter field values for metrics that were not selected or evaluated.**
- The overall condition scores should not be compared or contrasted between sites when parameters and metrics vary between project sites. To evaluate multiple sites, the same suite of parameters and metrics would need to be collected at all sites.
- Field methods described in this chapter and Appendix A are focused on single-thread, wadeable streams. Some metrics may be difficult to sample in non-wadeable or multi-thread systems and may require alternate field methodologies. For CWA §404 projects, sampling plans in these systems should be discussed with the Corps prior to data collection efforts.
- Reference curves to assign index values have been primarily derived from data within perennial, wadeable, single-thread stream systems. When applying metrics in other stream situations, the user should note this and select only applicable parameters and metrics (Table 7). While a parameter and associated metrics may be applicable to ephemeral and multi-thread channels, unique reference curves were not developed specifically for these systems. Where reference expectations for a particular metric may vary based on stream type or flow permanence, more focus should be placed on the difference in pre- and post-project scores rather than the absolute value.
- The tool architecture is flexible and can accommodate additional parameters and metrics that are accompanied by specific and defensible reference curves and index values. Any additional parameters or metrics should be provided in a written proposal to the Corps for consideration.
- When function-based goals and objectives include fish communities in warmwater streams, users should consider the expected species and their requirements (see Quist et al. 2003) during parameter and metric selection.

4.3.a. Specific Guidance on Parameter Selection

Reach Runoff Parameter – This parameter should be evaluated at all project sites. Both parameter metrics (land use coefficient and concentrated flow points) should be evaluated together. Within the lateral drainage area, land use coefficient characterizes the alteration of natural land covers while concentrated flow points characterize activities that drain the landscape.

Baseflow Dynamics Parameter – This parameter is recommended where hydraulic conditions during summer/fall baseflow periods may not support trout assemblages under existing or proposed conditions due to flow or channel alteration. This parameter is only applicable in single-thread, intermittent or perennial cold water streams (Temperature Tiers I and II) that have or are proposed to have regulated flow. Note that in settings where average velocities are naturally below 1.0 fps, this parameter should not be applied.

Both parameter metrics (average velocity and depth) should be evaluated together. Users should evaluate either the bankfull dynamics parameter or the baseflow dynamics parameter, not both. This metric is preferred over bankfull dynamics for cold water, multi-thread, high bedload reaches in the Volcanics area (Snake River, Francs Fork, Upper Wind River, Wiggins Fork, etc.).

Bankfull Dynamics Parameter – This parameter should be evaluated at all single-thread project sites, except in multi-thread systems or where the user has chosen to evaluate baseflow dynamics. Users should evaluate either the bankfull dynamics parameter or the baseflow dynamics parameter, not both. There is only one metric to assess this parameter, width/depth ratio state.

Floodplain Connectivity Parameter – This parameter should be evaluated at all project sites. Users should evaluate both the bank height ratio (BHR) and entrenchment ratio (ER) metrics, except in multi-thread systems, where the BHR should be applied alone. ER characterizes the horizontal extent of the floodplain while BHR characterizes the frequency of floodplain inundation.

The percent side channels metric is recommended in alluvial valleys where side channels could be supported, including beaver meadows and other stream-wetland complexes. This metric should not be applied in multi-thread systems (three or more channels active at baseflow) or in steeper colluvial systems. This metric would be applied in addition to BHR and ER.

Large Woody Debris (LWD) Parameter – This parameter should be assessed in project reaches with forested catchments, riparian gallery forests, or other streams that naturally do or would have a supply of LWD. This parameter can also be used where LWD is an appropriate element in restoration.

Users can evaluate either the Large Woody Debris Index (LWDI) or large wood piece count metric, but not both. The LWDI metric better characterizes the complexity of large wood in streams but takes more time to assess. For willow-dominated sites, the LWDI may be preferable, as it includes willow debris jams in the index, while the large wood piece count does not. The LWDI is also preferable at restoration sites where LWD is incorporated as part of the design.

Lateral Migration Parameter – This parameter should be evaluated at all project sites. Users should evaluate either the Greenline Stability Rating (GSR) metric or the dominant BEHI/NBS and percent erosion metrics together. The percent armoring metric should be applied in addition to the other metric(s) when armoring techniques are present or proposed in the project reach (Figure 33).

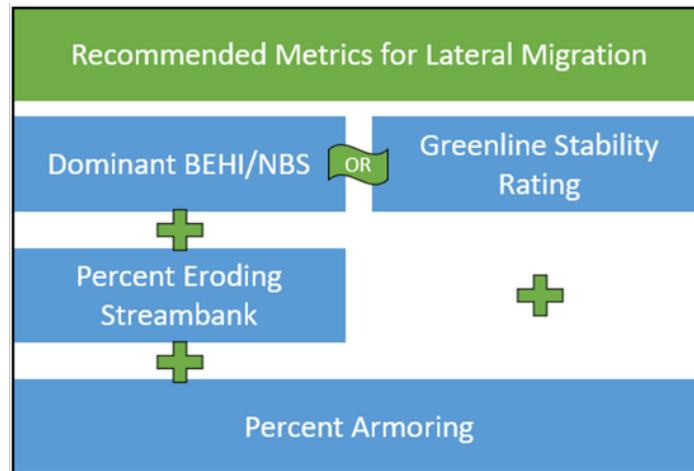


Figure 33. Metric Selection Guidance for Lateral Migration Parameter.

The GSR metric is applicable in all streams with less than 4% slope, including streams that are naturally unstable, like systems with naturally high rates of bank erosion or response systems (e.g., braided streams, ephemeral channels, or alluvial fans). GSR is not applicable in highly modified streams where natural and artificially hardened banks are less susceptible to vegetation influences; or in large rivers where landform features play the dominant role in regulating hydrologic influences.

The dominant BEHI/NBS and percent erosion metrics are applicable in single-thread channels. The dominant BEHI/NBS characterizes the magnitude of bank erosion, while percent erosion characterizes the extent of bank erosion within a reach. These metrics are not recommended in systems with naturally high rates of bank erosion or response systems (e.g., braided streams, ephemeral channels, or alluvial fans).

The percent armoring metric should be applied whenever man-made armoring is present or proposed in a project reach. Note that for project reaches where armoring exceeds 50% of the total bank length, the parameter will score a 0.00 and other metrics may not need to be assessed.

Bed Material Characterization Parameter – This parameter is recommended for alluvial or confined stream reaches where altered sediment transport processes have shifted the grain-size distribution away from the reference condition. This metric (percent fines) is only applicable in systems with a median grain size of gravel or coarser ($d_{50} > 2\text{mm}$) and is not applicable in natural sand or silt bed streams.

Bed Form Diversity Parameter – This parameter should be evaluated at all single-thread perennial and intermittent project sites. Users should evaluate pool spacing ratio, pool depth

ratio, and percent riffle metrics together, except natural bedrock systems where the pool spacing ratio would not apply.

Riparian Vegetation Parameter – This parameter should be evaluated at all project sites. Riparian extent and percent native cover should be evaluated at all project sites. Where the reference community type is herbaceous, herbaceous vegetation cover should be evaluated, whereas if the reference community type is woody, woody vegetation cover should be evaluated.

For CWA §404 projects with woody reference vegetation communities, a field value should still be entered for herbaceous cover although an index value will not be calculated for herbaceous cover.

Temperature and Nutrients – In the WSQT, these parameters are recommended for projects where impacts are likely to affect these functions, for projects with goals and objectives related to water quality improvements, or projects where improvements to these parameters are anticipated based on restoration potential. One or more parameters can be applied at a project site. The metrics for assessing these parameters are applicable in perennial streams.

The mean weekly average temperature (MWAT) metric may be applicable in intermittent streams where baseflow extends through August and fish are naturally present. The uncertainty of the NorWest model temperature predictions is greater for intermittent streams.

Reference curves were developed from epilithic samples, therefore the chlorophyll α metric for nutrients is applicable to stream reaches that contain gravel or larger bed materials and where riffles are present.

Macroinvertebrates – In the WSQT, this parameter is recommended for projects where impacts are likely to affect biological functions, and for restoration projects with goals and objectives related to biological improvements or where improvements in biological condition are anticipated based on restoration potential. There are two metrics for macroinvertebrates: WSII and RIVPACS. Both metrics should be applied within perennial streams, when applicable.

Both metrics for macroinvertebrates are stratified by bioregion and are limited to analyzing samples collected from riffles using the targeted riffle sampling method (WDEQ 2022). One or both metrics may be excluded if it can be demonstrated that the required WDEQ sampling method is not applicable to the project site, or the results are not representative of unique biological conditions found at the site (Hargett 2011; Hargett 2012). Exceptions to the use of either or both metrics are subject to Corps approval. It is important to keep in mind that RIVPACS requires predictor data (latitude, longitude, watershed area, bioregion, and alkalinity) and must be calculated by WDEQ. Practitioners should coordinate with WDEQ when RIVPACS is going to be applied at a project site.

Fish – In the WSQT, this parameter is recommended for projects where impacts are likely to affect biological functions, and for restoration projects with goals and objectives related to targeted improvements to the fish community. This parameter is also recommended for development projects that are likely to result in functional loss to priority conservation areas or other valuable fish habitats. When considering parameter selection, a user should consider whether their project reach falls within priority conservation areas identified in the Wyoming State Wildlife Action Plan (SWAP; WGFD 2017). Selection of this parameter requires

coordination with a WGFD Regional Fish Biologist. This parameter is applicable within intermittent and perennial streams where fish are naturally present.

Users can either apply the native species richness and Species of Greatest Conservation Need (SGCN) absent metrics together or the game species biomass metric (Figure 34). Additional guidance on metric selection follows:

- The native species richness and SGCN metrics should be applied together at sites where project goals and WGFD management objectives relate to native fish species restoration.
- The game species biomass metric should be applied at sites where project goals and WGFD management objectives relate to game fish species enhancement. For purposes of this metric, game species include naturally reproducing populations of native and non-native game species; game species of potential hatchery origin should not be included in this metric, and this metric is not applicable if there is potential for nearby stocked populations to influence biomass numbers within a project reach. NOTE: Selection and sampling of a control/reference reach is required for this metric. In addition, at least two sampling events in consecutive years are required (two pre-project AND two post-project).

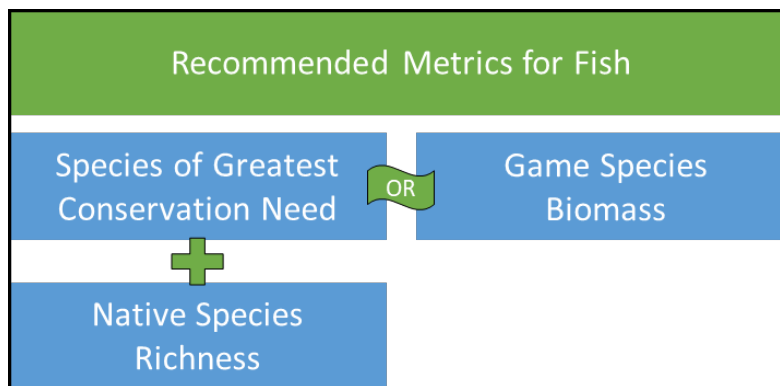


Figure 34. Metric Selection Guidance for Fish Parameter.

Flow Alteration Module: This module is recommended where there are available flow records and the project entails changes in operational commitments, acquisition/change of existing water rights, or new facilities that enable the proposed hydrology to occur within a specific length of stream. Metric selection within the module is discussed in Section 4.9.b. Note that application of the baseflow dynamics parameter should focus on hydraulic changes when hydrologic alteration is quantified using the FAM; refer to Section 4.5.b for instructions.

4.4. Bankfull Identification and Verification

Bankfull discharge is a discharge that forms, maintains, and shapes the dimensions of the channel as it exists under the current climatic regime. The bankfull stage or elevation represents the break point between channel formation and floodplain processes (Wolman and Leopold 1957). Correctly identifying bankfull stage is crucial, and the user should identify and verify bankfull using multiple lines of evidence. Bankfull stage and bankfull dimensions are needed to

calculate field values for several metrics, including bank height ratio, entrenchment ratio, large woody debris index, dominant BEHI/NBS, pool spacing ratio, pool depth ratio, and width/depth ratio state. Additionally, the WSQT uses bankfull in the definition of side channels; in identifying the length of the representative sub-reach; and delineating the meander width ratio for estimating expected riparian extent in altered systems.¹⁹

Bankfull identification should be performed by professionals with a background in geomorphology and the necessary experience to accurately complete the methods described here. Bankfull discharge modeling and return interval calculations should be performed by engineers or hydrologists with experience in hydrologic and hydraulic modeling in Wyoming, including the modeling of water diversions and withdrawals.

Users should apply the following hierarchical method to verify bankfull indicators and to calculate bankfull dimensions and discharge. A flow chart is provided to guide users through the decision-making process (Figure 35). The flow chart and methods described below are not exhaustive and other methods may be presented to the Corps for approval. **Method 1** is used when field indicators are present and bankfull is not affected by flow alteration; it includes a combination of field indicators and regional curves. **Method 2** is used when bankfull indicators are present, but flow alteration is substantial; it includes a combination of field indicators and return interval analysis. **Method 3** is used when indicators are not present; it includes stream surveys, bankfull regional curves if available, and modeling. Appendix D includes bankfull verification examples.

Bankfull verification should be documented on the Bankfull Verification Form provided in Appendix B.

4.4.a. Method 1

Users should first determine if bankfull indicators are present along the project reach. If bankfull indicators are present, the user will also need to determine if flow alteration within the watershed is significant enough to alter the return interval associated with the feature. The user should look for signs of flow alteration, e.g., diversion dams, water storage reservoirs, hydroelectric power operations or trans-basin diversions (refer to Section 2.2.a Flow Alteration sub-heading). This method relies on a comparison with regional curves; if regional curves are not available for the project watershed, the user should move to Method 2, step 3 in the flow chart.

If bankfull indicators are present and regional curves are available, the following steps should be followed:

- 1. Identify Field Indicators:** Bankfull stage or elevation data should be collected in the field following the methods outlined in the Bankfull Elevation – Field Identification section of the *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ 2022). The manual includes quality control for field identification of bankfull features, descriptions of primary and secondary field indicators, and methods to be followed for the entire reach.

¹⁹ Depending on the valley setting, there are alternative methods that do not rely on bankfull for determining the representative sub-reach length and expected riparian extent.

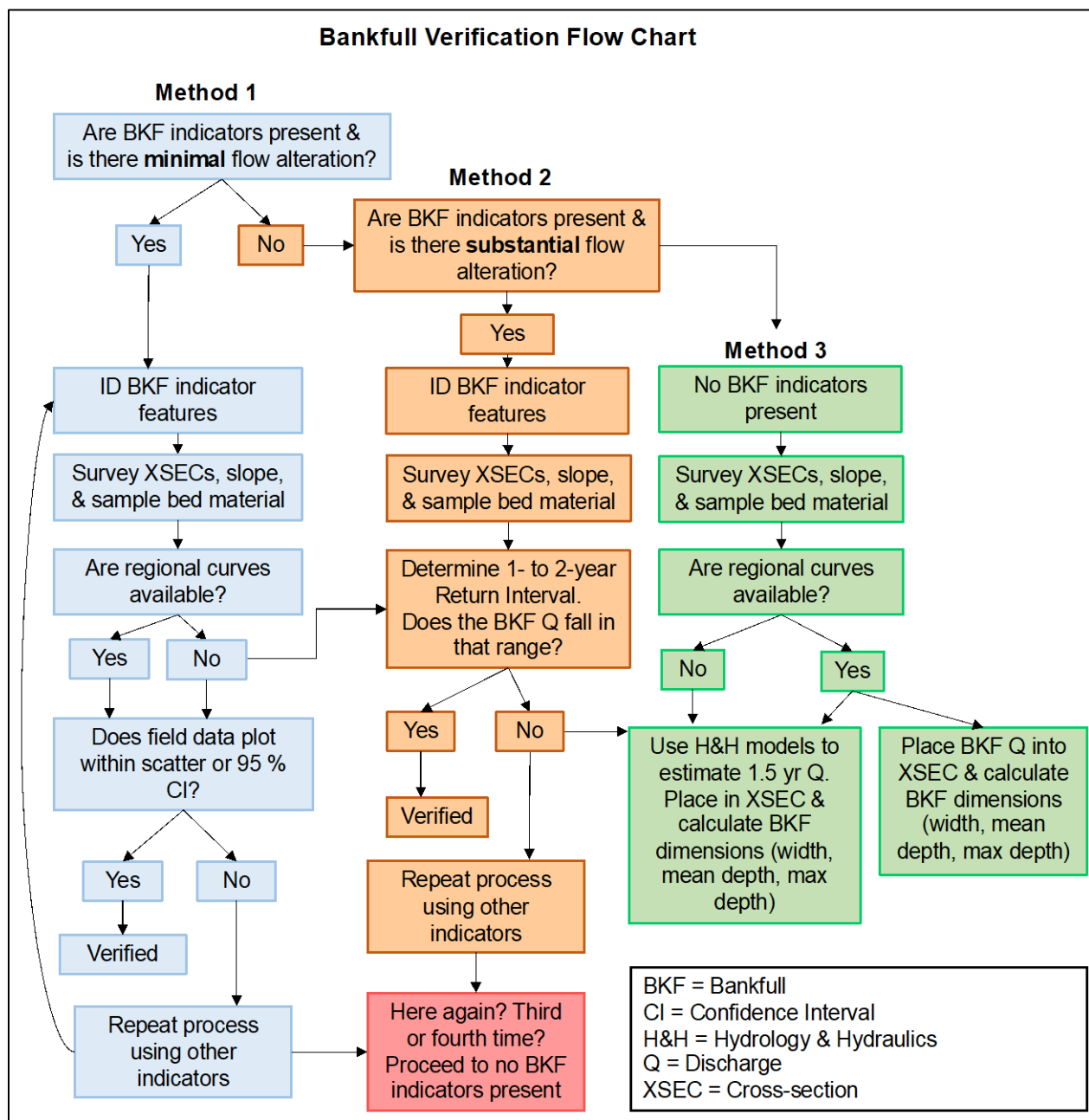


Figure 35. Bankfull Verification Process Flow Chart.

2. **Survey Riffle Cross-sections, Slope, & Sample Bed Material:** The cross-section(s) should be representative of the channel width and depth for the reach. Users are encouraged to find a stable riffle to survey for bankfull verification where possible. Selection of the stable riffle is critical; a suitable riffle will have stable width and depth, no signs of bank erosion or headcuts a bank height ratio near 1.0, bankfull width/depth ratio on the lower end of the range for the reach, and a cross-sectional area that falls within the range of scatter used to create the regional curve. Note: In a highly degraded reach, a stable riffle cross section may be used from an adjacent upstream or downstream reach. If a stable riffle is still not identified, the bankfull width and mean depth from the regional curve should be used. Field data collection includes:
 - Surveying cross-sections at riffles or crossover features, preferably where the thalweg is in the center of the channel. The cross-section should extend across the bankfull channel,
 - Surveying average channel slope, and
 - Bed material samples collected from the same riffle surveyed for the cross-section; these values are used to estimate bed roughness and the bankfull discharge calculation.²⁰
3. **Process data from Step 2:** Using the data collected above, calculate bankfull discharge and bankfull dimensions of area, width, and mean depth. The WSQT does not require or promote a single software to analyze cross-sections. A variety of single-section analyzers are available for calculating discharge using the cross-section survey, average slope, and bed material data. The Reference Reach Spreadsheet version 4.3 developed by Dan Mecklenburg with the Ohio Department of Natural Resources is a free, user-friendly tool that will calculate discharge, entrenchment ratio, and several other hydraulic variables.²¹ Note that a hydraulic model can also be used to determine the discharge that fills the channel throughout a project reach. The Hydrologic Engineering Center River Analysis System (HEC-RAS) is a free hydraulic modeling software but is best used by experienced hydrologists and engineers.²²
4. **Regional Curves:** Compare the measured bankfull dimensions from surveyed riffles to regional curve(s). The field data for the site, particularly the cross-sectional area, should fall within the range of scatter or 95% confidence limits of the regional curve for bankfull to be verified.

Due to the range of climatic conditions and underlying geology, regional curves can vary significantly throughout the state. Regional curves should only be used when they are applicable to the project site. Ideally, users may develop site-specific regional curves representative of the project catchment. Resources for regional curves within Wyoming include Foster (2012), Dunne and Leopold (1978) and Blackburn-Lynch et al. (2017).

²⁰ Bed material samples can be used to calculate a Manning's 'n' roughness value. Field measurements of velocity taken during a flow at or near bankfull can be used instead of bed material samples.

²¹ The spreadsheet is available at <https://stream-mechanics.com/stream-functions-pyramid-framework/> under spreadsheet tools.

²² <https://www.hec.usace.army.mil/software/hecras/>

If the bankfull cross-sectional area from the surveyed cross-section plots outside the range of scatter on the regional curve, the user should look for other potential bankfull indicators and repeat the process.

- If the measured area plots below the range of scatter, the indicator could be an inner berm feature.
- If the measured area plots above the range of scatter, the feature could be a terrace.
- If no indicators fall within the range of scatter, the user should move to the Method 3.

4.4.b. Method 2

If bankfull indicators are present along the project reach but flow alteration in the watershed has changed the return interval associated with the feature, then Method 2 should be used. Method 2 should also be used if the user did not find or develop regional curves that represent the project watershed. Without regional curves, bankfull cannot be verified using Method 1.

1. **Identify Field Indicators:** See above (Method 1, step 1)
2. **Survey Riffle Cross-sections and Estimate Bankfull Discharge:** See above (Method 1, steps 2 and 3).
3. **Return Interval Determination:** The user should determine discharges associated with the 1.01- to 25-year return interval. Users should apply the standard procedure for estimating flood frequency, a log Pearson frequency analysis as described in Bulletin 17B (Interagency Advisory Committee on Water Data 1982). Alternatively, Lowham (1988) provides regression relations for estimating peak-flow in Wyoming.

The program PeakFQ implements the Bulletin 17C procedures for flood-frequency analysis of streamflow records.²³ One of the simplest methods to determine return intervals, or flood frequency, for unregulated streams is StreamStats.²⁴

The minimum return interval reported is typically the 2-year discharge so the user may need to develop a return interval versus discharge curve and extrapolate down to determine the lower return intervals. Projects that have altered or otherwise complicated hydrology should include more robust hydrologic analyses, such as hydrologic models to estimate peak flow discharges and return intervals or develop empirical relationships from a nearby gage station.

The common range of bankfull return intervals for perennial streams is 1.01- to 2-years. If the discharge calculated from the bankfull feature in the surveyed riffle cross-section is between the 1.01- and 2-year return interval discharges, the feature can be verified. If not, proceed to Method 3. Note, in Method 2, the user can verify a bankfull feature with a return interval slightly above 2.0 if sufficient justification is presented to and accepted by the Corps.

4.4.c. Method 3

Method 3 should be used if bankfull indicators are not present in the project reach due to reach-wide instability or the calculated return interval in the Method 2 was greater than 2.0 years (and

²³ <https://water.usgs.gov/software/PeakFQ/>

²⁴ At writing, Wyoming application is under development with at-site, peak-flow statistics expected in 2025: <https://streamstats.usgs.gov/ss/>

justification for the higher return interval is not provided). It should be noted that Method 3 estimates bankfull discharge and dimensions from watershed hydrology and reach hydraulics and the method does not 'verify' a bankfull feature, e.g., floodplain elevation.

Method 3 does not include field identification of bankfull and an explanation should be provided on the Bankfull Verification Form provided in Appendix B.

1. **Survey Riffle Cross-sections, Slope, & Sample Bed Material:** See above (Method 1, step 2). A stable riffle cross-section must be surveyed whether there are bankfull indicators or not. The only difference between this survey and the other methods is there may be few or no bankfull features identified in the cross-section.
2. **Bankfull Discharge from Regional Curves:** If regional curves representing the project watershed are available, the bankfull discharge from the regional curve can be used to calculate bankfull dimensions in the project reach. The bankfull discharge estimated from the regional curve is placed in the cross-section from step 1 using a single-section analyzer or other tool to estimate the bankfull dimensions, i.e., bankfull area, width, and mean depth (see Method 1, Step 3).

Due to the range of climatic conditions and underlying geology, regional curves can vary significantly throughout the state. Regional curves should only be used when they are applicable to the project site. Ideally, users could develop site-specific regional curves representative of the project catchment. Resources for regional curves within Wyoming include Foster (2012), Dunne and Leopold (1978) and Blackburn-Lynch et al. (2017).

3. **Bankfull Discharge from Hydrologic Models:** If bankfull regional curves are not available, use hydrologic models to estimate the 1.5-year discharge to use as a surrogate for the bankfull discharge. Apply the 1.5-year discharge to the surveyed riffle cross-section(s) and calculate bankfull dimensions (area, width, mean depth).

When regional curves are available, the bankfull dimensions calculated from steps 2 and 3 can be compared. Otherwise, the results from step 3 should be used to calculate field values, identify side channels, determine the representative sub-reach length, and expected riparian area as needed based on parameter selection.

4.5. Reach Hydrology and Hydraulics Functional Category Metrics

There is one function-based parameter to assess reach-scale hydrology functions, reach runoff, and three function-based parameters to assess hydraulic functions: floodplain connectivity, baseflow dynamics, and bankfull dynamics. Each is discussed in the following sections.

4.5.a. Reach Runoff

Definition: The reach runoff parameter evaluates the infiltration and runoff processes of the land that drains laterally into the stream reach. The lateral drainage area is the portion of the catchment that drains directly to the reach from adjacent land uses (Figure 36).

The reach runoff parameter consists of two metrics that quantify different aspects of reach runoff: land use coefficient and concentrated flow points.

Experience Requirements: Data collection for reach runoff metrics should be performed by professionals with experience in GIS or other spatial analysis software.

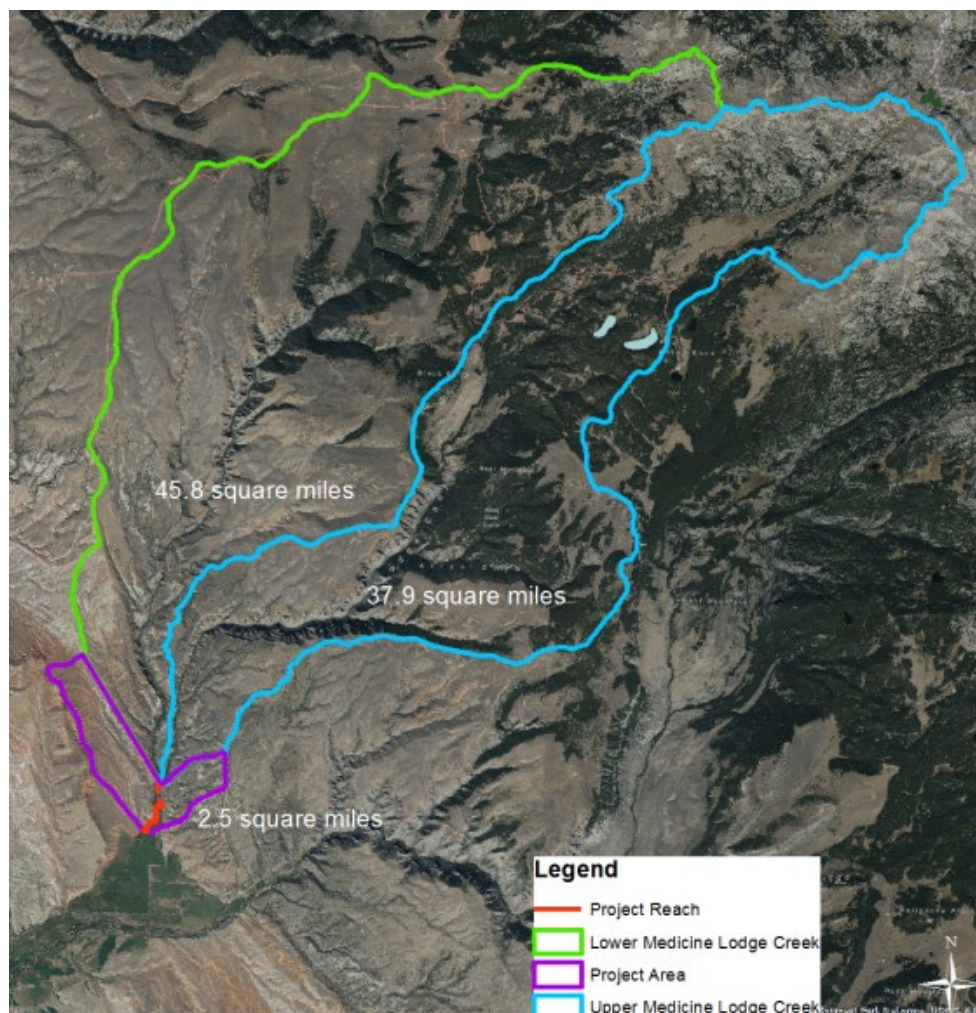


Figure 36. Lateral Drainage Area for Reach Runoff. The purple polygon (2.5 mi²) delineates the land draining laterally to the project reach and is the lateral catchment area evaluated by the land use coefficient metric.

1. Land Use Coefficient

Definition: An area weighted land use coefficient estimates runoff potential from land uses draining into the project reach between the upstream and downstream ends. Land use data can serve as a surrogate for runoff potential and infiltration, as vegetation removal and land cover change alter evapotranspiration, infiltration, interception volumes, snowpack distribution, and runoff processes. Land use coefficients are based on the curve numbers developed by the NRCS in *Urban Hydrology for Small Watersheds* (NRCS 1986), where higher values, nearer 100, indicate more runoff while lower values, nearer 0, indicate less runoff (Table 8).

Table 8. Land Use Coefficients adapted from NRCS (1986).

Land Use Description	Land Use Coefficient
<i>Natural Land Cover</i>	
Forested, mountain shrub, scrub-shrub, sage brush with grass understory	45
Herbaceous – mixture of grass, weeds, and low-growing brush, with brush the minor element	62
<i>Urban Areas</i>	
Open space (e.g., lawns, golf courses, parks, etc.)	61
Impervious surfaces (e.g., roofs, driveways, streets, parking lots, etc.)	98
<i>Agricultural Lands</i>	
Pasture, grassland, or range – continuous forage for grazing	61
Croplands and Farmsteads (e.g., buildings, lanes, driveways, and surrounding lots)	74

Method:

1. Delineate the lateral drainage area adjacent to the project reach and calculate the total lateral drainage area (see Figure 36). Open water (e.g., lake or impoundment) should be removed from the lateral drainage area total.
2. Using the USGS National Land Cover Database (NLCD) or recent aerial imagery, delineate the different land use types within the lateral drainage area and calculate the area occupied by each type listed in Table 8.
3. Using Table 8, assign each land use type a land use coefficient value²⁵. Note that open water is not included in the table.
4. Calculate an area-weighted land use coefficient. For each land use type, multiply the land use coefficient by the area of that land use type; sum all products and divide by the total lateral drainage area (see equation below).

$$Land\ Use\ Coefficient_{Area\ Weighted} = \frac{\sum(Area_i * Land\ Use\ Coefficient_i)}{Area_{total}}$$

NOTE: Once land uses are delineated for the existing condition, only the portions of the lateral drainage area within the project area, or otherwise affected by the project, should change in subsequent condition assessments.

Estimating proposed condition field values: Proposed field values for the land use coefficient can be calculated based on anticipated areas of land use change in the lateral drainage area *associated with the proposed project*. Stream restoration projects may convert land uses within the project area to natural land cover, particularly in the riparian area adjacent to the channel. Development can negatively impact reach runoff adjacent to the project area by removing native vegetation communities or by increasing impervious cover or other developed areas.

²⁵ Runoff processes and land use coefficients can be affected by wildfires (Yochum and Norman 2015). If the lateral drainage area of a project has recently burned, users should consult with the Corps about how this may affect field values for this metric.

For CWA §404 projects calculating for functional change for credit and debit calculations, the only land uses that should change between the existing and proposed conditions are those altered by the project (i.e., within the easement, limits of disturbance, etc.). Development and forest fires are risks that should be considered for the mitigation plan.

Documentation and Field Forms: Record the total lateral drainage area and the area within each land use type on the Field Value Documentation form in Appendix B; in the notes column, describe the source of the land cover data. Include a map depicting topography, lateral drainage area boundary and land uses, with data layers clearly labeled. The Field Value Documentation form will calculate the field value from the information entered.

2. Concentrated Flow Points (CFPs)

Anthropogenic impacts can lead to concentrated flows that erode soils and transport sediment into receiving stream channels (Al-Hamdan et al., 2013).

Definition: Concentrated flow points (CFPs) are defined as storm drains, outfalls, eroding or constructed features, such as swales, gullies, or ditches. Natural ephemeral tributaries and outlets of stormwater best management practices (BMPs) are not considered concentrated flow points in this method.

Anthropogenic causes of concentrated flow may include agricultural drainage ditches, impervious surfaces, storm drains, and others (Example 10). Irrigation return flows that come back to the channel in a ditch created for that purpose would be a CFP. If the return flow is returning to the channel in a natural feature, e.g., with a valley that extends beyond the irrigated land area, then the feature may be a separate reach undergoing flow alteration.

Example 10: Disconnected Concentrated Flow Point

A storm drain disconnected from the receiving reach by a stormwater detention BMP.



Method: This metric assesses the number of CFPs that enter the project reach per 1,000 linear feet of stream.

$$\text{CFPs} / 1000 \text{ ft} = \frac{\# \text{ CFPs}}{\text{Proposed Reach length (ft)}} * 1000 \text{ ft}$$

1. Review terrain and aerial imagery of the lateral drainage area to identify natural drainages and potential concentrated flow points before going in the field.
2. Walk the entire project reach, including both sides of the stream channel, and record any observed concentrated flow points on the Project Reach form (Appendix B).
3. Normalize the number counted using the equation above.

Estimating proposed condition field values: Proposed field values for this metric can be calculated based on anticipated changes to concentrated flow points in the project area associated with the proposed project. Stream restoration projects can reduce concentrated flow entering the channel by dispersing flow in the floodplain, increasing ground cover near the channel, or by installing stormwater BMPs within the project area. *Combining multiple concentrated flow points into a single concentrated flow point is not considered an improvement.* The restoration activity should diffuse or capture the runoff. Example activities include filling ditches, removing pipes, routing concentrated flow into created constructed wetlands, and other stormwater control measures.

Development can negatively impact stream channels by creating concentrated flow points such as stormwater outfalls or additional erosional or runoff features. Proposed grading and stormwater management plans for a project should be consulted to determine whether, and how many, concentrated flow points are likely to result from any proposed development within the project area.

Documentation and Field Forms: Concentrated flow points are identified in the field and should be recorded on the Project Reach form (Appendix B). The location and type of concentrated flow point should be recorded; photographs are recommended. Field values should be recorded on the Field Value Documentation form (this auto-populates from the Project Reach form).

4.5.b. Baseflow Dynamics

Definition: This parameter characterizes habitat conditions within the reach during baseflow. Baseflow ($Q_{baseflow}$), measured in cubic feet per second (cfs), is defined as the average of the mean daily flow values during the low flow period occurring in the late summer and early fall of the monitoring year.

There are two metrics to assess baseflow dynamics: average velocity and average depth. Terms used to derive field values for these metrics are shown in Figure 37.

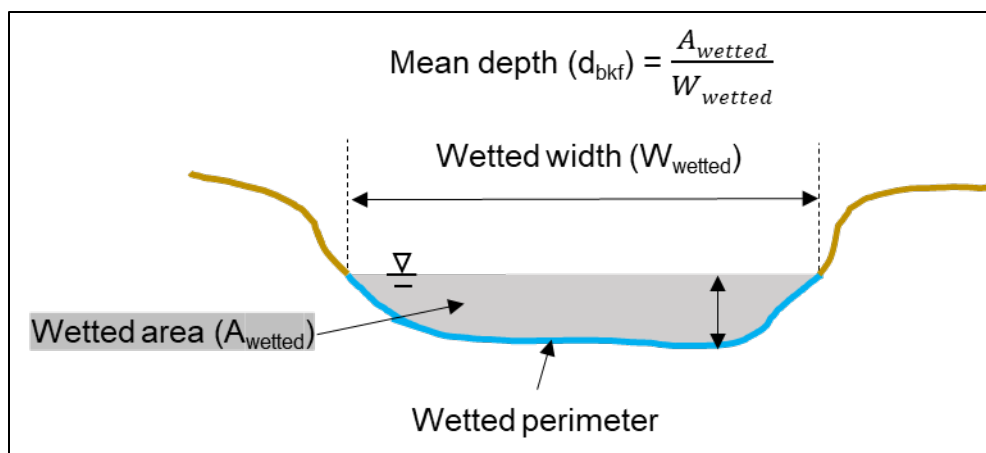


Figure 37. Wetted Dimensions for Baseflow Dynamics.

Experience Requirements: Data collection and analysis for baseflow dynamics metrics should be performed by professionals that have experience with standard survey techniques, at-a-station hydraulic analysis, gage installation and water level monitoring, and measuring velocity in-situ.

1. Average Velocity

Definition: Mean velocity is the baseflow discharge divided by the cross-sectional area wetted at the baseflow discharge (Figure 37). Velocity measurements may be collected to develop a stage-discharge relationship and can serve as a quality check for the calculated values within the reach.

This metric uses the continuity equation to determine the mean cross-sectional velocity (V) averaged from three riffles within the reach for the baseflow discharge ($Q_{baseflow}$).

$$Velocity = Q_{baseflow} / A_{wetted}$$

Where A_{wetted} (sf) is the wetted cross-sectional area of the cross-section at $Q_{baseflow}$ (cfs).

Method: To determine the field value for velocity (measured in feet per second; ft/s):

1. Determine baseflow discharge using existing stream gage data or by monitoring stream flow gages during the late summer and early fall of the monitoring year. Two methods can be used to measure the baseflow condition.
 - a. The preferred option is to establish a site-specific rating curve and deploy a pressure transducer to record stage data from the project reach for the month of August. Detailed instructions for establishing a rating curve and analyzing flow records is provided in *Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams* (EPA 2014). The site-specific rating curve is used to convert stage data to flow values and the mean monthly flow for August can be calculated from the flow record. Recent

instream flow studies available from the Wyoming Water Resources Data System provide an overview of this process as well.

- b. The second option is to follow the concurrent-discharge methodology as outlined by Lowham (2009) and collect individual flow measurement(s) during August. Taking three measurements throughout the month is recommended and it may be necessary to consult with upstream water diversions to avoid sampling on days when low flow will be impacted by releases. The field measurement(s) of discharge are related to the reference gage values for the same day and the gage data can then be used to estimate the mean August monthly flow for the project reach. The reference gage concept is discussed in more detail in Section 4.9 of this manual.
2. Survey a minimum of three riffle cross-sections within the reach using standard geomorphic survey protocols. Station and elevation data must be collected to accurately plot cross-sections and calculate baseflow dimensions.
3. Process survey data to determine the cross-sectional area wetted at baseflow at each riffle cross-section.
4. Calculate the mean velocity for each cross-section using the equation above. Average the values from the three cross-sections to calculate the field value for the average velocity metric in the WSQT.

Estimating proposed condition field values: This metric is intended to capture changes in velocity associated with changes to channel cross-section dimensions. Therefore, proposed conditions can be determined by analyzing baseflow data within the proposed channel cross-section. Alterations to the bankfull channel dimensions can improve baseflow depth and velocity where existing channels are overly wide. Alternatively, proposed channels that remove an inner berm feature or widen the channel can reduce velocity.

Note that it is also possible to apply this metric where there are changes in the baseflow discharge ($Q_{baseflow}$). In this case, users should estimate the anticipated baseflow in the channel using hydrologic and hydraulic assessments. Since annual variations in climate may alter the $Q_{baseflow}$, care should be taken to determine whether increases in $Q_{baseflow}$ are a result of the project (e.g., increased return flows or decreased groundwater pumping agreement with land-owner) rather than variations in climate. This option should only be used when the flow alteration module (Section 4.9) is **not used** to quantify hydrologic changes resulting from flow alteration.

Documentation and Field Forms: The following should be recorded on the Field Value Documentation form (Appendix B): the gage sampling period, gage number (if applicable) and baseflow discharge calculated for Step 1 and the wetted area for each cross section calculated in Step 3. The notes section should include the survey method and any post-processing tools used. Users should include a time-series plot of gage data used to calculate $Q_{baseflow}$, as well as a figure for each cross-section with labels for wetted dimensions and baseflow discharge. The Field Value Documentation form will calculate Step 4, including the average velocity for each cross section and the metric field value.

2. Average Depth

Definition: Mean depth is the area wetted at the baseflow discharge divided by the wetted width of the cross-section (Figure 37). The average depth is calculated using the mean depth from three surveyed cross-sections. This metric uses cross-section geometry to determine the average cross-sectional depth (d) at riffles within the reach for the baseflow discharge ($Q_{baseflow}$).

$$\text{Mean depth } (d_{bkf}) = A_{wetted} / W_{wetted}$$

Where A_{wetted} (sf) is the wetted cross-sectional area of the cross-section at $Q_{baseflow}$ (cfs) and W_{wetted} (ft) is the top width of the cross-section at $Q_{baseflow}$.

Method: To determine the field value for average depth (ft):

1. Follow Steps 1-3 for the average velocity metric (see above section). Process the survey data to calculate the top wetted width for each riffle cross-section.
2. Calculate the mean depth for each cross-section using the equation above. Average the values from the three cross-sections to calculate the field value for the average depth metric in the WSQT.

Estimating proposed condition field values: This metric is intended to capture changes in depth associated with changes to channel cross-section dimensions. Estimating proposed condition field values for this metric are the same as for the average velocity metric in the section above.

Documentation and Field Forms: In addition to the documentation described in average velocity above, record the top wetted width for each cross section on the Field Value Documentation form (Appendix B). The field value documentation form will calculate the average depth for each cross section and the metric field value.

4.5.c. Bankfull Dynamics

Definition: This parameter characterizes the dynamic flow conditions created by the interaction of flowing water against the stream bed and banks (Harman et al. 2012).

There is one metric to assess bankfull dynamics: width/depth ratio state (O/E).

Experience Requirements: Data collection for flow dynamics should be performed by professionals that have experience with standard survey techniques and experience with identification and verification of bankfull.

1. Width/Depth Ratio State

Definition: The width to depth ratio (W/D) is measured as the bankfull channel width divided by the bankfull mean depth. The bankfull mean depth is calculated as the cross-sectional area divided by the bankfull width. This ratio is then divided by a reference W/D. This metric is described as W/D ratio state by Rosgen (2014).

$$\text{Width Depth Ratio State} = \frac{W_{\text{bankfull}}}{D_{\text{bankfull mean}}} / \text{Reference } W/D$$

Method: Prior to calculating this metric, users need to complete the bankfull verification process (Section 4.4).

At every riffle within the representative sub-reach:

1. Measure the length of the riffle (refer to glossary for the definition of a riffle).
2. At the approximate mid-point of the riffle, identify the bankfull elevation and survey the bankfull cross-section with sufficient detail to calculate bankfull area. The bankfull verification process (Section 4.4) should be used to identify the bankfull elevation.

Standard survey protocols are required to collect accurate elevation data. Appendix A provides instructions for rapid survey methods which use a tape, survey rods, and hand levels.

3. Calculate the bankfull width, cross-sectional area, mean depth, and W/D for each riffle.
4. Using the W/D and riffle length for every riffle feature within the representative sub-reach, calculate the weighted W/D using the equation below.

$$W/D_{\text{weighted}} = \frac{\sum_{i=1}^n (W/D_i * RL_i)}{\sum_{i=1}^n RL_i}$$

Where, RL_i is the length of the riffle where W/D_i was measured.

5. Determine the reference W/D. Since the W/D can play a large role in the design process and is often linked to slope and sediment transport assessments, the reference W/D is selected by the user. The reference W/D can come from the stable riffle cross-section (Section 4.4), a riffle cross-section at a reference reach, or through the design process. Note that the reference W/D must remain consistent throughout all monitoring and condition assessments. Justification for the selected W/D should be provided.

Statistics from a compiled geomorphic reference dataset are shown in Table 9 to assist users in selecting a reference W/D. The compiled geomorphic reference dataset is described in the Scientific Support Document (WSTT 2023) and consists of geomorphic reference site data from the mountainous regions of Wyoming.

6. Calculate the field value by dividing the results of Step 4 by the reference W/D (Step 5). This value should then be entered in the WSQT.

Estimating proposed condition field values: The reference W/D value will remain the same for both the existing and proposed calculations. The proposed condition W/D should be based on the proposed riffle length and proposed channel cross-section for every riffle in a representative sub-reach of the proposed channel. Calculations should consider any proposed activities that may alter the cross-section, including bank angle and stabilization.

Table 9. Range of W/D Observed in the Compiled Geomorphic Reference Dataset for Wyoming.

Stream Type	B	C	E
25 th Percentile	16	16	7
Mean	20	20	8
Median	18	20	8
75 th Percentile	23	23	10

Documentation and field forms: Record the length of each riffle and W/D at each riffle on the Field Value Documentation form in Appendix B. On that form, note the survey method and any post-processing tools used. Users should also record the reference W/D, how it was calculated (e.g., from the stable riffle cross-section, a riffle cross-section at a reference reach, or through the design process), and provide any needed justification for the selected reference W/D. The Field Value Documentation form will calculate the metric field value from the data entered.

4.5.d. Floodplain Connectivity

Definition: The floodplain is the area adjacent to the channel that is inundated during overbank flow events. Floodplain connectivity considers how flows can access and the extent to which they access the floodplain.

Floodplain connectivity is assessed using three metrics: bank height ratio (BHR), entrenchment ratio (ER) and percent side channels.

Experience Requirements: Data collection for floodplain connectivity metrics should be performed by professionals that have experience with standard survey techniques and experience with identification and verification of bankfull.

1. Bank Height Ratio (BHR)

Definition: The BHR is a measure of channel incision and an indicator of whether flood flows can access and inundate the floodplain (Rosgen 2014). BHR is measured at riffles and calculated as the low bank height (LBH) divided by the bankfull riffle maximum depth (also referred to as bankfull maximum depth; D_{max}). Low bank height is defined as the lower of the left and right streambanks, indicating the minimum water depth necessary to inundate the floodplain. The lower bank is often on the inside of meander bends.

Typically, bank height ratios will be 1.0 or greater, meaning that bankfull is equal to or higher than the top of the streambank. The lower the ratio, the more frequently water can access the floodplain. Note that in systems experiencing aggradation, either due to natural processes or because of changes in sediment supply or transport, it is possible for the bank height ratio to be less than 1.0.

Method: Prior to calculating this metric, users need to complete the bankfull verification process (Section 4.4).

At every riffle within the representative sub-reach:

1. Measure the length of the riffle (refer to glossary for the definition of a riffle).
2. Identify the bankfull elevation and low bank feature. The bankfull verification process (Section 4.4) should be used to identify the bankfull elevation. For low bank height, identify the break between the channel and a floodplain or terrace on both sides of the stream and identify the bank with the lower elevation.

In incised channels with a bankfull bench, determining when bankfull and the top of bank are equal can be challenging. Two common scenarios are detailed in Appendix A to aid users in low bank identification.

3. At the approximate mid-point of the riffle, record the difference between the low bank elevation and the thalweg elevation (low bank height). Note, when the low bank elevation and the bankfull elevation are the same, the BHR equals 1.0.

Standard survey protocols are required to collect accurate elevation data for steps 2 and 3 above. Appendix A provides instructions for rapid survey methods which use a tape, survey rods and hand levels.

4. Record the difference between the bankfull elevation and the thalweg elevation (bankfull maximum depth).
5. Calculate the BHR for the riffle by dividing the low bank height (step 3) by the bankfull maximum depth (step 4).
6. Using the BHR and riffle length for every riffle feature within the representative sub-reach, calculate the weighted BHR using the equation below and Example 11. The weighted BHR should then be entered in the WSQT.

$$BHR_{weighted} = \frac{\sum_{i=1}^n (BHR_i * RL_i)}{\sum_{i=1}^n RL_i}$$

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

Example 11: Weighted BHR Calculation in an assessment segment with four riffles

Riffle ID	Length (RL)	BHR	BHR * RL
R1	25	1.0	25
R2	200	1.5	300
R3	75	1.4	105
R4	40	1.2	36
Total	340 ft	Total	466
Weighted BHR = 466/340 = 1.4			

Estimating proposed condition field values: The proposed condition field value for BHR should be based on the proposed riffle length and proposed channel cross-section for every riffle in a representative sub-reach of the proposed channel. Calculations should consider any proposed activities that may alter the cross-section or longitudinal profile, including floodplain excavation and construction of berms or levees.

Documentation and field forms: On the Field Value Documentation form in Appendix B, record the length of each riffle and the BHR at each riffle and note the survey method and any post-processing tools used. The Field Value Documentation form will calculate the metric field value from the data entered.

2. Entrenchment Ratio (ER)

Definition: ER characterizes the lateral containment of the river by evaluating the ratio of the flood-prone width to the bankfull channel width measured at a riffle cross-section (Rosgen 1996). The ER is a measure of approximately how far the 2-percent-annual-probability discharge (50-year recurrence interval) will laterally inundate the floodplain (Rosgen 1996). The flood-prone width is the cross-section width at a riffle feature perpendicular to the valley at an elevation of two times the bankfull max depth.

$$ER = \frac{\text{Flood Prone Width}}{\text{Bankfull Width}}$$

Method: Prior to calculating this metric, users need to complete the bankfull verification process (Section 4.4).

The ER should be calculated for each riffle within the representative sub-reach to calculate the weighted ER (see equation below and Example 12). At each study riffle:

1. Measure the length of the riffle (refer to the glossary for the definition of a riffle).
2. At the approximate mid-point of the riffle, i.e., half-way between the head of the riffle and the head of the run or pool, measure the bankfull channel width and flood-prone width. The bankfull verification process (Section 4.4) should be used to identify the bankfull elevation where the width is measured. If the flood-prone width is uniform (as verified using topographic data), it is unnecessary to measure at every riffle.

Standard survey protocols are required to collect accurate dimensions and elevation data. Appendix A provides instructions for rapid survey methods that use a tape, survey rods and hand levels.

3. Calculate the ER for each riffle. Using the ER and riffle lengths for every riffle feature within the representative sub-reach, calculate the weighted ER using the equation below and Example 12. The weighted ER should then be entered into the WSQT.

$$ER_{weighted} = \frac{\sum_{i=1}^n (ER_i * RL_i)}{\sum_{i=1}^n RL_i}$$

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

Estimating proposed condition field values: The proposed condition field value for ER will be based on the proposed riffle length, flood-prone area width, and channel width for every riffle in a representative sub-reach of the proposed channel. Calculations should consider any proposed activities that may alter the flood-prone area, cross-section, or longitudinal profile, including floodplain excavation and construction of berms or levees.

Example 12: Weighted ER Calculation in an assessment segment with four riffles

Riffle ID	Length (RL)	ER	ER * RL
R1	25	1.2	30
R2	200	2.1	420
R3	50	1.6	80
R4	30	1.8	54
Total	305 ft	Total	584
Weighted ER = 305/584 = 1.9			

Documentation and field forms: On the Field Value Documentation form in Appendix B, record the length of each riffle and ER at each riffle and note the survey method and any post-processing tools used. The field value documentation form will calculate the metric field value from the data entered.

3. Percent Side Channels

Definition: Side channels are small open water channels that are connected to the main channel at one or both ends. To focus on habitats connected to the main channel during typical water years rather than only connected at high flows, side channels can be included in this metric when one or both ends are connected to the main channel at a **depth of at least one-half the bankfull riffle maximum depth**. For example, if the bankfull riffle maximum depth is two feet, the floodplain side channel invert elevation must be a maximum of one foot lower than the bankfull elevation where the side channel intersects the main channel (Figure 38).

Side channels that have filled with sediment to the bankfull depth at both ends, or multiple channels created by islands and mid-channel bars are not considered side channels (Figure 39).

With regards to beaver ponds and other stream-wetland complexes, beaver dams can create side channel habitat that meet the criteria above. Where large portions of the valley are flooded, the mainstem length can be counted as having side channel habitat even where it is difficult to identify individual channels.

Method: Prior to calculating this metric, users need to complete the bankfull verification process (Section 4.4).

1. Measure the total length of all side channels within the valley bottom of the project reach area using a combination of desktop tools and field measurements, as needed. Side channels can be assessed from aerial photos and field reconnaissance. The lengths can be measured on arials if they are visible or measured in the field with a tape measure or range finder. Walk the entire project reach, including both sides of the stream channel, identify and verify any side channels that meet the definition outlined above, and record side channel lengths on the Project Reach form (Appendix B).
2. Divide the total side channel length by the total length of the main channel and multiply by 100 to report the field value as a percent.

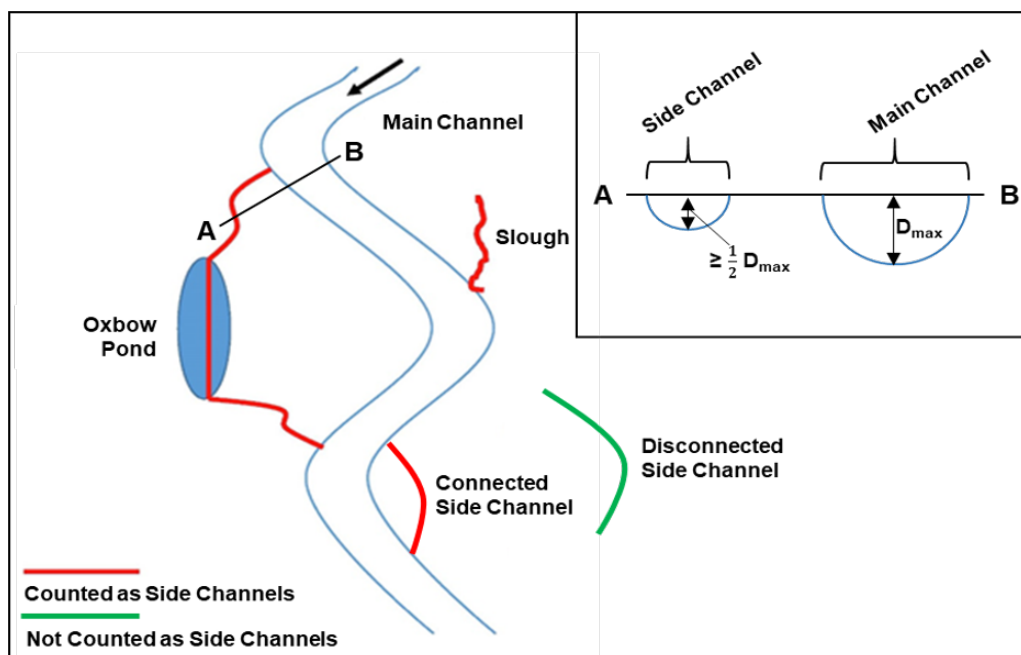


Figure 38. Examples of Side Channels. For the transect shown, if the bankfull elevation is 1,000 feet NAVD88 and bankfull depth is 2 feet (main stem invert = 998 feet), then the side channel invert must be 999 feet or lower to be considered connected at that end.



Figure 39. Example of an Island Splitting the Main Flow Does NOT Count as a Side Channel.

$$\text{Field Value} = 100 * \frac{\sum \text{Side channel length}(ft)}{\text{Reach length}(ft)}$$

Estimating proposed condition field values: The proposed condition field value is calculated using the length of side-channels proposed to be added or removed as part of the project and the proposed stream length.

Documentation and field forms: Record side channel lengths on the Project Reach form; this form will calculate the field value. The field value should auto-populate in the Field Value Documentation form. Users should also provide location information for side channels.

4.6. Geomorphology Functional Category Metrics

The WSQT contains the following function-based parameters to assess the geomorphology functional category: large woody debris, lateral migration, bed material characterization, bed form diversity, and riparian vegetation.

4.6.a. Large Woody Debris

Definition: Large woody debris is defined as dead and fallen wood over 1m in length and at least 10 cm in diameter at the largest end.²⁶ The wood must be within the stream channel or touching the top of the streambank; LWD that lies in the floodplain but is not at least partially in the active channel is not included. Note: Standing dead material is not included as LWD.

There are two metrics to assess large woody debris (LWD): the Large Woody Debris Index (LWDI) and an LWD piece count.

Experience Requirements: Data collection for large woody debris metrics should be performed by the same team performing floodplain connectivity and bed form diversity assessments, or individuals with experience in large wood assessments.

1. Large Woody Debris Index (LWDI)

Definition: The LWDI is a dimensionless value based on rating the geomorphic significance of LWD pieces and dams within a 100m section of stream. This index was developed by the USDA Forest Service Rocky Mountain Research Station (Davis et al. 2001).

Method: Identify the 100 m length of the project reach that contains the most LWD. Preferably this 100m reach is within the representative sub-reach. If the project reach is less than 100m, the LWDI should be determined using the entire reach length and the index value normalized to represent a value per 100m.

²⁶ Note: in willow-dominated systems, willow branches that form debris jams are included in the LWDI assessment even if they do not meet the minimum piece size. Additional discussion is provided in the LWDI manual.

Follow the guidance within Davis et al. (2001) or the *Application of the Large Woody Debris Index: A Field User Manual Version 1* (Harman et al. 2017) to score LWD pieces and dams and to calculate the reach LWDI. The LWDI score is entered as the field value in the WSQT.

Estimating proposed condition field values: The proposed condition field value is based on the proposed amount and anticipated recruitment of LWD in a 100m segment of the project reach. See Harman et al. (2017) for examples of structures using LWD and how they score. The proposed value should consider the removal of any existing LWD or installation of new LWD that would occur during project construction.

Documentation and field forms: An optional field form is included in the *Application of the Large Woody Debris Index: A Field User Manual Version 1* (Harman et al. 2017). Record the field value on the Field Value Documentation form in Appendix B.

2. Large Woody Debris (LWD) Piece Count

Definition: The LWD piece count metric is a count of the number of LWD pieces within a 100m section of stream.

Method: Identify the 100 m length of the project reach that contains the most LWD. Preferably this 100m reach is within the representative sub-reach. If the project reach is less than 100m, the LWD piece count should be determined using the entire reach length and the index value normalized to represent a value per 100m.

Count all pieces of dead and fallen wood wholly or partially within the active channel that are over 3.28 feet (1 m) in length and at least 3.9 inches (10 cm) in diameter at the largest end within the 100m reach. For debris dams, to the extent possible, count each piece within the dam that qualifies as LWD. The number of pieces observed within 328 ft (100m) is the field value input for the WSQT. No additional calculation is required.

Estimating proposed condition field values: The proposed condition field value is based on the proposed amount and anticipated recruitment of LWD in a 100m segment of the project reach. The proposed value should consider the removal of any existing LWD or installation of new LWD that would occur during project construction.

Documentation and field forms: Piece count data are recorded on the Project Reach form. The field value should auto-populate in the Field Value Documentation form in Appendix B.

4.6.b. Lateral Migration

Definition: Lateral migration is the movement of a stream laterally across its floodplain and is largely driven by processes influencing bank erosion and deposition.

There are four metrics for this parameter: dominant Bank Erosion Hazard Index /Near Bank Stress (BEHI/NBS), percent streambank erosion, percent streambank armoring, and Greenline Stability Rating (GSR).

Experience Requirements: Data collection for lateral migration metrics should be performed by professionals with training and experience in applying either the BEHI/NBS or GSR methods.

1. Dominant Bank Erosion Hazard Index/Near Bank Stress (BEHI/NBS)

Definition: The Bank Erosion Hazard Index (BEHI) is a method used to estimate the tendency of a given stream bank to erode based on factors such as bank angle, riparian vegetation, rooting depth and density, surface protection, and bank height relative to bankfull height. Near Bank Stress (NBS) is an estimate of shear stress exerted by flowing water on the stream banks. Together, BEHI and NBS are used to populate the Bank Assessment for Non-point source Consequences of Sediment model and produce cumulative estimates of stream bank erosion rates for surveyed reaches (Rosgen 2014). In the WSQT, the BEHI/NBS assessment is used to determine the dominant BEHI/NBS category for eroding banks within the representative sub-reach.

Method: Prior to calculating this metric, users need to complete the bankfull verification process (Section 4.4). BEHI/NBS should be evaluated throughout the representative sub-reach.

Follow the guidance in Appendix D of the *Function-Based Rapid Field Stream Assessment Methodology* (Starr et al. 2015) or *River Stability Field Guide, Second Edition* (Rosgen 2014).

1. Measure the bank length of every outside meander bend and determine its BEHI/NBS category. The outside of a meander bend is always assessed, even when it is not eroding.
 - a. Partition the banks based on different BEHI and NBS conditions. So a study bank that is a consistent BEHI condition but two NBS conditions should be assessed as two study banks.
 - b. Beginning upstream, the study bank begins at the first sign of active erosion or the point of tangency, whichever comes first. Then, proceed along the outside of the meander bend and end at the last sign of active erosion or point of curvature, whichever comes last.
2. Measure the bank length of any other bank that is actively contributing sediment and determine its BEHI/NBS category. Depositional zones, such as point bars, or other areas that are not actively eroding should not be evaluated (Rosgen 2014). Additionally, riffle sections that are not eroding and have low potential to erode are excluded from the WSQT BEHI/NBS assessment (refer to Table 10). Banks that are armored are not assessed with the dominant BEHI/NBS metric.
 - a. Partition the banks based on different BEHI and NBS conditions. So a study bank that is a consistent BEHI condition but two NBS conditions should be assessed as two study banks.
3. Sum the length of all assessed banks in the representative sub-reach.
4. Divide the length of each bank by the assessed bank length (4th column in Example 13).
5. The total percent is calculated for each category by adding the percent of total for each assessed bank length within that category (see Example 13). The dominant BEHI/NBS is the category that represents the greatest cumulative bank length; it does not need to describe over 50% of the assessed banks. If there are two or more BEHI/NBS categories with the same total percent, the category representing the highest level of bank erosion should be selected.

To enter the field value in the WSQT, a drop-down list of BEHI/NBS categories is provided in the condition assessments.

Example 13: Calculation of Dominant BEHI/NBS

In this example, data were collected in the field for 1100 feet of bank (including left and right banks). Actively eroding banks and those with a strong potential to erode were assessed using the BEHI/NBS methods.

Bank ID (Left and Right)	BEHI/NBS	Length (Feet)	Percent of Total (%)
L1	Low/Low	50	50 / 155 = 32
L2	High/High	12	8
R1	Mod/High	22	14
R2	High/High	31	20
L3	Low/Mod	9	6
R4	High/High	31	20
Total Length		155	100

There are four BEHI/NBS categories present. The length of each bank was summed and divided by the assessed bank length; the total percent is then calculated for each category (e.g., High/High = 8+20+20 = 48). The dominant BEHI/NBS category is High/High since that score is highest and describes 48% of the assessed banks.

Estimating proposed condition field values: The proposed condition field value should be based on any anticipated changes to channel bank or hydraulic conditions associated with the project within the representative sub-reach. Note that for the aspects of BEHI that pertain, or could pertain, to riparian vegetation (rooting depth and density, and surface protection) these should be estimated for conditions at project closeout.

For banks that are proposed to be armored, they are likely eroding during the existing condition assessment and would be assessed using the methods above during the existing condition assessment. Once the banks are armored (proposed condition and during monitoring), they are no longer assessed using this metric and are instead counted as armored.

Documentation and field forms: Record the total assessed length and up to six BEHI/NBS categories and respective bank lengths on the Field Value Documentation form in Appendix B. Field data should be provided with the submittal, along with a map of ratings along the representative sub-reach.

2. Percent Streambank Erosion

Definition: The percent streambank erosion is the proportion of the total length of streambank in the representative sub-reach that is actively eroding. The metric is calculated by dividing the length of streambank that is actively eroding by the total length of bank (left and right) in the representative sub-reach.

Method:

1. Perform the BEHI/NBS assessment as described in Section 4.6.b.1.
2. Sum the lengths of all banks within the BEHI/NBS categories that are considered actively eroding (Table 10).

Table 10. BEHI/NBS Stability Ratings that Represent Actively Eroding and Non-eroding Banks.

<i>Non-eroding Banks</i>	<i>Actively Eroding Banks</i>
Low BEHI, regardless of NBS M/VL, M/L, H/VL	M/M, M/H, M/VH, M/Ex, H/L, H/M, H/H, H/VH, H/Ex, Very High BEHI, regardless of NBS Extreme BEHI, regardless of NBS

3. Divide the total length of actively eroding bank by the total length of streambank within the sub-reach (Example 14). The total length of streambank is the sum of the left and right bank lengths within the representative sub-reach (approximately twice the channel length). Note: this value is different from the assessed bank length used to calculate the dominant BEHI/NBS metric.

$$\text{Percent Streambank Erosion} = \frac{\text{Length of Eroding Bank}}{\text{Total length of Streambank in Sub – Reach}} * 100$$

Example 14: Calculation of Percent Erosion

This example uses the same BEHI/NBS results as above. In the table below, actively eroding banks are identified in bold per Table 10. These bank lengths are added together (12+22+31+31) and divided by the total bank length (1100 feet including left and right banks). The total percent streambank erosion is 8.7%.

Bank ID (Left and Right)	BEHI/NBS	Length (Feet)
L1	Low/Low	50
L2	High/High	12
R1	Mod/High	22
R2	High/High	31
L3	Low/Mod	9
R4	High/High	31
Total Length		155

Estimating proposed condition field values: The proposed condition field value should be based on any anticipated changes to channel bank or hydraulic conditions associated with the proposed project within the representative sub-reach. For mitigation projects, this may include an estimate of the expected extent of bank erosion at the end of monitoring, keeping in mind

that monitoring events will document whether the proposed condition is achieved. For impact sites, the user must estimate the extent of bank erosion that is likely, e.g., considering hydraulic expansion/contraction effects associated with stream crossings. Removing vegetation along the bank (greenline) is also likely to lead to bank erosion.

Documentation and field forms: Record the total length of actively eroding banks and the field value on the Field Value Documentation form in Appendix B.

3. Greenline Stability Rating (GSR)

Definition: The greenline is a linear grouping of live perennial vascular plants on or near the water's edge. GSR are calculated by multiplying the percent composition of each community type along the greenline by the stability class rating assigned to that type (per methods referenced below) and calculating the average value for the project reach.

Method: Data collection should occur throughout the representative sub-reach following the guidance in either of two methods to measure the GSR:

The original GSR data collection procedures described in *Monitoring the Vegetation Resources in Riparian Areas* (Winward 2000)

The Modified Winward GSR procedures described in *Riparian Area Management: Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation* (USDOI 2011).

The Modified Winward GSR integrates a more systematic approach to collecting data by using plots instead of paces and calculating stability ratings by key species rather than community types to improve precision. It also includes additional species stability ratings not identified in Winward (2000). Regardless of the GSR method selected, Table H1 of the USDOI (2011) MIM document outlines procedures for developing a relative stability value for other plant species.

Estimating proposed condition field values: The proposed condition field value should be based on any anticipated changes to channel bank conditions or bank vegetation associated with the proposed project within the representative sub-reach. Note that because the method is based on establishment of riparian vegetation, the proposed GSR field value for mitigation projects should be estimated using anticipated condition and community composition at project closeout.

Documentation and field forms: Record the sampling method used, total percent composition for each stability rating observed at the site, the species observed, and record the final field value on Field Value Documentation form in Appendix B.

4. Percent Streambank Armoring

Definition: Bank armoring is defined as any rigid, human-made stabilization practice that permanently prevents lateral migration processes. More natural approaches to reducing excessive bank erosion, like toe protection and/or bioengineering, are not considered armoring. Examples of armoring include rip rap, gabion baskets, concrete, and other engineered materials that prevent streams from meandering.

Regarding failed or failing armoring, a bank cannot be both eroding and permanently preventing lateral migration processes. Where armoring has failed, the bank would be assessed using the dominant BEHI/NBS metric instead of being counted as armored.

Method:

1. Walk the entire reach, including both sides of the stream channel, and measure the length of armored banks.
2. Calculate the armoring field value by dividing the total length of armored banks (left and right) by the total length of bank (left and right). Multiply by 100 to report as a percentage of bank armoring. Enter the field value into the SQT.

$$\text{Percent Armoring} = \frac{\text{Length of Armored Bank}}{\text{Total length of Streambank in Reach}} * 100$$

Estimating proposed condition field values: The proposed condition field value is based on any additional armoring or armoring proposed to be removed as part of the project. This additional or reduced length should be added to or subtracted from the length of bank armoring measured in the existing condition and divided by the proposed total length of streambank in the reach (proposed reach length multiplied by two).

Documentation and field forms: Armored reach lengths should be recorded on the Project Reach form (Appendix B); the field value will automatically calculate once data has been entered. The field value will auto-populate from the Project Reach form to the Field Value Documentation form. Information on the location and type of armoring should also be provided.

4.6.c. Bed Material Characterization

Definition: Bed material consists of the particles within the active channel. Particles are characterized by the measurement of the intermediate axis.

There is only one metric associated with this parameter: percent fines.

Experience Requirements: Data collection should be performed by teams with experience conducting pebble counts following the methods outlined in the 'Pebble Counts - Reachwide and Cross-section' section of the *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ 2022).

1. Percent fines (<2mm)

Definition: Fines are bed material particles from a project reach that are smaller than 2mm in intermediate diameter. This metric assesses the accumulation of fine sediments in gravel and cobble streams and is not applicable to channels with a naturally fine median reach-wide particle diameter (reach-wide $d_{50} \leq 2\text{mm}$).

Method:

1. Within the representative sub-reach, conduct a riffle-only pebble count following the Cross-Section Pebble Count procedure in the *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ 2022). Refer to the source material for complete instructions.
2. Calculate the percent fines. The field value for the WSQT is the number of particles sampled with an intermediate axis of 2mm or less divided by the total number of particles counted, multiplied by 100.

$$\text{Percent Fines} = \frac{\# \text{ Particles} \leq 2\text{mm}}{\text{Total} \# \text{ Particles sampled}} * 100$$

Estimating proposed condition field values: Bed material is a parameter recommended for projects where fining of the bed material is occurring due to bank erosion or where activities are proposed that could lead to increased or decreased fine sediment deposition over coarse bed material (e.g., gravel). Projects that implement bank stabilization practices along a long project reach or restore flushing flows may be able to show a reduction in fine sediment deposition.

Documentation and Field Forms: The number of particles 2mm or less and the total number of particles should be recorded on the Field Value Documentation form in Appendix B. The form will calculate the field value from the information entered.

4.6.d. Bed Form Diversity

Bed forms include the various channel features that maintain heterogeneity in the channel form, including riffles, runs, pools and glides. Together, these bed features create important habitats for aquatic life. Riffles and pool types are defined in the glossary and described in Appendix A.

There are three metrics for this parameter: pool spacing ratio, pool depth ratio, and percent riffle.

Experience Requirements: Data collection for bed form diversity metrics should be performed by professionals that have experience with standard survey techniques, prior field experience identifying fluvial bed forms in Wyoming, and experience with identification and verification of bankfull. Users should have prior field experience in identifying bedform features sequences in different stream types, including experience differentiating between geomorphic pools and significant pools as defined by the WSQT.

1. Pool Spacing Ratio

The pool spacing ratio compares the stream length distance between sequential geomorphic pools to the bankfull width at a riffle (Rosgen 2014). Geomorphic pools are pools that remain intact over time and across a range of flow conditions and are associated with large planform features. Examples include pools associated with the outside of a meander bend (streams in alluvial valleys) and downstream of a large cascade or step (streams in colluvial valleys). See Appendix A for information on identifying geomorphic pools.

Method: Prior to calculating this metric, users need to complete the bankfull verification process (Section 4.4). The user should also determine and record the bankfull width as directed in Section 2.3.a (WSQT workbook) or Section 3.3.a (WSIT workbook). The same bankfull width is used to normalize all pool spacing ratio measurements for the project reach (existing, proposed, and monitoring)

1. Record the location along the longitudinal profile of the **maximum pool depth** of every **geomorphic pool** in the representative sub-reach. Measure and record the spacing between the maximum depths of the sequential pools.

Standard survey protocols are required to collect accurate location data of the stream centerline.²⁷ Appendix A provides instructions for rapid survey methods which use a tape, survey rods and hand levels.

2. The pool spacing ratio is calculated for each pair of sequential **geomorphic pools** in the representative sub-reach using the equation below. Note that the bankfull width to calculate this metric is from a stable riffle and is the value recorded in the Site Information and Reference Selection section.

$$\text{Pool Spacing Ratio} = \frac{\text{Distance between sequential geomorphic pools}}{\text{Bankfull width}}$$

3. Calculate the median of at least three pool spacing ratios and enter this as the field value.

When working in streams that have been straightened (channelized), a bed form sequence may not be present. This typically occurs because pool forming processes (meandering and scour processes) have been removed. **In this case, the reach will likely be mostly riffle habitat and the user should enter a field value of 0 for this metric.** This result indicates that a bed form sequence should be present based on the reference stream type, but it is absent due to channelization. This situation is most common in channelized streams where the meander width ratio (belt width / bankfull width) is less than 3.5 and the sinuosity is less than 1.2.

Estimating proposed condition field values: The proposed condition field value should be based on the proposed channel profile in colluvial valleys and based on the proposed channel profile and meander geometry in alluvial valleys.

Documentation and Field Forms: Record the number of geomorphic pools, the bankfull width and all calculated pool spacing ratios on the Field Value Documentation form in Appendix B; note the survey method and any post-processing tools used. The form will calculate the field value from the information entered. NOTE: a field value cannot be calculated with less than three pool spacing ratio measurements (i.e., four geomorphic pools are required).

2. Pool Depth Ratio

The pool depth ratio is a measure of pool quality with deeper pools scored higher than shallow pools. All geomorphic and significant pools are assessed. Geomorphic pools are defined above. Significant pools are often associated with wood, boulders, convergence, and backwater in the main channel, but are not classified as geomorphic pools. Significant pools must be deeper than the riffle, have a concave shaped bed surface and a width that is at least half the width of the channel. The pool may also have a flatter water surface slope than the riffle; however, this is not always the case, e.g., a pool downstream of a log in a steep-gradient channel. See Appendix A for information on bed feature identification. A geomorphic pool may also meet the criteria to be a significant pool but a geomorphic pool is not required to meet these criteria.

The pool depth ratio is calculated by dividing the maximum bankfull pool depth by the mean bankfull riffle depth. The pool depth ratio represents the difference in elevation between the deepest point of each pool and the bankfull elevation.

²⁷ Appendix A field methods instruct users to stretch the tape along the stream bank. Channel centerline and streambank are considered equivalent.

$$\text{Pool Depth Ratio} = \frac{D_{\text{max pool}}}{D_{\text{mean riffle}}}$$

Method: Prior to calculating this metric, users need to complete the bankfull verification process (Section 4.4). The user should also determine and record the bankfull mean depth consistent with the methodology used to determine the bankfull width for the Site Information and Stratification section (See Section 2.3.a or 3.3.a). Bankfull mean depth should align with values that would naturally occur absent from anthropogenic influences. This can be the bankfull mean depth calculated from a stable riffle (Section 4.4) or, for WSIT assessment of existing conditions, calculated from regional curves applicable to the project area. The same bankfull mean depth is used to normalize all pool depth ratio measurements for the project reach (existing, proposed, and monitoring).

1. At every **geomorphic and significant pool** within the representative sub-reach:
 - a. Identify the bankfull elevation and pool maximum depth. The bankfull verification process (Section 4.4) should be used to identify the bankfull elevation.
 - b. Measure and record the difference between the bankfull elevation and the thalweg elevation (bankfull pool maximum depth).

Standard survey protocols are required to collect accurate location data of the stream thalweg and elevation data. Appendix A provides instructions for rapid survey methods which use a tape, survey rods and hand levels.

2. Pool depth ratio is calculated for each pool by dividing the bankfull pool maximum depth by the bankfull mean depth from the stable riffle survey.

If a longitudinal profile is generated, the best-fit-line through the bankfull points should be used to calculate the bankfull elevation associated with each pool maximum depth. For the rapid survey, the difference in bankfull and water surface (established during the bankfull verification process) should be used at each bankfull pool maximum depth location.

3. Average the pool depth ratio values from all **geomorphic and significant pools** in the representative sub-reach and enter it as the field value into the WSQT.

Estimating proposed condition field values: The proposed condition field value should be based on the proposed channel profile in colluvial valleys and based on the proposed channel profile and meander geometry in alluvial valleys.

Documentation and Field Forms: Record the average pool depth, number of pools measured, mean riffle depth, and field value on the Field Value Documentation form in Appendix B; note the survey method and any post-processing tools used.

3. Percent Riffle

The percent riffle is the proportion of the representative sub-reach containing riffle and run bedform features, as distinct from pool features. Riffles are shallow, steep-gradient channel segments typically located between pools. Riffles are the river's natural grade control feature (Knighton 1998) and are sometimes referred to as fast-water channel units (Hawkins et al. 1993; Bisson et al. 2017). For purposes of the SQT, in meandering streams riffles broadly represent the section between lateral-scour pools known as a crossover, regardless of bed

material size. Therefore, the term riffle also refers to the crossover section (ripples) in a sand bed channel or the cascade section of steep mountain streams. Riffles are measured from head of riffle to head of pool; thus, runs are considered riffles and glides are considered pools (Rosgen 2014).

The percent riffle and percent pool (geomorphic or significant) should sum to 100% of the representative reach length. See Appendix A for information on bed feature identification.

Method:

1. Measure the length of each riffle in the representative sub-reach from the channel centerline. Riffle length is measured from the head (beginning) of the riffle downstream to the head of a geomorphic or significant pool. **Run features are included within the riffle length.** Riffle length may include riffles with small pools that do not meet the criteria for geomorphic or significant pool as defined in this manual. Glide features are classified as pools.

Standard survey protocols are required to collect accurate location data of the stream centerline and bed form features. Appendix A provides instructions for rapid survey methods which use a tape, survey rods and hand levels.

2. Add the length of all riffles within the representative sub-reach. Percent riffle is calculated by dividing the total length of **riffles** within the representative sub-reach by the total representative sub-reach length.

$$\% Riffle = \frac{\sum(Riffle\ length_{sub-reach})}{Total\ length_{sub-reach}}$$

Estimating proposed condition field values: The proposed condition field value should be based on the proposed channel profile in colluvial valleys and based on the proposed channel profile and meander geometry in alluvial valleys.

Documentation and Field Forms: Record the total riffle length within the sub-reach on the Field Value Documentation form in Appendix B; note the survey method and any post-processing tools used. The form will calculate the field value from the information entered.

4.6.e. Riparian Vegetation

Riparian vegetation represents the plant communities contiguous to and affected by surface and subsurface hydrology and fluvial disturbance within the stream corridor.

Data collection methods have been modified from previous versions of the WSQT to improve repeatability and consistency. Data collection methods intentionally allow for extrapolation of species information to draw inferences on vegetation composition and/or to apply additional regulatory performance standards at mitigation sites.

There are four metrics for riparian vegetation: riparian extent (%), woody vegetation cover (%), herbaceous vegetation cover (%) and percent native cover (%). Additional vegetation metrics may be used to monitor and determine successful establishment of riparian and wetland vegetation communities but are not included in the WSQT version 2.0.

Experience Requirements: Data collection for riparian vegetation metrics should be performed by professionals with experience identifying plant species and estimating absolute cover by species. Users will need to be able to key native and non-native plants commonly found in riparian zones within the region and should be able to identify at least 80% of the species within a plot.

1. Riparian Extent

The riparian extent metric describes the portion of the expected riparian area that currently contains riparian vegetation and is free from utility-related, urban, or otherwise soil disturbing land uses, fill, and development.

This metric characterizes the current, observed extent of the riparian area, as compared with the reference expectation for that site. The reference expectation, or expected riparian area, is an estimate of the natural or potential extent of the riparian area. Each of these values should first be estimated using aerial imagery interpretation and then validated in the field. The expected and observed riparian area are delineated for the entire project reach. Therefore the desktop delineation may be most efficiently performed for the entire project area and then divided into areas assigned to each project reach.

The riparian extent metric is the percentage of the expected riparian area that currently contains riparian vegetation and is free from disturbance, as described above. Riparian extent (%) is the field value entered into the WSQT and is calculated using the following equation:

$$\text{Riparian Extent} = \frac{\text{Observed Riparian Area}}{\text{Expected Riparian Area}} * 100$$

Method: The riparian extent metric relies on a combination of desktop methods described below and field verification methods described in Appendix A. Example 15 consists of two example calculations.

Expected Riparian Area:

1. Using aerial imagery and other spatial data such as topographic layers or digital elevation models, identify and delineate the edge of the expected riparian area. The expected riparian area includes the extent of the riparian corridor in each direction, landward from the stream to the extent of substrate, geomorphic, hydrologic, and biotic indicators. Wherever possible, historical photographs and other data pre-dating human disturbance should be used to support the expected riparian extent.

Substrate indicators are found within the portion of the valley bottom influenced by fluvial processes under the current climatic regime while **hydrologic indicators** are found where the valley bottom would be flooded at the stage of the 50-year or 100-year recurrence interval flow²⁸. Indicators may include a fluvially formed break in slope between bank edge and valley (or terrace) edge, a change in sediment from fluvial sediments (rounded) to hillslope sediment

²⁸ The floodplain extent may be tied to recurrence intervals less than the 100-year, depending on the process domain at the project site (see Merritt et al. 2017 and Polvi et al. 2011).

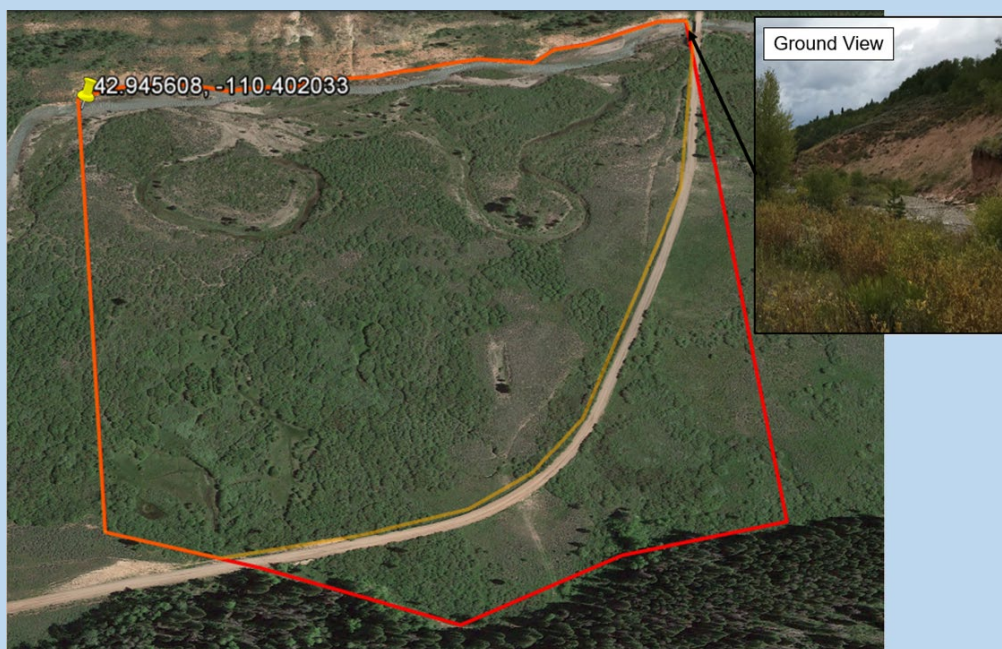
(angular), or evidence of flood events (e.g., bar deposition, staining, water marks, floodplain mapping²⁹, etc.).

Biotic indicators include riparian vegetation characteristic of the region and plants known to be adapted to shallow water tables and fluvial disturbance (Merritt et al. 2017). Riparian areas have one or both of the following characteristics: 1) distinctly different vegetation species than adjacent areas, and 2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms (USFWS 2009). Biotic indicators may not be useful to inform expected riparian extent where human disturbance is present (e.g., where there are changes in hydrology due to water diversion or incision, or where changes in land use have altered the natural extent of riparian vegetation).

This step must be performed and the presence or absence of indicators of the expected riparian extent must be documented.

Example 15a: Riparian Extent

The following is an example showing how the riparian extent metric can be calculated by delineating the observed (yellow) and expected (red) riparian area within a project reach. The riparian area boundaries were delineated using aerial photographs and indicators of the extent were verified in the field. Review of aerial imagery included identification of any observable topographic and valley edge indicators, including valley edge, slope break/terrace, change in sediment, and change in vegetation. Existing riparian extent was delineated by also considering indicators of anthropogenic modification, in this case, the presence of a road. In this example, the observed riparian area (yellow) was 39.7 acres, the expected riparian area (red) was 48.6 acres, and the O/E calculation was 81.7%.



²⁹ U.S. Forest Service national riparian areas base map for the conterminous United States in 2019
<https://www.fs.usda.gov/rds/archive/catalog/RDS-2019-0030>

Example 15b: Riparian Extent

The following is an example showing how the riparian extent metric can be calculated by delineating the observed and expected riparian area within a project reach. Existing substrate and hydrologic indicators are absent due to the recent housing development; current topography has been altered to reduce the floodplain and riparian area. Review of historical imagery indicated a wide, flat valley. By comparing the USFS 2019 mapping of riparian areas (light green shading) to historical imagery, it was evident that the data pre-dated the development adjacent to the reach. The observed extent of biotic indicators supports the use of the USFS 2019 mapping (light green shading) and the expected riparian extent is delineated in red in the image on the right.

The presence of riparian vegetation and anthropogenic modification within the expected riparian extent was determined. Areas excluded from the observed riparian area are shown in yellow. In this case, the 0.7 acres of trails and 1.6 acres of development were not included in the observed riparian extent but did not truncate the observed riparian extent. The trail along the bottom of the figure is raised and paved, restricting hydrology and removing 0.5 acres of trees from the observed riparian extent.

In this example, the observed riparian area was 4.3 acres, the expected riparian area (red) was 7.1 acres, and the O/E calculation was 61%.



2. Calculate the area within the delineated expected riparian extent (Example 15). This area should include the stream channel itself. The expected riparian area value and indicators should be noted on the Riparian Extent form prior to going out in the field. If, and only if, natural indicators are no longer present due to anthropogenic modification, see Step 4 below.

3. During riparian data collection, expected riparian area indicators and extent should be verified in the field using the procedure outlined in Appendix A.
4. Where aerial imagery, spatial data and/or field indicators cannot be used to delineate the expected riparian extent (e.g., extensive development or grading), there are two options:
 - a. Historical images and other data pre-dating human disturbance can be used to determine the expected riparian extent. These data may include historic topographic images, geomorphic, geologic and soils maps. Map the expected riparian extent by comparing the historic data to current topographic images and identifying hydrologic and substrate indicators per step 1.
 - b. The meander width ratio (MWR) may be used to calculate expected riparian extent only when other resources have been explored and evaluated as not suitable. The MWR is the belt width of a meandering stream in its valley divided by the bankfull width (Rosgen 2014). This option does not require the MWR to be measured but instead applies a typical MWR based on the valley type (Table 11). To determine the expected riparian area width using this method, multiply the **bankfull width of the channel** by a selected MWR for the given valley type and add an additional width for outside meander bends (see equation below and Figure 40). The expected riparian area width should then be multiplied by valley length to calculate the expected riparian area. Valley length should be calculated along the centerline of the valley.

$$\text{Riparian Area Width} = W_{\text{Bankfull}} * \text{MWR} + 2 * W_{\text{additional}}$$

Note that the expected riparian extent should remain the same for all calculations: existing, proposed and for post-project monitoring. The **bankfull width of the channel** for this calculation should be from the stable riffle cross-section.

Table 11. MWR by Valley Type. Adapted from Harman et al. (2012) and Rosgen (2014).

Valley Type	MWR	Additional Width $W_{\text{additional}}$
Alluvial Valley	7	25
Confined Alluvial	3	15
Colluvial	2	10

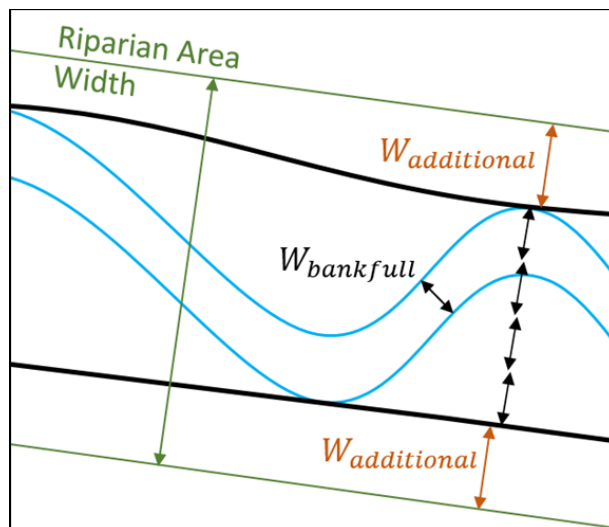


Figure 40. Expected Riparian Width Calculation Relying on Meander Width Ratio.

Observed Riparian Area:

1. Using aerial imagery and other spatial data via desktop methods, identify and delineate the observed riparian area throughout the project reach. The observed riparian area is the area that currently contains riparian vegetation and is free from anthropogenic disturbance, including urban development, intensive agricultural land uses, resource extraction and changes in hydrology.

Disturbances are human caused development and activities that remove, destroy, or inhibit growth and the extent of riparian vegetation. Disturbances can also be direct or indirect stressors that may physically limit or truncate riparian extent through disruption of surface or subsurface hydrology (connectivity) to the stream. Anthropogenic disturbances are not included in the observed riparian area. However, not all anthropogenic features will truncate the riparian extent. If there is evidence to suggest that riparian vegetation extends beyond the disturbance, the observed riparian area should include the area beyond the disturbance.

Examples of disturbances to observed riparian extent may include: Removal of riparian vegetation, hardening, cultivation, intensive land and water use practices, berms, ditches, buried utility lines that are not properly restored to original elevations, contours and native riparian vegetation, and/or that appear to disrupt/interrupt shallow water tables. Other disturbances to the riparian area, e.g., caused by incision or flow diversion, are more difficult to identify, and users may need to consider whether the historic extent of characteristic riparian vegetation has changed in response to impacts to floodplain connectivity and hydrologic processes.

Certain types of disturbances, such as raised, paved, and compacted roads and pathways, that restrict or cut off hydrology supporting riparian vegetation effectively truncate the observed riparian extent. Features that **may not** truncate riparian extent: properly restored surface utility lines and buried utility lines; uncultivated hay meadows or mowed areas; unimproved two-track roads or trails; at-grade gravel pathways <5 ft wide; and stream- and riparian restoration-related grading and disturbances.

2. Calculate the area within the observed extent (Example 15), including the channel itself. Observed riparian area values and indicators should be noted on the Riparian Extent field form prior to going out in the field.
3. During riparian data collection, observed riparian area indicators and extent should be verified in the field using the procedure outlined in Appendix A.
4. Apply the field-verified expected riparian area and observed riparian area measurements to the equation identified at the beginning of this section to calculate the WSQT value for riparian extent (%).

Estimating proposed condition field values: The field value for this metric is an observed value divided by an expected value; the expected value should remain the same for all calculations, including existing and proposed calculations and for post-project monitoring. The observed value for the proposed condition can be calculated based on restoration or creation of disturbed areas, and anticipated areas of riparian vegetation planting, changes in the extent of anthropogenic disturbance in the expected riparian area associated with the proposed project, or anticipated changes in riparian vegetation extent following project-related alterations to floodplain connectivity or hydrologic processes.

Documentation and Field Forms: Complete the Riparian Extent form and provide aerial imagery or maps outlining the extent of the observed and expected riparian areas. If the MWR method was used to delineate expected riparian extent, an explanation is required on the Riparian Extent form. The field value will calculate automatically and auto-populate on the Field Value Documentation form in Appendix B.

2. Woody Vegetation Cover

Definition: Woody vegetation cover characterizes abundance and type of woody vegetation which can affect channel stability, floodplain roughness and provide habitat for riparian dependent wildlife. The woody vegetation cover field value for the WSQT is the sum of absolute percent woody plant cover from shrub and tree species, averaged across all plots within the representative sub-reach.

$$\text{Woody vegetation cover} = \text{Woody}_{\text{Shrub Species Cover}} + \text{Woody}_{\text{Tree Species Cover}}$$

Note that estimates among different species are independent of each other, so the sum of the woody cover for overlapping species combined could add up to more than 100%.

Method: Riparian vegetation should be assessed during the growing season within nested sampling plots located along the bankfull or greenline (whichever is closer to the stream) of the representative sub-reach (Figure 41). Procedures for determining riparian vegetation plot locations and layout are provided in Appendix A. Users shall consult with USACE about plot placement when the project area does not align with the expected riparian extent.

1. Within each riparian plot for the representative sub-reach, follow the riparian vegetation plot data collection method outlined in Appendix A. The methods represent a combination of techniques borrowed from the *Corps of Engineers Wetland Delineation Manual Arid West, Great Plains and Western Mountains and Valleys Regional Supplements* (USACE 2008, 2010a, and 2010b), the Hydrogeomorphic (HGM) Approach (Hauer et al. 2002), and the Bureau of Land Management Assessment, Inventory, and Monitoring projects (BLM 2017).

Methods include visual estimation of the percent absolute cover of each plant species within the nested plot types to determine vegetation abundance, structure, composition and complexity. Practitioners will need basic knowledge of or the ability to key native and nonnative plants commonly found in riparian zones within the region to identify at least 80% of the species within a plot.

2. Add the cover values for all shrub and tree species within each plot. Note: this calculation will be done automatically for each plot on the Riparian Vegetation form.
3. Average values across all plots to calculate the field value for the WSQT.

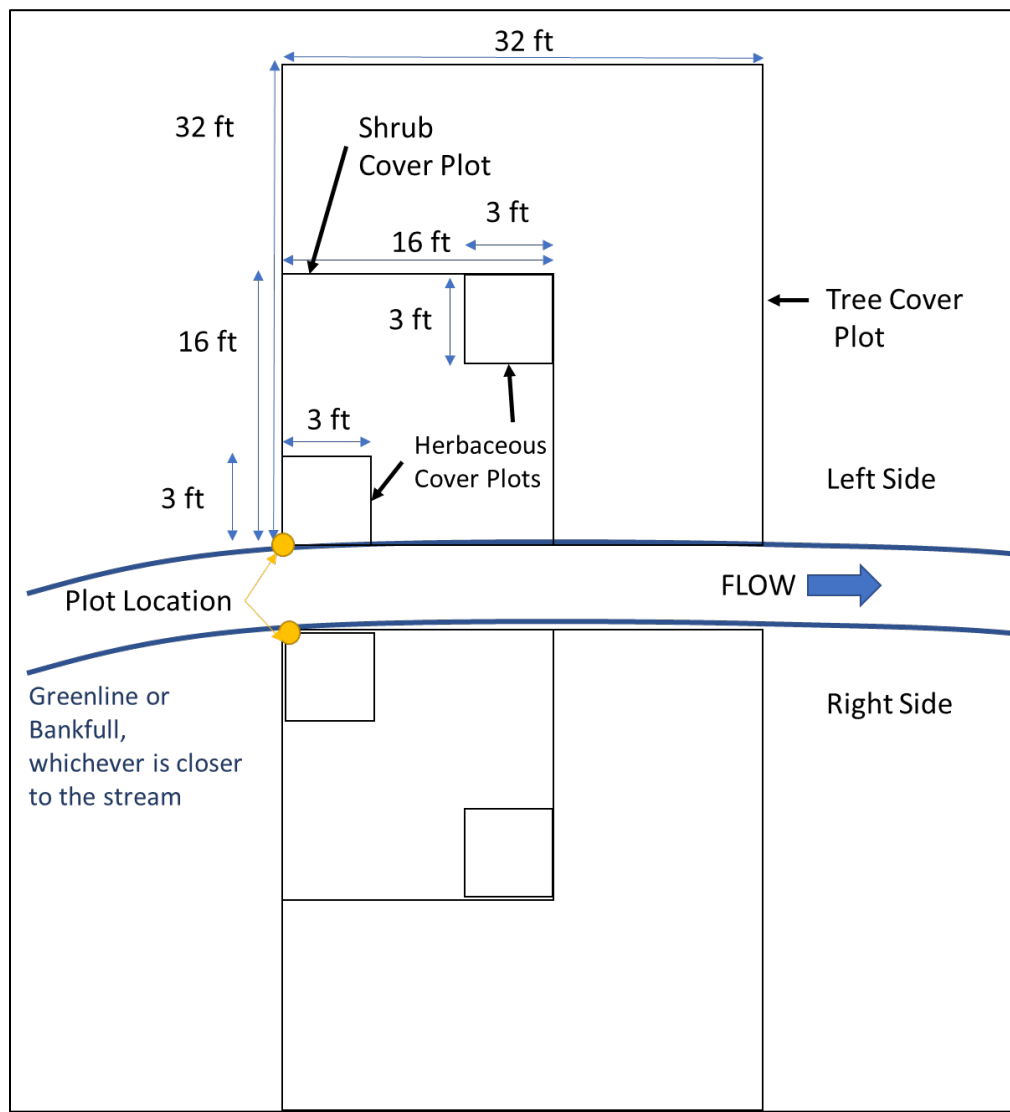


Figure 41. Riparian Vegetation Sample Plot Layout.

Estimating proposed condition field values: Users should consider the extent of preserved vegetation, vegetation removal, and the growth rates and expected cover for planted vegetation over the monitoring period.

For stream restoration and mitigation projects, the proposed condition field value should be an estimate of woody cover for conditions at project closeout. This metric may capture substantial woody plant losses due to reconstruction and limited gains by project closeout (5 - 7 years of monitoring) with typical growing conditions in Wyoming. Proposed condition estimates within this timeframe for restoration projects should be very conservative while long-term vegetation establishment goals can be communicated in a project narrative.

Documentation and Field Forms: All data from riparian vegetation plots should be recorded on the Riparian Vegetation form. Record the number of plots and the woody vegetation cover value for each plot on the Field Value Documentation form. The field value will automatically calculate from the values provided.

3. Herbaceous Vegetation Cover

Definition: Herbaceous vegetation cover is important for bank stability, water quality, and habitat, particularly in systems where woody vegetation is not prevalent. The herbaceous vegetation cover field value for the WSQT is the sum of absolute percent herbaceous plant cover from herbaceous species averaged across all plots within the representative sub-reach.

$$\text{Herbaceous vegetation cover} = \text{Herbaceous Ground Cover}$$

Note that estimates among different species are independent of each other, so the sum of the herbaceous cover for overlapping species combined could add up to more than 100%.

Method:

1. See Step 1 under the method for Woody Vegetation Cover (Section 4.6.e.2).
2. Add the cover values for all herbaceous species within each plot. Note: this calculation will be done automatically for each plot on the Riparian Vegetation form.
3. Average values across all plots to calculate the field value for the WSQT.

Estimating proposed condition field values: Users should consider the extent of preserved existing vegetation, vegetation removal, and the expected cover for planted seeds given shading and seral expectations over the monitoring period. For stream restoration and mitigation projects, the proposed condition field value should be an estimate of herbaceous cover for conditions at project closeout.

Documentation and Field Forms: All data from riparian vegetation plots should be recorded on the Riparian Vegetation form. Record the number of plots and the herbaceous vegetation cover value for each plot on the Field Value Documentation form. The field value will automatically calculate from the values provided.

4. Percent Native Cover

Definition: This metric characterizes the proportion of native species at a project site, compared with total vegetation cover, and serves as an indicator of the composition and condition of the riparian communities. Native cover excludes species that are introduced (i.e., non-native or naturalized) per the USDA PLANTS Database <http://plants.usda.gov>. The percent native cover metric for the WSQT is the relative cover of native species averaged across all

plots within the representative sub-reach. Relative cover is the absolute cover of a species or group of species divided by the total coverage of all species, expressed as a percent.

$$\% \text{ Relative Native Cover} = \frac{\text{Native Vegetation Cover}}{\text{Herb Vegetation Cover} + \text{Woody Vegetation Cover}} * 100$$

Note that this metric converts summed absolute cover values into relative cover, therefore, the metric value will not exceed 100%.

Method:

1. See Step 1 under the method for Woody Vegetation Cover (Section 4.6.e.2).
2. The percent native cover is calculated at each plot using the equation above. For each plot, add the cover values for all native species, divide by the total cover for all species within the plot to calculate percent native cover. Note: this calculation will be done automatically for each plot on the Riparian Vegetation form.
3. Average values across all plots to calculate the field value for the WSQT.

Estimating proposed condition field values: The field value for the proposed condition is an estimate of conditions at the end of monitoring or project closeout. The value can be estimated based on proposed invasive species removal and any associated monitoring and management plan (or lack thereof). Invasive species can often take over a recently disturbed site and, for restoration projects, require active management to ensure success of planted native species. Where there is a seed source for invasive non-native species, an impacted site will likely see an increase in non-native cover unless a vegetation management plan is implemented.

Documentation and Field Forms: All data from riparian vegetation plots should be recorded on the Riparian Vegetation form. Record the number of plots and the native cover value for each plot on the Field Value Documentation form. The field value will automatically calculate from the values provided.

4.7. Physicochemical Functional Category Metrics

The WSQT contains two function-based parameters to assess the physicochemical functional category: temperature and nutrients.

4.7.a. Temperature

Definition: Temperature plays a key role in both physicochemical and biological functions, and there are several aspects of thermal regimes that affect biota (e.g., magnitude, variability, frequency, duration and timing of thermal events as described in Arismendi et al. 2013).

There is one metric included in the WSQT for this parameter, the maximum weekly average temperature (MWAT), which characterizes the magnitude of August stream temperature.

Experience Requirements: Data collection should be performed by personnel with experience calibrating and installing stream temperature gages and processing data.

1. Maximum Weekly Average Temperature (MWAT)

Definition: The Maximum Weekly Average Temperature (MWAT) is the largest mathematical mean of multiple, equally spaced, daily temperatures over a seven-day consecutive period.

Method: Install continuous in-water temperature sensors following *Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams* (USEPA 2014). Note that procedures require the deployment of an air temperature sensor.³⁰ Daily air temperature observations from the nearest active weather station can be used in lieu of air temperature sensors.

For the WSQT, the sample period is the month of August for the sampling year. The sensors should be set to record point temperature measurements at intervals that do not exceed 1 hour.

To determine the field value for the MWAT (measured in degrees Celsius):

1. Calculate the average temperature recorded for each day in the sample period (August; minimum 31 days). These are the mean daily temperatures.
2. Calculate the weekly average temperatures from the mean daily temperatures on a rolling seven-day basis for the August sampling period.
3. Identify the maximum of the rolling weekly average temperatures and enter as the field value in the WSQT.

Only one year of data are required to characterize the existing condition. As water temperature is strongly influenced by meteorological conditions, it is recommended that multiple years of data are collected and averaged to inform the existing condition field value.

Estimating proposed condition field values: The proposed condition field value should estimate/predict the expected change in the MWAT field value resulting from the project. Reference reach monitoring near the project can inform proposed condition field values. Practices that could impact in-stream summer temperatures include, but are not limited to, altering streamside vegetation and channel shading, groundwater connections, or summer baseflows (altered through management agreements).

Documentation and Field Forms: Record the date and time of the first and last sensor reading, sampling interval, date range used to calculate the MWAT and the field value on the Field Value Documentation form in Appendix B. Include a time-series plot of the temperature data used to calculate the field value. If multiple years of data were used to calculate the MWAT, indicate as such in the notes column.

4.7.b. Nutrients

Definition: Excessive nitrogen and/or phosphorous can lead to excessive plant and algal growth, which in turn can degrade stream microhabitats, cause periodic low oxygen concentrations, and blooms of toxin producing algae.

³⁰ The air temperature data helps determine if water temperature sensors are dewatered during their deployment and provides insight about the responsiveness of stream temperatures to air temperatures.

There is currently one metric for the nutrient parameter, chlorophyll α , measured in milligrams per square meter (mg/m^2).

Experience Requirements: Data collection and analysis should be performed by personnel with training and experience collecting and processing periphyton samples.

1. Chlorophyll α

Definition: Chlorophyll is the pigment that allows plants (including algae) to use sunlight to convert simple molecules into organic compounds via the process of photosynthesis. Chlorophyll α is the predominant type found in green plants and algae and concentrations are directly affected by the amount of nitrogen and phosphorus in the stream. Chlorophyll data should be expressed as milligrams of chlorophyll α per square meter of sampled rock substrate (mg/m^2).

Methods:

1. Chlorophyll α samples should be collected and processed according to the Periphyton: Sampling Methods/Subsample Processing for Chlorophyll Analysis and Taxonomic ID methods outlined in the *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ 2022). Only the rock scrape method (epilithic method) is applicable to the WSQT, meaning this metric is only applicable within stream reaches that contain gravel or larger bed materials and where riffles are present.

Only one sample is required to characterize the existing condition. It is **recommended** that multiple samples be collected if feasible to capture intra-annual variability. Refer to the monitoring section (Section 2.3.c) for more detail.

2. The milligrams of chlorophyll α per square meter of sampled rock substrate (mg/m^2) is the field value entered into the WSQT.

Estimating proposed condition field values: The proposed condition field value should estimate/predict the expected change in chlorophyll α resulting from the project activities. Practices that could impact chlorophyll α include, but are not limited to, altering nutrient loads entering the stream channel from the lateral drainage area (through management agreements or buffer planting). Altering flow volumes could also lead to measurable changes in measured chlorophyll α concentration.

Documentation and Field Forms: Sample collection date(s) and the field value should be recorded on the Field Value Documentation form. If multiple samples were used to calculate the field value, indicate as such in the notes column. Provide copies of any laboratory results used in data analysis.

4.8. Biology Functional Category Metrics

The function-based parameters included in the WSQT for the biology functional category are macroinvertebrates and fish.

4.8.a. Macroinvertebrates

Definition: Macroinvertebrates are an integral part of the food web and are commonly used as indicators of stream ecosystem condition.

Two metrics are included in this parameter and include the two biological models that use macroinvertebrate communities to assess biological condition of Wyoming streams: the multi-metric Wyoming Stream Integrity Index (WSII) and the multivariate River Invertebrate Prediction and Classification System (RIVPACS).

Experience Requirements: Field values for macroinvertebrate metrics should be collected by professionals with training and experience sampling and preserving samples in accordance with *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ 2022). Samples require laboratory identification and enumeration at a professional taxonomic laboratory.

1. Wyoming Stream Integrity Index (WSII)

Definition: The WSII is a statewide, regionally calibrated macroinvertebrate-based multi-metric index designed to assess biological condition in Wyoming perennial streams (Hargett 2011). Index scores for the WSII are calculated by averaging the standardized values of selected metrics (composition, structure, tolerance, functional guilds) derived from the riffle-based macroinvertebrate sample. The selected metrics are those that best discriminate between reference and degraded waters. The assessment of biological condition is made by comparing the index score for a site of unknown biological condition to expected values that are derived from an appropriate set of regional reference sites that are minimally or least impacted by human disturbance.

Method:

1. Collect macroinvertebrates consistent with the Macroinvertebrate Sampling – Targeted Riffle Method section in the *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ 2022).
2. Process and identify macroinvertebrates consistent with the methods outlined in the *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ 2022).
3. Once taxa are identified from the sample (generally to the genus level), WSII values can be calculated using the WSII report (Table 7 in Hargett 2011). Laboratories providing taxonomic identification services may also calculate metrics required for the WSII upon request. Additional resources needed to calculate metric values for the WSII are described or cited in the WSII report. Contact WDEQ for questions on macroinvertebrate sampling and assistance with calculating WSII scores, if needed.
4. The WSII score is entered as the field value for the WSQT.

Only one sample is required to characterize the existing condition. It is recommended that multiple samples be collected if feasible to capture intra-annual variability. Refer to the monitoring section (Section 2.3.c) for more detail.

Estimating proposed condition field values: The proposed condition field value should estimate/predict the expected change in WSII score resulting from the project. Practices that could impact macroinvertebrate communities include, but are not limited to, altering in-stream water quality, presence and extent of macroinvertebrate habitat, and landscape and aquatic connectivity. Altering flow volumes could also lead to measurable changes in measured macroinvertebrate communities.

Documentation and field forms: Sample collection date(s) and the field value should be recorded on the Field Value Documentation form. If multiple samples were used to calculate the field value, indicate as such in the notes column. Provide copies of any laboratory results used in data analysis.

2. River Invertebrate Prediction and Classification System (RIVPACS)

Definition: RIVPACS is a statewide, macroinvertebrate-based predictive model that assesses stream biological condition by comparing the riffle-based macroinvertebrate community observed at a site of unknown biological condition with that expected to occur under reference condition (Hargett 2012). The expected macroinvertebrate taxa are derived from an appropriate set of reference sites that are minimally or least impacted by human disturbance. The deviation of the observed from the expected taxa, a ratio known as the O/E value, is a measure of compositional similarity expressed in units of taxa richness and thus a community level measure of biological condition. O/E values near 1 imply high biological condition while values <1 imply some degree of biological degradation.

Method:

1. See Steps 1 and 2 outlined in the WSII metric (2.10.a.1).
2. Once taxa are identified to genus, they should be consolidated into operational taxonomic units (OTUs) and reported in a taxa-abundance matrix. RIVPACS requires predictor data (latitude, longitude, watershed area, bioregion, and alkalinity) and must be calculated by WDEQ. Contact WDEQ for questions on sampling, OTUs and assistance with calculating RIVPACS scores.
3. The RIVPACS score is entered as the field value for the WSQT.

Only one sample is required to characterize the existing condition. It is recommended that multiple samples be collected if feasible to capture intra-annual variability. Refer to the monitoring section (Section 2.3.c) for more detail.

Estimating proposed condition field values: The proposed condition field value should estimate/predict the expected change in RIVPACS score resulting from the project. Practices that could impact macroinvertebrate communities include, but are not limited to, altering in-stream water quality, presence and extent of macroinvertebrate habitat, and landscape and aquatic connectivity. Altering flow volumes could also lead to measurable changes in measured macroinvertebrate communities.

Documentation and field forms: Sample collection date(s) and the field value should be recorded on the Field Value Documentation form. If multiple samples were used to calculate the field value, indicate as such in the notes column. Provide copies of any laboratory results used in data analysis.

4.8.b. Fish

Definition: Fish are an integral part of aquatic food webs in functioning river ecosystems.

Three metrics for fish are included in the WSQT: native fish species richness, absence of Species of Greatest Conservation Need (SGCN); and game species biomass.

Experience Requirements: Users should have experience performing standard fish sampling techniques to capture the full array of potential species at a site. Electrofishing, species identification, and population estimates should be performed by trained fisheries biologists or aquatic biologists. Fisheries biologists or aquatic biologists performing species identification should be able to identify 100% of the fish species present, including species that hybridize.

A Chapter 33 permit from WGFD is required prior to collecting fish samples.

Note: Project specific consultation should occur with a regional fish biologist from the WGFD who can provide local information on potential limiting factors to improving fish communities or indicate whether project goals should center on native fish restoration or game fish species based on the management objectives within a specific sub-basin.

1. Native Fish Species Richness (% of expected)

Definition: This metric documents the diversity of the native fish community in comparison to reference expectations. The deviation of the observed from the expected taxa, a ratio known as the O/E value, is a measure of compositional similarity expressed in units of taxa richness and thus a community level measure of biological condition.

The percent of the expected native fish assemblage observed in the stream is the field value entered into the WSQT and is calculated using the following equation:

$$\text{Native Fish Species Richness} = \frac{\text{Observed Native Fish Assemblage}}{\text{Expected Native Fish Assemblage}} * 100$$

Method:

Expected Fish Community:

1. Users should first determine the expected species assemblage. Review the species assemblage list included in Appendix C for a preliminary estimate of the expected native fish assemblage at a site. These assemblages are based on the 2017 SWAP (WGFD 2017) and are organized by the six major river basins in Wyoming and differences in stream temperature (cold, transitional, warm) and gradient. Recognizing that each fish species' distribution varies naturally within any basin due to underlying factors such as geology, flow regime and duration, water temperatures, or natural barriers, the list of expected species in a project area reflects a subset of the assemblage list for the entire basin and may require further refinements based upon local knowledge. There may also be anthropogenic factors outside of a restoration practitioner's control that influence the number of species present,

including flow alteration, barriers to movement, etc. While these anthropogenic factors may limit the restoration potential at a site, they should not be considered in estimating the “expected” fish community. Therefore, the “expected” community consists of the fish that should be naturally present in the absence of anthropogenic influence.

2. Once a preliminary estimate of the number of native fish species is made, the user should coordinate with a regional fish biologist at WGFD to further refine the expected species assemblage.

Observed Fish Community:

1. Determine if fish community data are available from the Wyoming Natural Resources and Energy Explorer (NREX)³¹. These data may serve as a preliminary estimate of the number of native species present. The publicly accessible data are programmed to yield species lists of all species ever sampled from the closest fish sampling station. At this time, it is not possible for the public user to identify the sampling history or distance to WGFD sampling sites to judge whether the species list is current or derived from a nearby site. Therefore, the practitioner should coordinate with the regional fish biologist at the WGFD to evaluate these questions.
2. If representative data have not been collected within the previous 3 years, detailed fish surveys should be conducted.
 - Detailed fish surveys should be conducted within the project reach using standard methods (Bonar et al. 2009). An approved sampling methodology should be used, such as multi-pass depletion or mark-recapture techniques. Sampling methods should remain consistent throughout the project.
 - Because of inter- and intra-annual variability in native fish communities, at least two sampling events occurring in different seasons (at least 60 days between sampling occurrences) or ideally different years are needed to establish the observed fish community.
 - To verify fish identification, practitioners must collect and preserve voucher specimens of each fish species identified.
3. Calculate the percent of species from the expected native fish assemblage that were observed during at least one of the two sampling events. Enter this value as the field value in the WSQT.

Estimating proposed condition field values: The proposed condition field value should estimate/predict the number of native species anticipated to be present following the proposed project. Consultation with a WGFD regional fish biologist to determine the expected species assemblage will inform the anthropogenic causes of impairment and whether the proposed actions would adversely affect or improve the observed assemblage. For restoration and mitigation sites, the regional fish biologist will also be able to advise the user whether improvements to the native fish community at a given site are possible or whether native fish species restoration is an appropriate project goal.

³¹ <https://nrex.wyo.gov/>

Documentation and Field Forms: Record number of expected native fish species on the Field Value Documentation form in Appendix B; include the list of species and the names of any aquatic biologists consulted in developing the list in the notes column. Record the sampling dates, the observed number of native fish in each sample, and the number of native fish species that occurred in the second sample, but not the first. The field value will automatically calculate from the information provided.

2. Absence of Species of Greatest Conservation (SGCN)

Definition: SGCN are identified in the SWAP (WGFD 2017) as those species whose conservation status warrants increased management attention and funding, as well as consideration in conservation, land use, and development planning in Wyoming.

SGCN species are classified into tiers where tier 1 species have the highest conservation need while tier 3 species have less of a conservation need than tier 1 or 2 species. Once the list of SGCN species with natural potential at the site is determined, report the number of SGCN absent in each tier for the site. The number of SGCN absent at the site in each tier is used to calculate the field value for the WSQT (Table 12).

Method:

1. See methods outlined in the native species richness metric for determining the expected and observed fish community (Section 4.8.b.1).
2. Identify which species, if any, in the expected fish community are listed as tier 1, 2 or 3. For any project where this metric is used, the practitioner should consult with a WGFD regional fish biologist to determine whether there is natural potential at the site for SGCN to be present. Note, natural potential is not limited by anthropogenic factors like culverts or flow alteration that may limit the existing distribution of a SGCN. For an initial site review, the SWAP can be consulted to determine the potential for SGCN species to be present within the project reach.
3. Consolidate the observed species list for both sample events. Count how many tier 1, 2 and 3 species were not in the observed fish community. Note that if there are no expected species in a tier for the site then there are no species absent for that tier.
4. Use Table 12 to calculate the field value for this metric. The weighted number of SGCN species absent is the field value to be entered into the WSQT (Example 16).

Table 12. How to Calculate the Field Value for SGCN Metric.

Column A	Column B	Column C
# Tier 1 Species Absent	3	$C_1 = A_1 * B_1$
# Tier 2 Species Absent	2	$C_2 = A_2 * B_2$
# Tier 3 Species Absent	1	$C_3 = A_3 * B_3$
Field Value for the WSQT =		$C_1 + C_2 + C_3$

Example 16: Calculation of SGCN metric

A project is proposed in a transitional stream in the Bear River Basin. According to Appendix C, two SGCN species (Bonneville cutthroat trout, tier II and Northern leatherside chub, tier II) are expected in the stream under pristine conditions. Upon coordination with the regional fish biologist, it is determined that only the Bonneville cutthroat trout has the natural potential to occupy that catchment. The user then determines if Bonneville cutthroat trout are present by sampling using standard methods over at least two sampling events. No Bonneville cutthroat trout are detected. The field value in the WSQT would be 2 since there was one Tier 2 SGCN species expected that was absent.

Estimating proposed condition field values: The proposed condition field value should estimate/predict the number of SGCN anticipated to be present following the proposed project. Consultation with an area aquatic biologist to determine the expected species assemblage will inform the anthropogenic causes of impairment and whether the proposed actions could improve the observed assemblage.

Documentation and Field Forms: On the Field Value Documentation form (Appendix B), record the sampling dates and the expected and observed number of SGCN species in tier 1, 2, and 3; include the list of SGCN species and the names of any aquatic biologists consulted in developing the list in the notes column. The field value will automatically calculate from the information provided.

3. Game Species Biomass (% Increase)

Definition: This metric measures the increase in biomass of native or non-native game fish species following a restoration project relative to the change observed at a control site. Game fish are species determined to be a management priority following consultation with the WGFD. This metric is not applicable to characterize functional loss, impact projects or in stocked streams.

Note: Consultation with the area fish biologist is important to determine whether certain species or age classes should be excluded from biomass estimates because of stocking efforts within the watershed or poor capture probability due to small fish sizes (for young age classes).

Method:

1. Identify a control reach. This metric requires collection of fish data from a nearby control reach to account for variability. The control reach should have a similar elevation and geomorphic setting as the project reach and should be of reference quality (to the extent practicable). A control reach can be located upstream or downstream from the project reach, or in a separate catchment within the same river basin as the project reach. A control reach should be geographically proximate to the project reach but outside the influence of the project actions and not immediately adjacent to the project reach.
2. Prior to the start of the project, conduct at least two sampling events (Bonar et al. 2009) at both the project reach and a control reach to establish baseline pre-project biomass estimates and determine the productivity class input into the Site Information and Reference Selection section. Paired sampling at the project and control sites should occur, and both sites should be sampled within a 7-day window.

An approved sampling methodology should be used, such as multi-pass depletion or mark-recapture techniques. Whichever sampling methods are used to assess fish populations at the start of the project must be continued throughout all subsequent monitoring events. Fish should be weighed; however, length/weight curves can also be used when available.

3. Enter a field value of 0.0 for the existing condition assessment.
4. For post construction sampling, conduct at least two sampling events in consecutive years at both the project reach and the control reach post-construction. Sampling events should occur at a similar time of year and should avoid spawning seasons.
5. For each post-construction sampling event, calculate the percent change in biomass for the project site and the percent change in biomass at the control site.
6. For each post-construction sampling event, subtract the percent change in biomass at the control site from the percent change in biomass at the project site to determine the percent change in biomass for that event. Subtracting the change in biomass at the control site helps account for inter and intra-annual variability inherent in fish populations and reduces the influence of climactic or other external factors in determining increases in biomass associated with a restoration project.
7. Average two consecutive sampling events together to calculate the field value for entry in the WSQT. Since this metric recommends two years of data to calculate field values, the average value should be entered into the SQT for both monitoring events. If an As-Built condition assessment is performed, then the average of the year 1 and year 2 monitoring should be used for the As-Built condition assessment as well (as shown in Example 17).

Estimating proposed condition field values: The proposed condition field value should estimate/predict the change in biomass likely to occur following the project. Users should consider the current productivity class, recognizing that streams with an already productive fishery may be less likely to see large additional increases in productivity following a restoration project.

Documentation and Field Forms: On the Field Value Documentation form in Appendix B, record the data from the baseline assessment (dates of project and control site sampling events, average biomass from two pre-project control sampling events and average biomass from two pre-project project site sampling events). For post-project sampling, also record the biomass data and dates of all sampling events on the Field Value Documentation. Provide the location of the control site and sampling methodology in the notes column.

Example 17: Calculation of Game Species Biomass

This example is for a yellow ribbon trout stream where data are collected in different years.

Baseline Data for Game Species Biomass in a Yellow Ribbon Trout Stream:

Monitoring Event	Sampling Event Yield (lbs/mile)	
	Project Site	Control Site
Baseline Year 1	65	90
Baseline Year 2	85	110
Pre-Project Average	75	100

Monitoring data for game species biomass in a Yellow Ribbon trout stream:

Monitoring Event	Sampling Event Yield (lbs/mile)		Percent Increase		Difference
	Project Site	Control Site	Project Site	Control Site	
Baseline	75	100			
Post Construction Year 1	100	115	$\frac{100 - 75}{75} = 33\%$	15%	18%
Post Construction Year 2	90	105	20%	5%	15%
Average					16.5%

Field Values for Game Species Biomass in a Yellow Ribbon Trout Stream:

Condition Assessment	Biomass Field Value
Existing	0
Proposed	30
As-Built	16.5
Monitoring Year 1	16.5
Monitoring Year 2	16.5

4.9. Flow Alteration Module (FAM)

Definition: Flow alteration in the WSQT refers to changes in operational commitments, acquisition/change of existing water rights, or new facilities that enable the proposed hydrology to occur.

The module and metrics are provisional and subject to testing and revision. For restoration projects, users should ensure that:

- Water is available in the reach to restore one or more aspects of the flow regime,
- Flow protections can be applied within a specified length of stream, and
- The restoration of flow in the reach will not have adverse effects elsewhere.

Experience Required: Field values for metrics within the flow alteration module (FAM) should be calculated by engineers or hydrologists with experience with Wyoming hydrologic studies.

Instream flow biological and hydrological feasibility reports are available online from the Wyoming Water Development Office³² and Wyoming Water Resources Data System (WRDS).³³ Example analysis is provided in Instream Flow Study Muddy Creek Basin Carbon County, Wyoming (Biota and Harmony 2014).

4.9.a. Affected Stream Length

Where flow alteration will occur, the reach affected by the flow altering activities may be shorter or longer than the reaches assessed using the WSQT condition assessments. The affected stream length in the FAM is defined at the upstream end where impacts or flow protection would initiate, and at the downstream end by the location of the next point of diversion, water rights user, significant tributary junction, or terminus beyond which the flow modification has no material effect on SQT parameters. When used for CWA §404 compensatory mitigation projects and impact sites, the FAM is applicable where impacts from flow alteration or improvements associated with flow protection can be evaluated within the affected stream length.

For affected reaches within the project area where the stream length is changed by project activities, the affected length should align with values that would naturally occur given the valley morphology and absent from anthropogenic influences. For instance, where a stream in an alluvial valley is being channelized, the existing stream length should be used. For a channelized stream in an alluvial valley that is being re-meandered, the proposed stream length should be used.

4.9.b. Metric Selection

The FAM includes six metrics (Table 13). Metric selection will vary based on ecological relevance and data availability.

Table 13. Flow Alteration Module Metrics.

Metric	Description	Aspect of Hydrologic Alteration Characterized	Data Requirements
Mean Annual Q (O/E)	The average of mean monthly flows (cfs) for each water year in the period of record.	Changes in annual flow volume	Daily or Monthly Average Flow Data
Mean Aug Q (O/E)	The average flow rate (cfs) for the calendar month of August in each water year in the period of record.	Summer/Fall baseflow alteration	Daily or Monthly Average Flow Data
Mean Sept Q (O/E)	The average flow rate (cfs) for the calendar month of September in each water year in the period of record.	Summer/Fall baseflow alteration	Daily or Monthly Average Flow Data
Mean Jan Q (O/E)	The average flow rate (cfs) for the calendar month of January in each water year in the period of record.	Winter baseflow alteration	Daily or Monthly Average Flow Data

³² https://wwdc.state.wy.us/instream_flows/instream_flows.html

³³ http://library.wrds.uwyo.edu/instream_flow/instream_flow.html

Metric	Description	Aspect of Hydrologic Alteration Characterized	Data Requirements
Mean Annual Peak Daily Q (O/E)	The average of the peak daily discharge (cfs) for each water year in the period of record.	High flow pulses	Daily Flow Data
7-Day Minimum (O/E)	The minimum of the 7-day moving average mean for each water year in the period of record.	Extreme low flows	Daily Flow Data

Flow Regime: The FAM metrics characterize different aspects of hydrologic alteration and may vary depending on the flow regime in the affected stream length (Table 14). Where these six metrics may not be representative of a critical aspect of the flow regime within a specific reach or watershed, **substitution of flow metrics may be considered** where enough information is available to demonstrate a metric's importance to the local native flow regime. **Note:** any alternate metric should be based on flow or water level field values, otherwise the reference curves are not applicable.

Table 14. FAM Metric Selection Based on Flow Regime.

Flow Regime	Annual Flow Volume	Summer Baseflow**	Winter Baseflow	Extreme Low Flows	High Flow Pulses
Intermittent	Mean Annual Q (O/E)	Select a month (or months) critical to spawning instead of a baseflow*		# Zero flow days*	Mean Annual Peak Daily Q (O/E)
Perennial		Mean Aug Q (O/E) AND/OR Mean Sept Q (O/E)	Mean Jan Q (O/E)	7-Day Minimum (O/E)	
* Metric not included in the FAM but may qualify as an acceptable substitution.					
** August and September should not be used where climatic variations preclude these months from representing baseflow. Alternative months or a single month should be selected.					

Data Availability: Flow records for hydrologic analyses must be sufficiently long (e.g., 20 years of data) to account for inter-annual variability (TNC 2009). Daily flow data should be used for all metrics if it is available. Where daily flow data are unavailable, the annual peak daily flow and 7-day minimum metrics cannot be calculated. The minimum time step requirement is monthly flow data.

Flow records for hydrologic analyses can be obtained from sources such as USGS gages or state-operated streamflow gages. Each of these data sources are discussed below. All datasets should be checked for data gaps prior to analysis to determine if sufficient data are available to calculate each flow metric. All extrapolated data should be reviewed as well.

Gages: Hydrologic analyses in Wyoming requires a reference gage be identified for the project reach. The reference gage should have similar runoff characteristics to the project site and an

assessment of reference gages should consider geology, elevation, and precipitation (Lowham 2009). Empirical relationships from a reference gage station can be developed to produce flow records for the affected stream reach (TNC 2009; Archfield and Vogel 2010; Gianfagna et al. 2015). Any flow datasets should be evaluated to identify data gaps, data quality outliers, or other anomalies, and then compared to historic documentation to establish whether the native flow condition can be determined.

The most common source of continuous stream flow data is the USGS gage network.³⁴ There are also State operated stream gage networks through the State Engineers Office.³⁵ The Bureau of Reclamation also operates gages in Wyoming. Note that some stream gages generally exclude non-irrigation season data (Nov - March), and thus the January mean Q may not be an available metric for sites without these data unless flow can be modeled for the missing values. Similarly, the dataset for the mean annual Q value may need to be truncated to the same period for each year.

Other Hydrologic Models: There are various hydrologic models developed as part of river basin plans, available through the Water Development web site under the Wyoming State Water Plan. For example, the Bear River Basin Update 2011 plan has a “2010 Model” for download.³⁶

Hydrologic regression equations from Lowham et al. (2002), Miselis et al. (1999), and Lowham (1988) can be used as a source of native flow estimates. Existing hydrologic analyses performed in Wyoming that may be useful can be found in Instream Flow Study Muddy Creek Basin Carbon County, Wyoming (Biota and Harmony 2014).

Where streamflow data are not available or sufficient in length, the user can create a hydrologic model of the reach catchment to generate stream flows. Note that watershed hydrologic models can be very inaccurate due to their need to parameterize entire watersheds. Records such as daily diversion records and reservoir volumes may be required for modeling existing, pre-project conditions. Precipitation datasets used in hydrologic modeling, similar to flow datasets mentioned above, should be evaluated to identify data gaps, data quality outliers, or other anomalies. The USACE Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS; USACE 2020b) can also be used to generate flow records.

Although developed for Colorado, StateMod can be applied to streams in Wyoming as well. StateMod is a surface water allocation and accounting model that can be used to simulate various water management approaches in Colorado (StateMod 2016), including simulation of flows after accounting for flow alteration within the river system. The user would need to apply the Base Flow module and the simulation module to generate data characterizing the native flow, i.e., expected values. StateMod generally estimates average monthly flows, but an advanced StateMod user can generate daily time step data. Users should consult the StateMod User Manual for instructions and limitations (StateMod 2016).

Note, the **WSQT does not require the use of a specific software for performing these analyses.**

³⁴ <https://nwis.waterdata.usgs.gov/nwis/sw>

³⁵ <https://seoflow.wyo.gov/>

³⁶ <https://waterplan.state.wy.us/plan/bear/bear-plan.html>

4.9.c. Methods

All metrics in this module are calculated from hydrologic analyses of flow records. While several approaches are available to perform the necessary analyses, these procedures are beyond the scope of this manual.

For each metric, the value of interest (e.g., mean annual Q) is calculated for each water year in the flow record. Then **the median value for the flow record is calculated** (non-parametric analysis). For most analyses, the distribution of the value of interest within the flow record will be non-normal and the median value should be used (TNC 2009). Justification will need to be provided to use the mean value (parametric analysis).

The field value input to the WSQT is the ratio of the observed value to the expected value (O/E). For each metric, field values are calculated as the deviation from a reference condition (Table 1 in Section 1.3). Therefore, the user needs to calculate the value of interest for three scenarios:

1. Native Flow – For the purposes of the WSQT, native flows are estimates of the stream flows that would result from natural hydrologic processes such as rainfall-runoff and snowmelt-runoff without anthropogenic influence at a given location. This is the expected (E) condition in the O/E calculations.
2. Pre-project condition – The amount of flow seen by the system prior to project implementation. This is the observed (O) condition in the O/E calculations for the existing condition assessment.
3. Post-project condition – The amount of flow seen by the system because of project implementation. The post-project condition reflects changes to the operating rules or modeling parameters that reflect the implementation of the project. Ideally, this value is determined through modeling that uses the same period of record as the pre-project condition. This is the observed (O) condition in the O/E calculations for the proposed condition assessment and post-project monitoring assessments.

The pre-project condition is compared to the native flow to calculate the **existing** condition O/E field value for all six metrics and quantifies the flow alteration within the system **before** the project (impact or restoration) is implemented.

The post-project condition is compared to the native flow to calculate the proposed condition O/E field values and quantifies the flow alteration within the system **after** the project is implemented.

The Indicators of Hydrologic Alteration (IHA; Richter et al. 1996) is a commonly applied approach for evaluating flow alteration in rivers (Richter et al. 1996; Mathews and Richter 2007; Poff et al. 2010). IHA is a standalone software application that can be used to evaluate hydrologic alteration and develop environmental flow targets using daily stream gage records or modeled daily flows. Users should refer to the IHA Version 7.1 User's Manual for more detail (TNC 2009). IHA requires daily streamflow data, with the software performing linear interpolation over any gaps in the datasets loaded into the software (TNC 2009). Example 18 shows how IHA can be used to generate field values for the WSQT.

Note, the **WSQT does not require the use of IHA**. Other software or tools can be used to calculate streamflow statistics and generate field values, for example, there is also an R

package called EFlowstats.³⁷ Where USGS stream gages are at or near the project site, some of the metrics may be calculated directly on the USGS NWIS webpage.³⁸

Data Collection: Field data collection needs will vary depending on the data source for flow records. Individual flow measurements may be sufficient to validate empirical relationships that convert flow values from a nearby gage to the affected stream length. Ultimately, the data requirements and study design should be developed based on project specific needs.

Field data collection may include surveying cross-section(s), measuring discharge in the field using a current meter, installing stream gages, calculating the average channel slope, and sampling the bed material. Placement and use of stream gages should follow *Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams* (USEPA 2014). Surveying and bed material sampling methods are detailed in WDEQ (2022).

Proposed Condition: The existing condition field values are derived from data collection and analysis methods outlined above. The proposed condition field values are generated through altering the pre-project condition flow record to reflect the proposed hydrology according to operational commitments, acquisition/ change of existing water rights, or new facilities that enable the proposed hydrology to occur.

Monitoring: In the WSQT workbook, the FAM contains ten condition assessments for monitoring to verify that the proposed hydrology has been achieved. Two methods can be used to monitor flow. The preferred option is to establish a site-specific rating curve and deploy a pressure transducer to record stage data from the affected reach. The second option is to follow the concurrent-discharge methodology as outlined by Lowham (2009) and collect individual flow measurement(s). At project closeout, the average observed values from the monitoring period measured at the project site could be used to calculate the final field values. However, flow is highly dependent on annual variations in weather (precipitation, temperature, etc.). Flow can also be impacted by catchment stressors and activities such as clear cutting in the watershed and annual variations in the utilization of upstream water rights. Care should be taken to determine whether measured changes are a result of the project activity.

³⁷ <http://adsabs.harvard.edu/abs/2013AGUFM.H43E1508T>

³⁸ <https://maps.waterdata.usgs.gov/mapper/index.html>

Example 18: Flow Alteration in the Fraser River, CO

Average daily flows for the Fraser River near the Winter Park stream gage in Colorado were used to develop this example. Flow alteration began in 1936 when the Moffat Tunnel began diverting water from the Fraser basin to the Colorado Front Range. Historical data from 1911-1935 were used to represent native hydrology. Native flows were compared to current hydrology using data from 1988-2017. The comparison of native vs. current flows was used to create an existing condition score for the flow alteration reach, which extends 10.5 miles (55,213 ft) from the Fraser River near Winter Park stream gage to the confluence of the Fraser and Colorado rivers.

Sample IHA output are shown on the following page with the values used to calculate field values for the FAM highlighted in yellow. Example field value calculations are provided below for the mean January Q and mean annual Q metrics. The flow record was evaluated, and a parametric analysis was found to be more appropriate; therefore, means are reported below. Typically, a non-parametric analysis is preferred.

The existing condition field value for the mean January Q metric = $O/E = 5.496 \text{ cfs} / 7.772 \text{ cfs} = 0.71$

The existing condition field value for the mean annual Q metric = $O/E = 20.04 \text{ cfs} / 44.28 \text{ cfs} = 0.45$

The existing condition assessment in the FAM is shown below. The existing condition score of 0.61 indicates that the affected reach is functioning-at-risk with respect to flow alteration.

Metric	Field Value	Index Value	Module
Mean Annual Q (O/E)	0.45	0.50	0.61
Mean Aug Q (O/E)	0.39	0.43	
Mean Sept Q (O/E)	0.46	0.51	
Mean Jan Q (O/E)	0.71	0.79	
Mean Annual Peak Daily Q (O/E)	0.55	0.62	
7-Day Minimum (O/E)	0.74	0.83	

A hypothetical flow augmentation scenario that added 10 cfs to each daily value from August to November comprised the proposed condition. The mean annual Q, mean annual peak daily Q, 7-day minimum, and mean Jan Q were unchanged; however, the mean Aug Q and mean Sept Q were affected upwards by this scenario, with associated increases in index value.

Metric	Field Value	Index Value	Module
Mean Annual Q (O/E)	0.45	0.50	0.73
Mean Aug Q (O/E)	0.64	0.71	
Mean Sept Q (O/E)	0.85	0.95	
Mean Jan Q (O/E)	0.71	0.79	
Mean Annual Peak Daily Q (O/E)	0.56	0.62	
7-Day Minimum (O/E)	0.74	0.83	

The Functional Feet value is calculated by multiplying the affected stream length (55,213 LF) by the change in condition scores ($0.73 - 0.61 = 0.12$) and applying a 20% weight factor, for a gain of 1,325 FF.

Example 18 Continued: Sample IHA Output from the Fraser River

IHA Parametric Scorecard		
Fraser River at Winter Park Two-Period Parametric Analysis		
	Pre-impact period: 1911-1935 (25 years)	Post-impact period: 1988-2017 (30 years)
NormalizationFactor	1	1
Mean annual flow	44.28	20.04
Non-Normalized Mean Flow	44.28	20.04
Annual C. V.	1.52	1.97
Flow predictability	0.68	0.6
Constancy/predictability	0.44	0.63
% of floods in 60d period	0.88	0.89
Flood-free season	272	242

	MEANS	
	Pre	Post
Parameter Group #1		
October	18.170	8.647
November	13.920	6.344
December	9.708	5.730
January	7.772	5.496
February	6.967	5.449
March	7.422	6.108
April	16.480	9.682
May	90.670	29.210
June	204.500	96.520
July	89.490	39.950
August	40.250	15.810
September	25.360	11.650
Parameter Group #2		
1-day minimum	5.388	4.086
3-day minimum	5.601	4.187
7-day minimum	5.787	4.302
30-day minimum	6.229	4.722
90-day minimum	7.030	5.224
1-day maximum	316.600	175.500
3-day maximum	299.200	167.500
7-day maximum	280.800	152.400
30-day maximum	217.900	108.200
90-day maximum	131.900	56.760
Number of zero days	0.000	0.000
Base flow index	0.137	0.262

Chapter 5. Applications

5.1. Passive Versus Active Restoration Approach Examples

The WSQT evaluates the functional lift of restoration activities through changes in site condition of function-based parameters and not by scale of restoration activities, e.g., the amount of heavy equipment used in a project, or the number of in-stream structures installed. Therefore, the tool can evaluate lift across a range of restoration approaches that require varying amounts of effort. While an active approach that includes significant earthwork may be needed in some streams, this is not always the case.

In Wyoming, the most common type of mitigation is small permittee-responsible projects. The WSQT can show functional lift in less intensive projects if fundamental parameters (e.g., flow dynamics, floodplain connectivity, bed form diversity, lateral migration and/or riparian vegetation) are already in a functioning condition or have the potential to trend in that direction without significant manipulation.

This section includes examples of three restoration approaches and the potential lift that can be captured using the WSQT. The three example approaches include passive, moderate, and active, which relate to the amount of landscape modification needed to achieve functioning physical conditions for a project reach. Active restoration approaches typically include significant earthwork and more passive approaches typically avoid heavy machinery and may include management actions (e.g., cattle exclusion). All examples evaluate the following parameters:

- Reach Runoff
- Bankfull Dynamics
- Floodplain Connectivity
- Large Woody Debris
- Lateral Migration
- Bed Form Diversity
- Riparian Vegetation
- Nutrients
- Macroinvertebrates
- Fish

To illustrate the benefit of monitoring physicochemical and biological condition, ΔFF is reported at the end of this section for two monitoring scenarios, where 1) Hydrology, Hydraulics and Geomorphology are monitored, and 2) all functional categories are monitored. Thus, it was assumed that all projects could show modest improvements in nutrients, macroinvertebrates, and fish parameters.³⁹

5.1.a. Passive Restoration Approach

In this hypothetical example, 1000 linear feet of stream is flowing through open rangeland. An existing condition assessment showed that the stream has not been channelized in the past and meanders within an alluvial valley. Cattle have access to the stream; however, due to the meandering nature of the stream, bed form diversity was functioning (pools were located in the outside of the meander bends and were deep). Most of the riparian vegetation has been removed by grazing, which led to moderate erosion of several outside meander bends but not significant incision. Erosion is also evident where cattle have concentrated at convenient stream

³⁹ Without evaluating the physicochemical and biological parameters, the maximum overall score in the WSQT will be 0.60. Selecting and assessing parameters in both functional categories will increase the maximum overall score to 1.00 and will increase the amount of functional feet generated.

crossings. Channel widening is likely to continue so long as cattle have access to the stream. Bank heights are low, and energy continues to be dissipated by spreading flood waters across the floodplain.

The mitigation approach is to remove intensive grazing pressure by fencing out the cattle and replanting the riparian area. This passive approach is feasible because floodplain connectivity, bankfull dynamics and bedform diversity are already within a functioning range of condition (note, it often takes significant channel modification to fix these parameters). With these functions in place, a newly planted riparian corridor will improve lateral migration and support higher level functions in the physicochemical and biology functional categories (Figure 42). For this type of restoration approach, it is likely that removing the cattle would benefit water quality within the monitoring period, and if the reach is connected to suitable habitat, the macroinvertebrates and fish parameters as well.

Function-Based Parameter	Existing Parameter	Proposed Parameter	Change in Condition
Reach Runoff	0.80	0.87	0.07
Baseflow Dynamics			
Bankfull Dynamics	0.75	0.75	0.00
Floodplain Connectivity	0.73	0.73	0.00
Large Woody Debris	0.00	0.00	0.00
Lateral Migration	0.60	1.00	0.40
Bed Material Characterization			
Bed Form Diversity	0.81	0.81	0.00
Riparian Vegetation	0.20	0.66	0.46
Temperature			
Nutrients	0.15	0.20	0.05
Macroinvertebrates	0.21	0.36	0.15
Fish	0.80	0.83	0.03

Figure 42. Passive Restoration Approach WSQT Example.

5.1.b. Moderate Approach

In this hypothetical example, the stream reach is in a similar setting as the passive example with one major exception - the stream reach has been channelized and stream length is 800 linear feet. Due to the presence of bedrock, however, the stream has not incised. Channelization that included the removal of large wood has prevented pool-forming processes within the stream reach. Riparian vegetation has been substantially grazed, which also negatively affects lateral migration; however, floodplain connectivity, bankfull dynamics and reach runoff are in the functioning range of condition.

In this scenario, the mitigation approach involves fencing out the cattle, riparian planting, and adding large woody debris and a few in-stream structures to create step-pools in the straightened channel. The addition of large wood will improve the large woody debris score and the new step-pool structures will improve pool depth and percent riffle scores (Figure 43). With these functions in place, a newly planted riparian corridor will improve lateral migration and

support higher level functions in the physicochemical and biology functional categories. For this type of restoration approach, it is likely that removing the cattle would benefit water quality within the monitoring period, and if the reach is connected to suitable habitat, the macroinvertebrates and fish parameters as well.

Function-Based Parameter	Existing Parameter	Proposed Parameter	Change in Condition
Reach Runoff	0.80	0.87	0.07
Baseflow Dynamics			
Bankfull Dynamics	0.75	0.75	0.00
Floodplain Connectivity	0.73	0.73	0.00
Large Woody Debris	0.00	0.57	0.57
Lateral Migration	0.52	1.00	0.48
Bed Material Characterization			
Bed Form Diversity	0.39	0.67	0.28
Riparian Vegetation	0.20	0.66	0.46
Temperature			
Nutrients	0.15	0.20	0.05
Macroinvertebrates	0.21	0.36	0.15
Fish	0.80	0.83	0.03

Figure 43. Moderate Restoration Approach WSQT Example.

5.1.c. Active Approach

In this hypothetical example, the stream reach is in a similar setting as the last two examples, except now the stream has been channelized and is incised, resulting in floodplain connectivity and lateral migration scoring within the not functioning range of condition because bank heights are high due to the floodplain disconnection and channel incision, which is exacerbated by the lack of riparian vegetation.

Since the channel is disconnected from its floodplain, a passive restoration approach is not likely to see improvements in channel condition during monitoring as flood flows will continue to erode the channel. Significant modification is needed to establish a new channel geometry and reconnect the stream to a floodplain, either by raising the bed or lowering the floodplain. The new channel pattern is used to create meander pools instead of step-pool structures used in the moderate example. Improvements in parameter scores are shown in Figure 44.

Function-Based Parameter	Existing Parameter	Proposed Parameter	Change in Condition
Reach Runoff	0.80	0.87	0.07
Baseflow Dynamics			
Bankfull Dynamics	0.69	1.00	0.31
Floodplain Connectivity	0.00	0.87	0.87
Large Woody Debris	0.00	0.49	0.49
Lateral Migration	0.24	1.00	0.76
Bed Material Characterization			
Bed Form Diversity	0.39	0.81	0.42
Riparian Vegetation	0.20	0.66	0.46
Temperature			
Nutrients	0.15	0.20	0.05
Macroinvertebrates	0.21	0.36	0.15
Fish	0.80	0.83	0.03

Figure 44. Active Restoration Approach WSQT Example.

The functional lift for each of the three scenarios outlined above is summarized in Table 15. For the passive and active restoration approaches, the proposed stream length is 1,000 linear feet but for the moderate approach, the channelized stream length remains at 800 linear feet. Even though the proposed condition scores are similar across all three scenarios, the most functional lift was achieved by the active approach because the existing channel in this scenario was in the worst condition. Additionally, greater lift was achieved when all functional categories were monitored instead of only reach hydrology & hydraulics and geomorphology, demonstrating the value in monitoring physicochemical and biology even if they do not achieve reference condition.

Table 15. Summary of Restoration Approach Scenarios.

Approach	Change in Functional Feet (FF) Monitoring RH&H and Geomorphology	Change in Functional Feet (FF) Monitoring RH&H, Geomorphology, Physicochemical and Biology
Passive	72	100
Moderate	113	135
Active	325	379

5.2. Savery Creek Project Example

The Savery Creek restoration project is located just downstream of High Savery Dam within the Green River Basin. The project was undertaken to address eroding banks and improve floodplain connectivity, riparian vegetation, and aquatic habitat for trout. The project was a Trout Unlimited-led collaboration with Little Snake River Conservation District, Bureau of Land Management, Wyoming Water Development Office, and WGFD with major funding from Wyoming Wildlife and Natural Resource Trust.

The project area encompasses a four-mile reach starting from the dam and extending downstream. There are 14 existing vertical sheet pile weirs within the reach, and these weirs were used to delineate the project area into individual reaches for SQT assessment. Existing condition of reaches 8 – 11 were assessed using WSQT v1.0 in 2019 (Figure 45). Construction occurred in fall 2019 and 2020, and these reaches were assessed again in 2020/2022 for post-project monitoring using WSQT v1.0. These data were entered into the WSQT v2.0 for purposes of this example. Some metrics, including width depth ratio state and riparian extent required re-analysis of data to calculate field values for v2.0.



Figure 45. Savery Creek Restoration WSQT Example Reach Breaks (Imagery from Google Earth).

Restoration efforts were focused mostly within the existing channel and included the following treatments: J-hook vanes, cross vanes, toe wood, bankfull benches, log vanes, bank toe logs, log sills, rock sills and channel narrowing.

The following materials are provided in Appendix E as part of this example:

- WSQT v2.0 workbook for Reaches 8-11
- Select Appendix B forms for Reach 11 post-project monitoring, including:
 - Parameter Selection Checklist
 - Project Reach form
 - Rapid Survey form
 - Riparian Vegetation forms: Left bank plots, Right bank plots, Summary, and Field Value Documentation for the vegetation cover metrics.

Note that some required Appendix B forms are not provided in this example, including Riparian Extent, Bankfull Verification, and most Field Value Documentation forms. Because this example was built using data collected for WSQT v1.0, some of these field forms were not available at the time of data collection.

Prior to data collection, the overall project area was delineated into project reaches for data collection and analysis. Information on project reach delineation and an aerial photograph is provided on the Project Summary worksheet (Appendix E). Note that aerial photos should also identify the location of representative sub-reach assessments. These are not identified in this example but are recommended for v2.0.

Existing stream type was determined using the stream classification section of the Project Reach form (Appendix E). All reaches were identified as C streams. Because Savery Creek is in an unconfined alluvial valley with slope <1%, reference stream type was also identified as C. As no changes were proposed for stream type, the proposed and design stream types are also C.

Parameter and metric selection included the basic suite of required parameters and metrics (within reach runoff, floodplain connectivity, bankfull flow dynamics, lateral migration, bedform diversity and riparian vegetation parameters). Large woody debris was also evaluated using the LWD piece count metric. These selections can be viewed on the Parameter and Metric Selection Checklist (Appendix E).

Bankfull should be determined and verified using the methods outlined in Section 4.4. In v2.0, users are required to complete the Bankfull Verification form in Appendix B. This form is not included in this example, as data were collected using WSQT v1.0 methods and forms.

The functional lift for each of the evaluated reaches is summarized in Table 16. The restoration project resulted in an increase in functional feet throughout the project, although this was less in reaches without large wood, or where pool spacing or riffle improvements were not achieved. Additional lift is anticipated in future years as riparian vegetation continues to recover following construction activities. Woody debris values were lower in post-project monitoring than proposed due to the use of shorter toe wood logs, and the fact that most toe wood was buried and thus didn't yield countable pieces. Rootwads also did not yield countable pieces. Use of the LWDI may have been more appropriate to estimate LWD within structures. In Reach 10, the project design did not include enough riffle to achieve functioning index values, and in all reaches less riffles were constructed than proposed in the design (riffles were in the location as designed, but shorter than proposed) which resulted in lower monitored values than proposed. Additional lift could have been achieved by restoring meanders or re-activating oxbows to improve bedform diversity, adding additional wood, constructing less structures in riffles and ensuring constructed riffle lengths were consistent with the design (Paul Dey, personal communication).

Table 16. Summary of Proposed and Monitored Changes in Functional Feet.

Reach	Proposed		Monitored (Year 1)	
	Change in Functional Feet (Δ FF)	Percent Change (%)	Change in Functional Feet (Δ FF)	Percent Change (%)
QT_8	143.0	25	104.0	18
QT_9	265.4	27	44.3	5
QT_10	43.6	9	21.8	5
QT_11	131.3	33	60.6	15
TOTAL	583.3		230.7	

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Appendix A – Field Data Collection Methods for the WSQT

A1. Introduction and Purpose	2
A2. Field Preparation Information.....	2
Rapid Versus Detailed Assessment Methods	3
Data Forms	4
Equipment List	5
Metric Sampling Periods & Restrictions	5
A3. Reach and Representative Sub-Reach Assessments	6
Riffle Surveys	9
A4. Rapid Geomorphic Survey for Floodplain Connectivity, Bankfull Flow Dynamics and Bed Form Diversity	10
Rapid Survey Method.....	10
Rapid Method for Surveying the Stable Riffle Cross-section	12
A5. Riparian Extent and Riparian Vegetation Plots.....	13
Riparian Extent Field Verification Method	13
Riparian Vegetation Plot Layout.....	13
Riparian Vegetation Plot Data Collection Method	16
Rapid Alternatives for Riparian Plot Data Collection.....	18
A6. Identifying Low Bank Height in Incised Streams	19
A7. Bed Feature Identification.....	20
Identifying Geomorphic Pools in Alluvial Valleys	21
Identifying Geomorphic Pools in Colluvial and V-Shaped Valleys:	22
A8. References.....	23

A1. Introduction and Purpose

The purpose of this document is to assist the user in preparing for and collecting data to inform metrics within the Wyoming Stream Quantification Tool (WSQT) workbook and Stream Impact Tool (WSIT) workbook. This appendix lays out a recommended set of steps for data collection that integrates methods unique to the WSQT along with methods and measurements that are commonly applied and/or detailed in other instruction manuals or literature.

Teams collecting and analyzing these data should have experience and expertise in botany, aquatic ecology, hydrology, and geomorphology as well as experience and expertise applying the assessment methods used to calculate the metrics included in the SQT. **Interdisciplinary teams of at least two people with a combination of these skill sets are necessary to ensure consistent and accurate data collection and analyses.**

This appendix is a compliment to Chapter 2 of the User Manual (UM), which provides experience requirements for each parameter; and information on how to select parameters, calculate metric field values from field/desktop data, and input these values into the WSQT and WSIT workbooks.

A2. Field Preparation Information

Parameter selection will dictate the methods and number of visits necessary to accomplish data collection for all metrics. Prior to going into the field, the user should determine which parameters and metrics to assess and complete the Parameter Selection Checklist (see UM Section 2.5 and Appendix B). Rapid survey options for field data collection are available for some hydraulic and geomorphic parameters. Some methods are not provided in this appendix (Table A.1), and **users should be familiar with the methods and review the following references prior to field sampling.**

Table A.1: Field Methods Not Included in This Document.

Metric or Method	References
Bankfull Identification	<ul style="list-style-type: none">Bankfull Elevation – Field Identification section of the <i>Manual of Standard Operating Procedures for Sample Collection and Analysis</i> (WDEQ 2022).
Pebble Count	<ul style="list-style-type: none">For stream type classification, see <i>River Stability Field Guide, Second Edition</i> (Rosgen 2014)Pebble Counts - Reachwide and Cross-section section of the <i>Manual of Standard Operating Procedures for Sample Collection and Analysis</i> (WDEQ 2022)
Large Woody Debris Index (LWDI)	<ul style="list-style-type: none">Pages 73 – 77 of <i>Monitoring Wilderness Stream Ecosystems</i> (Davis et al. 2001)<i>Application of the Large Woody Debris Index: A Field User Manual Version 1</i> (Harman et al. 2017)

Metric or Method	References
Bank Erosion Hazard Index/Near Bank Stress (BEHI/NBS)	<ul style="list-style-type: none"> Appendix D of <i>Function-Based Rapid Field Stream Assessment Methodology</i> (Starr et al. 2015), or <i>River Stability Field Guide, Second Edition</i> (Rosgen 2014)
Greenline Stability Rating	<ul style="list-style-type: none"> <i>Monitoring the Vegetation Resources in Riparian Areas</i> (Winward 2000), or Riparian Area Management: Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation (USDOI 2011).
Detailed Longitudinal and Cross-sectional Surveys	<ul style="list-style-type: none"> <i>Stream Channel Reference Sites: An Illustrated Guide to Field Technique</i> (Harrelson et al. 1994), or Survey Method sections of <i>Manual of Standard Operating Procedures for Sample Collection and Analysis</i> (WDEQ 2022), or <i>River Stability Field Guide, Second Edition</i> (Rosgen 2014)
Temperature	<ul style="list-style-type: none"> <i>Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams</i> (EPA 2014)
Chlorophyll- α	<ul style="list-style-type: none"> 'Epilithic method' within the Periphyton: Sampling Methods/Subsample Processing for Chlorophyll Analysis and Taxonomic ID Section outlined in the <i>Manual of Standard Operating Procedures for Sample Collection and Analysis</i> (WDEQ 2022).
Macroinvertebrates	<ul style="list-style-type: none"> Macroinvertebrate Sampling – Targeted Riffle Method section in the <i>Manual of Standard Operating Procedures for Sample Collection and Analysis</i> (WDEQ 2022).
Fish	<ul style="list-style-type: none"> Bonar et al. (2009)
Flow Alteration Module	<ul style="list-style-type: none"> <i>Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams</i> (EPA 2014).

Rapid Versus Detailed Assessment Methods

Before going to the field, the assessment team should determine if a rapid or detailed geomorphic survey will be completed. This decision will affect the equipment and data processing tools needed to complete the assessment. A rapid survey method may be used for the existing condition assessment applied to the WSIT, early stages of a stream restoration/mitigation project (e.g., site selection and prospectus phases), and monitoring for some restoration (not mitigation) projects. More detailed survey methods are used for approved

mitigation projects and restoration projects where the user wants to have profile and cross section plots that provide more information.

The **rapid geomorphic survey method** means that a survey tape will be stretched along the channel. Survey rods, hand levels, line levels, a range finder, and tape measures are used to take the measurements. Survey equipment like a laser level or Total Station is not needed. A step-by-step approach to performing a rapid survey is provided in Section A4.

Detailed survey methods use standard surveying methods and rely on equipment like a laser level, total station, or real-time kinetic (RTK) technologies. The equipment is used to survey a longitudinal profile of the thalweg, water surface, inner berm (if present), bankfull, and top-of-low-bank features. Cross section surveys are collected for the riffles (and pools if desired). Survey data are processed in the office to calculate field values. Detailed survey methods are not outlined in this Appendix, as standard survey techniques can vary (e.g., Harrelson et al. 1994; Rosgen 2014).

Large Woody Debris: There are rapid and more detailed methods for assessing large wood, depending on the metric selected. The same field equipment is used for the piece count and LWDI; however, it often takes more time to assess the LWDI (detailed) versus counting pieces (rapid).

Riparian Vegetation: Rapid alternatives for collecting plot data are outlined in Section A5.

Data Forms

Forms for data collection and completion of the WSQT are provided in Appendix B and listed below. Several of the data forms are also available as Microsoft Excel workbooks where data can be entered upon returning from the field. There is a shading key on some of the field forms that indicates which cells are to be filled out in the office versus the field, and which cells perform calculations. The calculation cells will automatically calculate values from provided field data in the workbook versions. These cells can also be filled out on a printed field form. Other data processing tools, such as the Mecklenberg Reference Reach Spreadsheet (Mecklenberg 2004) can be used to process field data and calculate metric values.

<u>Required Forms (Appendix B):</u>	<u>Optional Forms (Appendix B)</u>	<u>Externally Available Forms</u>
<ul style="list-style-type: none">• Parameter Selection Checklist• Project Reach Form• Bankfull Verification• Field Value Documentation (FVD) Forms• Riparian Extent Form• Riparian Vegetation Form	<ul style="list-style-type: none">• Rapid Survey Form	<ul style="list-style-type: none">• Longitudinal Profile Survey Data Sheet• Cross-section Survey Data Sheet• Lateral Migration Form• Pebble Count• LWDI• Physicochemical and Biology Forms

Equipment List

This list provides the equipment needed to assess the basic suite of metrics within reach hydrology and hydraulics and geomorphology functional categories. Additional equipment will be needed for detailed survey methods and additional metrics. At a minimum, the following field gear will be needed:

- Field forms and maps (Rite in the Rain paper)
- Clipboard, pencils, and sharpies
- Waders (breathable)
- Wading boots (no felt bottoms)
- Pin flags (50)
- Roll of flagging
- Camera
- Metric ruler
- Pocket rod
- Measuring tapes (e.g., 300ft, 100ft and 50 ft)
- Calipers or DBH tape (not required, but helpful for the LWD assessment)
- Clinometer (for bank angle measurements of BEHI)
- GPS unit (helpful with lateral migration, riparian extent, and sinuosity field measurements)
- Survey equipment – The rapid geomorphic survey methods described this appendix allow measurements to be made with a hand or line level and stadia rod. Detailed geomorphic survey methods will require standard survey equipment, such as laser level, total station or RTK (see A4).

Metric Sampling Periods & Restrictions

Sampling periods for metrics vary. Most metrics in the WSQT can be assessed in a single day or visit, but multiple days or visits may be required, depending on the complexity and size of the site and which metrics were selected for analysis. Table A.2. shows sampling restrictions and considerations by parameter. Parameters that are not listed do not have sampling restrictions.

Table A.2: Sampling Periods and Restrictions by Parameter.

Parameter	Sampling Periods and Restrictions
Bedform Diversity	Sampling should occur during baseflow periods for safety and efficiency.
Riparian Vegetation and Lateral Migration	Sampling should occur during the growing season. Ongoing sample collection should occur at a similar time of year.
Temperature	August; minimum 31 days
Nutrients Macroinvertebrates	<p>Perennial streams: August through October in Middle Rockies, Wasatch and Uinta Mountain and Southern Rockies level III ecoregions; July 15 through October in Northwestern Great Plains, Western High Plains, Snake River Basin / High Desert and Wyoming Basin level III ecoregions</p> <p>Intermittent streams: June 1 through August - post spring runoff but prior to cessation of flow (depending on duration of seasonal flow).</p> <p>All streams: Ongoing sample collection at the same site each year is performed +/- 2 weeks of the original sampling date to maximize comparability of annual samples.</p>
Fish	<p>Pre-project: At least two sampling events occurring in different seasons (>60 days between sampling events) or different years.</p> <p>Control reach: Paired sampling at the project and control sites should occur within a 7-day window.</p> <p>All streams: Sampling should avoid spawning seasons. Ongoing sample collection should occur at a similar time of year.</p>

A3. Reach and Representative Sub-Reach Assessments

The following sequence of steps is recommended to collect data in the field. Depending on which parameters are selected, not all steps are needed for all projects.

1. Prior to field work, the user should determine whether the project area should be delineated into multiple project reaches (see Section 4.1 of the User Manual).
2. Conduct necessary pre-field desktop activities; review Chapter 4 of the User Manual. For each reach users should review available information and prepare a list of action items for the field to:
 - a. Complete the Restoration Potential worksheet (WSQT workbook only; not applicable to WSIT workbook),

- b. Complete the Site Information and Reference Selection section of the Quantification Tool worksheet (WSQT workbook) or Existing Condition worksheet (WSIT workbook) and the Site Information section of the **Project Reach form**.
 - c. Determine drainage area and obtain regional curves to support identification and verification of bankfull in the field,
 - d. Identify valley type, likely reference stream type (e.g., Rosgen stream type using entrenchment ratio, W/D ratio, sinuosity, slope, bed material) and evolution scenarios, and
 - e. Collect desktop data for applicable/selected metrics.
3. In the field, walk along the stream throughout the project area to verify the delineation of project reaches. Determine whether additional segmentation is needed based on field conditions. Record the GPS location at the upstream and downstream ends of each reach.

When multiple project reaches exist on the same stream, data collection typically proceeds from upstream to downstream. However, when biological sampling is being performed, plan to evaluate the most downstream reach first and work upstream. Collect biological samples prior to any other instream work to avoid muddy waters and impacted samples. Fish sampling may need to be scheduled on a separate day from other data collection and biological sampling, especially in small streams.
4. Within each project reach, walk along the stream bank to view locations and character of riffles, the number of concentrated flow points, length of armoring, presence of side channels, and bankfull indicators. Data can be recorded in the **Project Reach form**.
 - a. Record number and location of concentrated flow points (see UM Section 4.5.a.2).
 - b. Record location and length of any armored sections of bank (see UM Section 4.6.b.4).
 - c. Identify and verify any side channels and record their length(s) (see UM Section 4.5.d.3).
 - d. Measure and record the difference between bankfull stage and water surface elevation at multiple points along the project reach. Use this data to come to a consensus on the difference between the bankfull elevation and water surface elevation. If the channel does not have water, use the edge of channel in riffles as a surrogate for water, but avoid scour areas and bars. Note, this method will create more variability in the measurement. Follow the bankfull identification and verification process described in UM Section 4.4.
 - e. Identify a stable riffle cross-section. Selection of the stable riffle is critical; a suitable riffle will have stable width and depth, no signs of bank erosion or headcutting, a bank height ratio near 1.0, bankfull width/depth ratio on the lower end of the range for the reach and the cross-sectional area plots fall within the range of scatter used to create the regional curve. Note: The preference is for the stable riffle to be located within the project reach. However, in disturbed settings, this cross-section may be located upstream or downstream of the reach. If a stable riffle is still not identified, the bankfull width and mean depth from the regional curve should be used.
 - f. Using the stable riffle cross section, classify the stream using the Rosgen method. The slope and sinuosity can come from the reach-scale assessment (see Riffle Survey section below).

5. Select the location within the reach for biological sampling (if applicable).
6. If applicable, sample macroinvertebrates in accordance with WDEQ (2022). Processed samples should be immediately preserved and stored in a cool, shaded area for the remainder of data collection.
7. If applicable, sample chlorophyll- α ; refer to WDEQ (2022).
8. If applicable, sample fish using standard fish sampling methods (e.g., Bonar et al. 2009). An approved sampling methodology should be used, such as multi-pass depletion or mark-recapture techniques. Sampling methods should remain consistent throughout the project. Note: fish sampling may need to be scheduled on a separate day from other data collection and biological sampling, especially in small streams.
9. Determine the location of the representative sub-reach within each project reach. Record the GPS location at the upstream and downstream ends of each representative sub-reach.
 - a. Measurements from the representative sub-reach will quantify floodplain connectivity, bankfull dynamics, large woody debris, lateral migration (except armoring), bed material characterization, bed form diversity, and riparian vegetation parameters.
 - b. The representative sub-reach should begin and end at the head of a riffle and extend downstream at least 20 times the bankfull width or two meander wavelengths (Leopold 1994), whichever is longer. If the entire reach is shorter than 20 times the bankfull width, then the entire project reach should be assessed. Record the length of the representative sub-reach.
10. Within each representative sub-reach, collect bed form diversity, bankfull dynamics, and floodplain connectivity data using rapid or detailed geomorphic survey methods. For efficiency, data can be collected from each sequential feature moving from upstream to downstream.
 - a. Data to calculate the bank height ratio and width/depth ratio should be collected at every riffle in the representative sub-reach. These data can be collected from cross-sections at the center of each riffle and riffle data collected for the longitudinal survey (UM Section 4.5.d.1).
 - b. Sections A6 and A7 provide additional information on identifying low bank height in incised streams and bed form identification, respectively.
11. Assess Greenline Stability Rating per methods outlined in Winward (2000) or USDOJ (2011) **OR** collect dominant BEHI/NBS measurements throughout the representative sub-reach per methods outlined in Rosgen (2014) or Starr et al. (2015) with the following modifications:
 - a. For dominant BEHI/NBS, partition the banks based on different BEHI and NBS conditions.
 - b. For dominant BEHI/NBS, measure the bank length of **every** outside meander bend and determine its BEHI/NBS category. The outside of the meander bend is always assessed, even when it is not eroding. For meander bends that are not actively eroding, it is sufficient to assess the bank length where the NBS is the highest. This could be point of tangency to point of curvature or defined by the thalweg depth and location relative to the bank.

- c. For dominant BEHI/NBS, measure the bank length of **any other bank that is actively contributing sediment** and determine its BEHI/NBS category. The following areas should not be included in the assessment: depositional zones (e.g., point bars) or other areas that are not actively eroding, riffle sections that are not eroding and have low potential to erode and banks that are armored.
12. Conduct a large woody debris assessment, bed material characterization, and riparian vegetation surveys, as applicable based on parameter selection.
- a. For LWD, identify the 328 feet (100 m) length of the project reach that contains the most LWD, preferably within the representative sub-reach. For LWDI index, see methods and field forms within Davis et al. (2001) or (Harman et al. 2017). For LWD piece count, count all pieces of dead and fallen wood wholly or partially within the active channel that are over 3.28 feet (1 m) in length and at least 3.9 inches (10 cm) in diameter at the largest end within the 328-foot reach. For debris dams, to the extent possible, count each piece within the dam that qualifies as LWD. Record LWD piece counts on the **Project Reach form**.
 - b. For bed material characterization, conduct a 100-particle pebble count within riffles (see WDEQ [2022]).
 - c. For riparian vegetation, see Riparian Vegetation section below. **Riparian Extent** and **Riparian Vegetation forms** are provided in Appendix B.
13. Install temperature sensors and stream gages as applicable based on parameter selection (see EPA [2014]).

Riffle Surveys

Riffle cross-sections are used for multiple purposes in the SQT, including bankfull identification and verification; for bank height ratio, width/depth ratio state, and entrenchment ratio measurements; and bankfull width and mean depth measurements used to calculate bedform diversity metric ratios. More information is provided below on the use of riffle cross sections.

- A stable riffle (defined in UM Section 4.4) is used for *bankfull verification*. Dimensions from this riffle can also provide the denominator for pool spacing and pool depth ratios.

For the stable riffle, space is provided on the **Project Reach form** to calculate the bankfull mean depth and cross-sectional area. These calculations are automatically performed in the Microsoft Excel workbook version of the **Project Reach form**. A rough estimate of the mean depth can be calculated by adding all the depth measurements (except for zeros at bankfull) and dividing by the number of observations. Compare the bankfull width, mean depth, and area to the regional curve values on the field form (see UM Figure 34).
- At least one riffle cross-section is needed to determine the *existing stream type* of the project reach. This riffle should be located in the representative sub-reach. This cross-section can be but is not required to be the same cross-section as the stable riffle noted above. Where flood-prone width is uniform throughout the reach (as verified using topographic data), measurements from this riffle can be used to calculate the entrenchment ratio metric field value.
- Data to calculate the bank height ratio and width/depth ratio state should be collected at every riffle in the representative sub-reach to quantify floodplain connectivity and bankfull

dynamics. To calculate these metrics, riffle data are needed from cross-sections at the center of each riffle and from the longitudinal survey (see relevant sections of UM Chapter 4).

A4. Rapid Geomorphic Survey for Floodplain Connectivity, Bankfull Flow Dynamics and Bed Form Diversity

This section outlines rapid survey methods to collect data to inform floodplain connectivity, bankfull dynamics, and bed form diversity parameters. These rapid survey techniques are considered more rapid than surveying the longitudinal profile and cross-sections using standard survey techniques that rely on equipment like a laser level or total station. They require little post-processing of the field data. The rapid methods described in this section may be used for the existing condition assessment for the WSIT workbook, or for restoration projects when profile and cross-section plots are not needed.

The Rapid Survey form is provided in Appendix B. There is a shading key on the field form that indicates which cells are intended to be filled out in the office versus the field, and which sections are for performing field calculations. The calculation cells can be filled out on a printed field form. In the workbook version, these cells will automatically calculate values from provided field data. Field values that can be entered directly into the Quantification Tool worksheet (WSQT workbook) or Existing Condition worksheet (WSIT workbook) from this field form are bolded. These include: weighted bank height ratio (BHR), weighted entrenchment ratio (ER), width/depth ratio state (WDRS), percent riffle, average pool depth ratio, and median pool spacing ratio.

For these methods, the following gear will be needed:

- Hand or line level
- Enough 300' tapes for the assessment reach length (note: a tape with feet on one side and metric on the other is recommended)
- 100' Tape
- Stadia rod

Rapid Survey Method

1. Beginning at the upstream end of the representative sub-reach, stretch tape(s) along either the left or right bank as close to the edge of the channel as possible, threading them through riparian vegetation or other obstructions if necessary. Tape(s) can be secured to the ground with range pins, vegetation, or rocks. Stationing of features will be obtained from the tape. Begin and end the representative sub-reach at the head of a riffle feature.
2. Record sub-reach length in the **Rapid Survey form**.
3. Working from upstream to downstream, take measurements at every riffle and pool within the sub-reach. NOTE: Review pool identification instructions provided in Section A7.

- a. Measure the following at every riffle within the sub-reach and record values in the **Rapid Survey form**. These data are used to calculate the BHR, ER (if applicable), WDRS, and percent riffle metrics.
 - i. Measure the length of the riffle, including runs, if present. Riffle length is measured by taking a station reading from the tape at the head (beginning) of the riffle and another station reading downstream at the head of a **significant or geomorphic pool**.
 - ii. Identify the middle of the riffle feature and bankfull elevation. The sample location doesn't have to be the exact center; look for places that have bankfull indicators and a good line of site to the top of bank and flood-prone width, but that is also representative of the riffle condition.
 - iii. From mid-riffle, measure the bankfull width using a bankfull indicator. If an indicator is not present, use the difference in water surface and bankfull to pin the tape. The difference in water surface and bankfull was determined during the bankfull identification and verification process. Make sure the tape is level.
 - iv. From mid-riffle, measure the difference in stadia rod readings from the thalweg to the top of the lower of the two streambanks. Record this value as the low bank height on the **Rapid Survey form**. The low bank height is the lower of the left and right streambanks, indicating the minimum water depth necessary to inundate the floodplain. NOTE: see Section A6 for how to identify low bank in incised streams.
 - v. From mid-riffle, measure the difference in stadia rod readings from the thalweg to the bankfull elevation, and record this value as the bankfull maximum depth on the **Rapid Survey form**. Alternatively, measure the difference in stadia rod readings from the thalweg to the water surface then add the value recorded for the difference between bankfull stage and water surface.
 - vi. From mid-riffle, measure the difference in stadia rod readings from the edge of channel, which is the breakpoint between the streambed and streambank, to the bankfull elevation, and record this value as the mean depth on the **Rapid Survey form**.
- Note: Using the edge of channel up to the bankfull elevation measurement as an estimate of mean depth works best in streams where the thalweg is close to the middle of the channel. If scour or large sediment deposits are at the edge of the channel, this method should not be used. An alternative approach in this case is to measure multiple bankfull depths across the channel (refer to Rapid Riffle Survey instructions below), average the depths, and record this value as the mean depth on the **Rapid Survey form**.
- vii. Flood-prone width should also be measured at each riffle in sub-reaches with changes in valley width or a bank height ratio near, or greater than, 2.0. At mid-riffle, 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 bankfull maximum depth (see Figure A.1 for illustration). Record flood-prone width on the **Rapid Survey form**.
- b. Identify pools within the sub-reach. Refer to pool definitions in Section A7 of this appendix for geomorphic and significant pools.

- c. Measure the following at every pool within the sub-reach and record values in the **Rapid Survey form**. These data are used to calculate the pool spacing and pool depth ratio metrics.
 - i. Note whether the pool is a geomorphic pool.
 - ii. Determine the deepest point of the pool and record the station.
 - iii. Measure the maximum pool depth by placing the stadia rod at the deepest point in the pool and recording the depth **to bankfull elevation**. Alternatively, measure the difference in stadia rod readings from the deepest point in the pool to the water surface and then add the value recorded for the difference between bankfull stage and water surface.

Rapid Method for Surveying the Stable Riffle Cross-section

1. Determine the location of the cross-section within the riffle. Make sure that the cross-section is perpendicular to the direction of flow at bankfull.
2. Stretch a tape from the left bankfull indicator to the right bankfull indicator. Use the primary bankfull indicator or the difference between bankfull stage and water surface elevation from the reach walk (Section A3).
3. Level the tape by attaching a line level or by measuring the distance from the water surface to the tape at the left and right edge of water surface (i.e., the location where the water meets the streambank). The distance should be the same on both sides.
4. Record the bankfull width.
5. Working from left to right, record the station from the tape and the depth from the tape to the ground using a stadia rod. Include bankfull, major breaks in slope, edge of channel, water surface, the thalweg, and other points along the channel bottom.
6. Identify the flood-prone elevation (e.g., relative elevation or stadia rod reading) and measure the flood-prone width (FPW) as shown in Figure A.1. The flood-prone width should be measured perpendicular to the fall line of the valley. The FPW can be measured using a tape, range finder, or GPS.

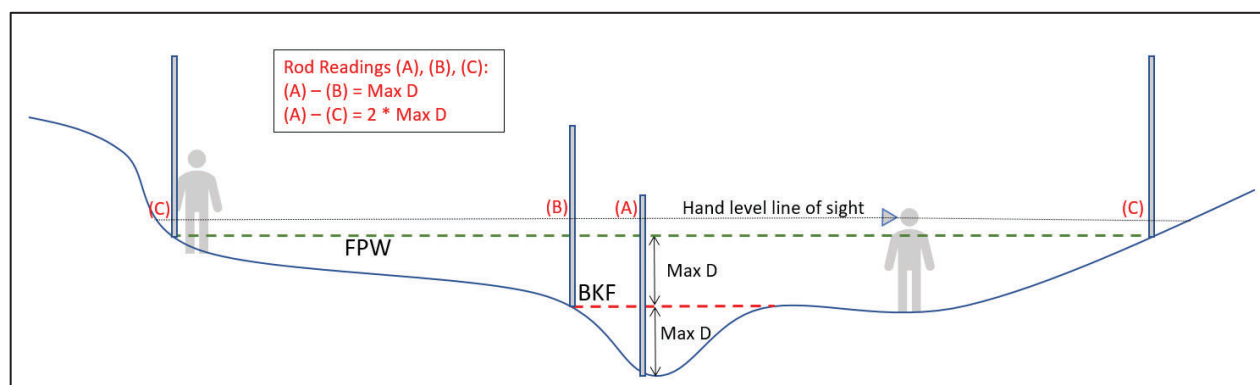


Figure A.1: Surveying Flood-prone Width.

A5. Riparian Extent and Riparian Vegetation Plots

Riparian Extent Field Verification Method

1. Field data can be used to verify the indicators used to determine expected and observed riparian area extent obtained from desktop assessments (UM Section 4.6.e.1). Examine the reach and landscape.
2. Where practicable or possible, verify the **expected** riparian extent and record the GPS location of the indicators of expected riparian extent observed in the field. On the **Riparian Extent form**, indicate which field indicators were used to verify this extent. If needed, the riparian extent measurements and mapping can be revised in the office later.

Expected riparian area includes the area of the stream, extending landward in each direction to the extent of substrate, hydrologic and biotic indicators. Field indicators such as a fluvially formed break in slope between bank edge and valley edge, a change in sediment from fluvial sediments (rounded) to hillslope sediment (angular), or evidence of flood events (e.g., bar deposition, staining, water marks, etc.) can be used to delineate the expected riparian area. Where significant anthropogenic modification of the riparian area has occurred (e.g., development, grading, etc.) and aerial imagery and/or field indicators cannot be used to delineate the expected riparian extent, the absence of indicators must be documented and the meander width ratio may be used to calculate expected riparian area (see UM Section 4.6.e).

3. At the station ID recorded for each plot location, verify the **observed** riparian area extent, and record the GPS location of the observed edge of existing riparian vegetation. On the **Riparian Extent form**, record the observed riparian measurements and indicators used to determine the extent. If needed, the riparian extent measurements and mapping can be revised in the office later.

The observed riparian area is the area that currently contains riparian vegetation and is free from anthropogenic disturbance. Disturbances are human caused development and disturbances that remove, destroy, or inhibit growth and the extent of riparian vegetation. Disturbances can be direct or indirect stressors that may physically limit or truncate riparian extent through disruption of surface or subsurface hydrology (connectivity) to the stream. Examples of disturbances to observed riparian extent may include: Removal of riparian vegetation, hardening, cultivation, intensive land and water use practices, berms, ditches, elevated utility lines, buried utility lines that are not properly restored to original elevations, contours and native riparian vegetation, and/or that appear to disrupt/interrupt shallow water tables.

Riparian Vegetation Plot Layout

The location of the first plot must be determined as follows:

1. Determine the number of riparian plots for each project reach using the representative sub-reach length as shown in Table A.3. Plots should be systematically distributed along each bank such that the minimum number of plots are evenly spaced along the known length of the representative sub-reach. Fewer plots may be considered (and approved by the Corps) if the representative sub-reach is short or if the riparian vegetation is very uniform in

structure and composition throughout the sub-reach. Additional plots may be added at sites with variable riparian vegetation.

2. Calculate the spacing interval of the plots by dividing the representative sub-reach length by the number of plots per side.
3. Select a random starting point within the first 20 feet of the sub-reach length for the first plot.

Table A.3: Number of Sampling Plots per Representative Sub-reach.

Sub -Reach Length	Number of Plots per Side	Number of Plots per Sub-Reach
300-400 ft	3 plots	6 plots
400-600 ft	4 plots	8 plots
600-900 ft	6 plots	12 plots
900 - >1300 ft	8 plots	16 plots

Set up the first plot at the random starting point on the left-hand side of the stream (looking downstream). The plot should begin at the bankfull or greenline, whichever is closer to the stream, and extend landward and downstream from this point. All vegetation sampling is conducted within the reach's **expected** riparian area, and thus may extend into developed or modified upland areas (see Riparian Extent - Field Verification). Users shall consult with USACE about plot placement when the project area (e.g., conservation easement) does not align with the expected riparian extent. In narrower or colluvial valleys, square plots may need to be reshaped to a rectangular plot of the same area to keep the plots within the expected riparian area of the reach. This could affect the location of subsequent plots, and subsequent plots may need to be relocated to avoid overlap. Plots should be located adjacent to the primary channel if high flow secondary channels exist, and outside active intricately braided channels, mid-channel bars, and beaver ponded areas.

4. Subsequent sampling plot locations should be identified using the spacing interval identified in step 2 above. Locations should be determined using the station reading from the geomorphic survey. Plot locations on the right side of the stream should use the same station locations as identified on the left unless they need to be relocated. Consecutively number the plots down the left bank and up the right bank.
5. If a riparian plot needs to be relocated, adjust the location to the minimum extent possible upstream or downstream from the designated station to avoid the problem (e.g., overlap of tight meander bend plots or reshaped plots; inaccessible locations; or at the confluence of a large secondary channel or tributary, etc.). If necessary, vegetation plots may extend beyond the downstream end of the representative sub-reach but should not extend outside the project reach. Relocation of a plot on the left side of the channel does not necessarily require relocation on the right side as well. Record the new station location and note the reason for relocation.
6. Plots may be sampled in any order once plot locations are identified. However, it is recommended that riparian data sampling start at the most upstream plot on the left side of

the stream and move downstream. After data from the last plot is collected on the left side, cross the stream and place the first plot on the right side and move upstream collecting data on the remaining number of evenly spaced plots.

7. On the left side of the stream (looking downstream), for each plot, place the corner of the plot at the appropriate station reading either at the greenline or bankfull, whichever is closer to the channel; this is the starting point in Figure A.2. The plot should extend landward and downstream from this point and contain the nested sub-plot configuration according to the diagram provided in Figure A.2. When sampling the right side of the stream place the corner of the plot at the same station reading where it intersects the greenline or bankfull, whichever is closer to the channel. The plot should extend landward and downstream from this point such that the plots are mirror images across the channel at each designated station (Figure A.2).
8. At each plot, measure or pace out the bounds of a 32-ft x 32-ft (10m²) tree (canopy) plot and a 16-ft x 16-ft (5 m²) shrub (understory) nested plot and mark corners with pin flags as depicted in Figure A.2. Note: if trees are not present on site, users do not need to measure or pace out the 32-ft x 32-ft plot. Then mark two 3-ft x 3-ft (1 m²) herbaceous ground cover nested plots at the starting point and the diagonally opposite corner of the shrub plot. Nested plots are helpful to sample variable understories and smaller sized species over a larger area. Alternatively, herb cover data may be collected in the 16-ft x 16-ft plot, but this requires additional survey effort for plant species within a larger area and may be less precise and more time consuming. Consistent plot size should be used for all aspects of the project.

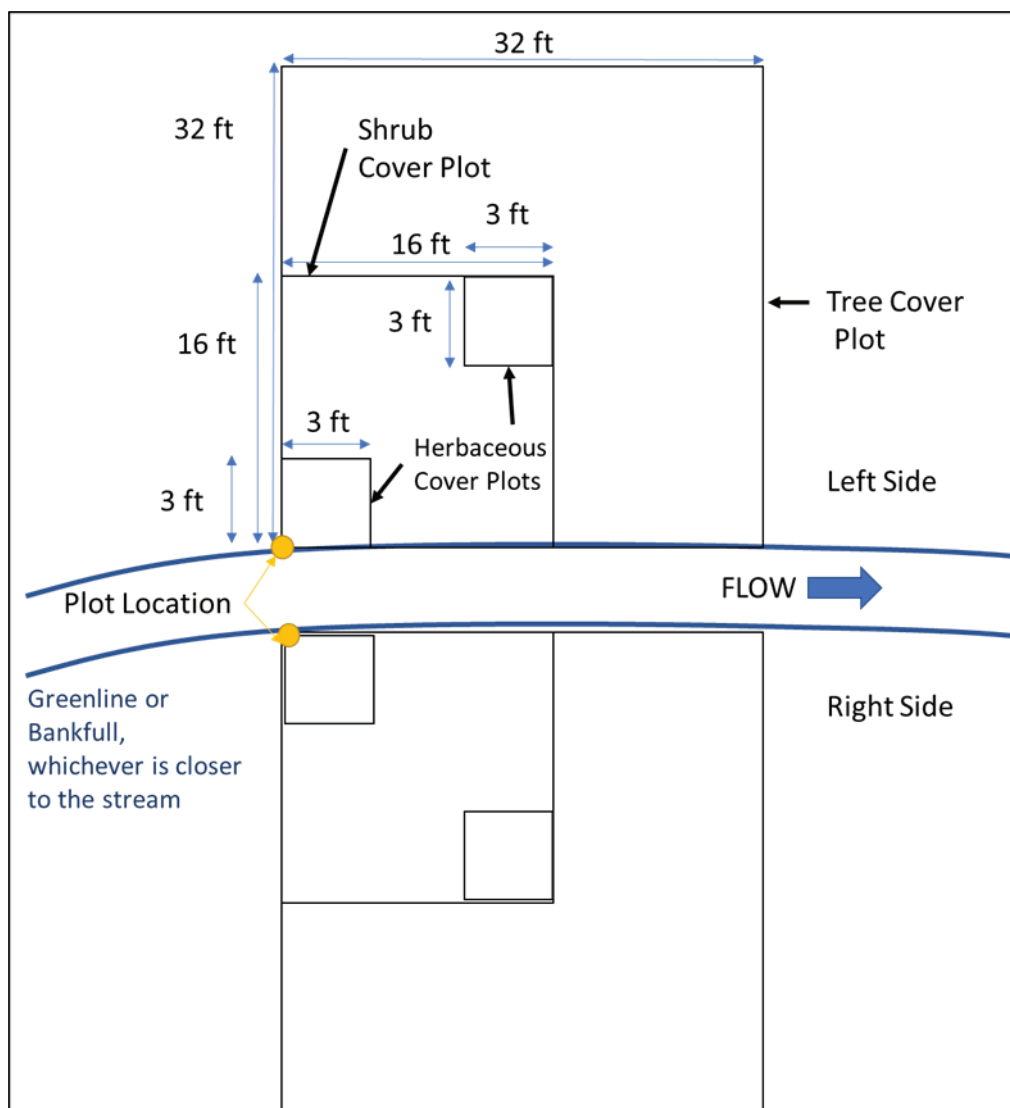


Figure A.2: Standard Riparian Vegetation Plot Layout.

Riparian Vegetation Plot Data Collection Method

Field data should be collected during the growing season at the same time of year for pre- and post-project evaluations. A **Riparian Vegetation form** is provided to record data (Appendix B). Grey cells will perform field calculations. The calculation cells can be filled out on a printed form. In the workbook version, these cells will automatically calculate values from provided field data.

Procedure:

1. Take a photo of the riparian plot so that the near-stream herbaceous plot is visible in the foreground and a good portion of the remaining riparian plot is in the background. Note the photo number on the data form or include the plot number in the photograph.
2. Record the station ID and plot number. Cover type will be filled in in Step 5.

3. Note the geomorphic location of the 32-ft x 32-ft plot as inside meander (I), outside meander (O), or straight/riffle (S). If this changes over the length of the plot, record the geomorphic location of the majority of the plot.
4. Within each riparian plot, visually estimate the percent absolute cover of each plant species within the nested plot types to determine vegetation abundance, structure, composition, and complexity (USACE 2008, 2010a, 2010b; Kittel et al., 1999). Practitioners should be able to identify at least 80% of the species within a plot. Absolute cover is the percentage of the ground surface that is covered by the aerial portions (leaves and stems) of a plant species when viewed from above. It can also be described as an estimate of the amount of shadow that would be cast by a particular plant species if the sun were directly over the plot area.
 - a. Where trees are present, identify and record tree species and visually estimate the portion of the plot each species covers. Absolute tree cover by species includes woody plants greater than 3 inches DBH and greater than 16 ft (5 m) tall and is measured within a 32-ft by 32-ft plot.
 - b. Where shrubs are present, identify and record shrub plant species and visually estimate the portion of the plot each species covers. Absolute shrub cover by species includes woody plants less than 3 inches DBH and less than 16 ft (5 m) tall and is measured within a single 16-ft by 16-ft nested plot (see Figure A.2).
 - c. Absolute herbaceous (herb) cover by species should be measured at every riparian plot location within each of two nested 3-ft by 3-ft herb plots (see Figure A.2), then averaged.
 - i. Identify and record the herbaceous plant species that occur within the plot and visually estimate the portion of the plot each species covers.
 - ii. Record total bare ground/litter and total embedded rock (> 15 cm diameter) as separate absolute values (out of 100 percent) to document uncovered or partially exposed substrate. Note that high flow or minor secondary channels are counted as bare ground.
 - iii. If using nested herb plots, repeat the procedure for the second herb plot and average species values across herb plots for a combined list within each riparian plot. In the workbook version, these cells will automatically calculate values from provided field data.
 - d. Calculate the sum of tree, shrub and herbaceous species cover separately, then calculate the sum of shrub and tree species cover together as woody vegetation cover and the sum of all plant species cover as total vegetation cover for the riparian plot. In the workbook version, these cells will automatically calculate values from provided field data.
 - e. Identify and record which species are native (N) or introduced (I) (i.e., non-native or naturalized). Use USDA PLANTS Database <http://plants.usda.gov> to verify. Calculate the sum of all native species cover. In the workbook version, these cells will automatically calculate values from provided field data.
5. Based on the data collected, determine the general vegetation cover type for the riparian plot area as herbaceous, scrub-shrub, or forested and record at the top of the form. The cover type is distinguished as woody or herbaceous. Woody sites are those whose reference condition is greater than or equal to 20% absolute cover of woody vegetation. This

includes scrub/shrub and forested systems. Herbaceous sites are those whose reference condition is less than 20% absolute woody cover.

Additional notes on sampling procedure:

- Individual species aerial cover estimates cannot exceed 100% but can be less than 100%.
- Due to overlapping plant canopies, the sum of absolute cover values for all species in a community or stratum may exceed 100 percent. (In contrast, “relative cover” is the absolute cover of a species divided by the total coverage of all species in that stratum, expressed as a percent. This is how the percent native vegetation metric is determined.)
- Naturalized species are not considered native.
- Absolute cover for riparian and non-riparian (upland) species should be estimated.
- Plants over-hanging the plot do not need to be rooted in the plot to be counted as absolute aerial cover; however, species rooted outside of the expected riparian width that are overhanging the riparian plot would not be counted.
- Standing dead shrubs/trees should be included in aerial cover estimates but eliminated from percent native cover calculations.
- Additional data collected and not reported in the WSQT provides context for riparian area reporting.

Rapid Alternatives for Riparian Plot Data Collection

Less intensive methods of collecting riparian cover information data will result in similar but less accurate data and would only be available for cursory characterization or planning estimates. These methods would not be appropriate for mitigation projects or monitoring efforts.

1. Abundance-only data could be collected using the methods outlined above with the following exception. Abundance-only data for herbaceous and woody vegetation cover metrics would involve estimating absolute cover by species without taxonomic identification and summarizing information by life form (e.g., herbaceous species A, B, C and D; shrub species A, B, and C). Native cover would not be accurately determined using this method.
or
2. Data could be collected from a reduced number of plots, e.g., one or two representative plots per bank. Plot locations should be selected based on representativeness, after considering the overall abundance and composition of riparian communities throughout the reach. Sampling methods would be the same as outlined above.

A6. Identifying Low Bank Height in Incised Streams

In incised channels with a bankfull bench, determining when bankfull and the top of bank are equal can be challenging. Two common scenarios are described to aid users in low bank identification.

Incised Stream Scenario 1 – If the bankfull elevation is identified as the back of the bench (Figure A.3), then the low bank feature is the top of the left bank in the cross-section shown.

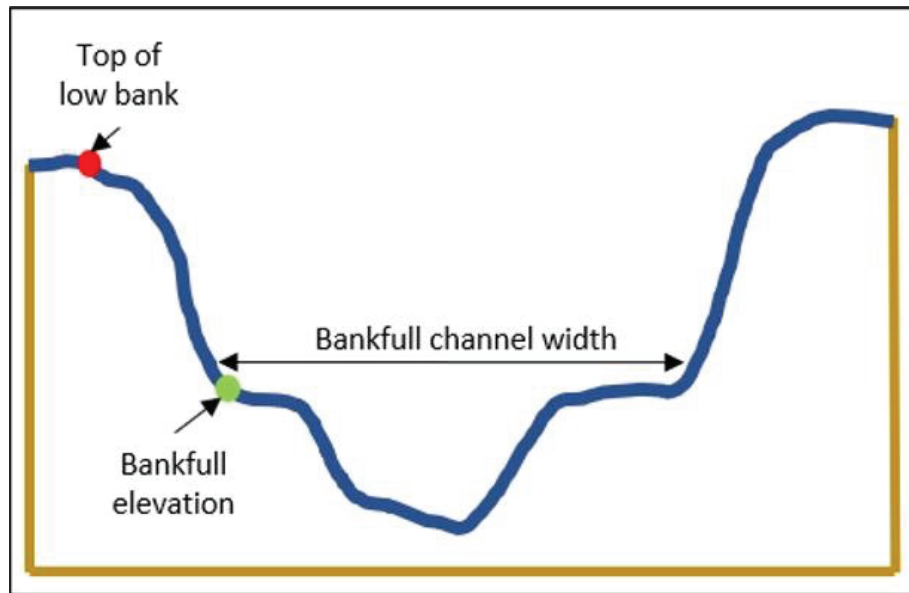


Figure A.3: Incised Stream Scenario 1. Where bankfull and low bank elevation are not equal.

Incised Stream Scenario 2 – If the bankfull elevation is identified as the front of the bench (Figure A.4), then the width of the bankfull bench(es) must be considered before the low bank feature can be determined.

- For C/E reference stream types, if the total width (left bench + bankfull channel + right bench) is greater than 2.2 times the bankfull channel width, then the low bank feature is equal to bankfull (shown as the green dots in Figure A.4).
- For B reference stream types, if the total width is greater than 1.4 times the bankfull channel width, then the low bank feature is equal to bankfull (shown as the green dots in Figure A.4).
- If total width is less than or equal to the 2.2 for C/E reference stream types or 1.4 for B reference stream types, then the low bank feature is top of the left bank (shown as the red dot in the cross-section in Figure A.4).

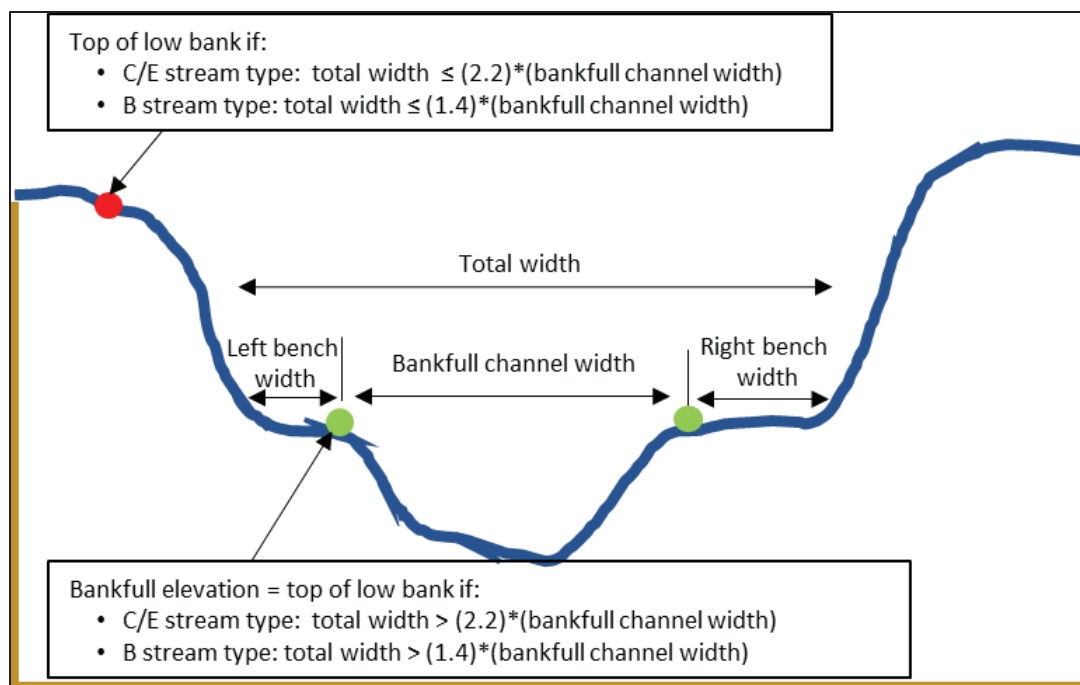


Figure A.4: Incised Stream Scenario 2. Where bankfull bench width determines low bank elevation.

A7. Bed Feature Identification

Bed forms include the various channel features that maintain heterogeneity and stability in the channel form, including riffles, runs, pools, and glides (Rosgen 2014). Together, these bed features create important channel patterns and habitats for aquatic life. Riffles and pool types are defined in this section.

Riffles are shallow, steep-gradient channel segments typically located between pools. Riffles are the river's natural grade control feature (Knighton 1998) and are sometimes referred to as fast-water channel units (Hawkins et al. 1993; Bisson et al. 2017). For purposes of the SQT, in meandering streams riffles broadly represent the section between lateral-scour pools known as a crossover, regardless of bed material size. Therefore, the term riffle also refers to the crossover section (ripples) in a sand bed channel or the cascade section of steep mountain streams. Riffle lengths are measured from head of riffle to head of pool; thus, runs are considered riffles and glides are considered pools.

The SQT requires identification of two pool types: **geomorphic pools** and **significant pools**. Guidance for identifying pools in different valley types is provided below. **Note: Pool identification is slightly different for pool spacing than it is for pool depth and percent riffle metrics (see relevant metric sections in UM Section 4.6.d).**

Geomorphic pools are pools that remain intact over time and across a range of flow conditions and are associated with large planform features. Examples include pools associated with the outside of a meander bend (streams in alluvial valleys) and downstream of a large cascade or

step (streams in colluvial valleys). Only geomorphic pools are used to calculate the pool spacing ratio metric field value.

Significant pools are pools often associated with installed structures, wood, boulders, convergence, and backwater in the main channel, but are not classified as geomorphic pools. Significant pools must be deeper than the riffle, have a concave shaped bed surface and a width that is at least half the width of the channel. The pool may also have a flatter water surface slope than the riffle; however, this is not always the case, e.g., a pool downstream of a log in a steep-gradient channel. Significant pools and geomorphic pools (see above) are used in calculating the pool depth ratio and percent riffle metrics.

A geomorphic pool may also meet the criteria to be a significant pool but a geomorphic pool is not required to meet these criteria. Note: pools that do not meet the criteria for significant pools are sometimes called micro-pools. Micro-pools are small and may not last for a long period of time or after a large flow event. Micro-pools can be found in riffles and cascades. An example is a scour pool downstream of a single piece of large woody debris that is less than $\frac{1}{2}$ the channel width. **Micro-pools are never counted as pools in the SQT.**

Identifying Geomorphic Pools in Alluvial Valleys

Geomorphic pools in alluvial valleys are located along the outside of the meander bend. Figure A.5 provides an illustration of what is and is not counted as a geomorphic pool (pools counted are marked with an 'X'). The figure illustrates a meandering stream, where the pools located in the outside of the meander bend are counted for the pool spacing measurement, and the 'X' marks the approximate location of the deepest part of the pool. The pools associated with the large woody debris and boulder clusters in this figure are not geomorphic because they are not associated with meander bends. Compound pools that are not separated by a riffle within the same bend are treated as one pool. However, compound bends with two pools separated by a riffle are treated as two pools. Rosgen (2014) provides illustrations for these scenarios.

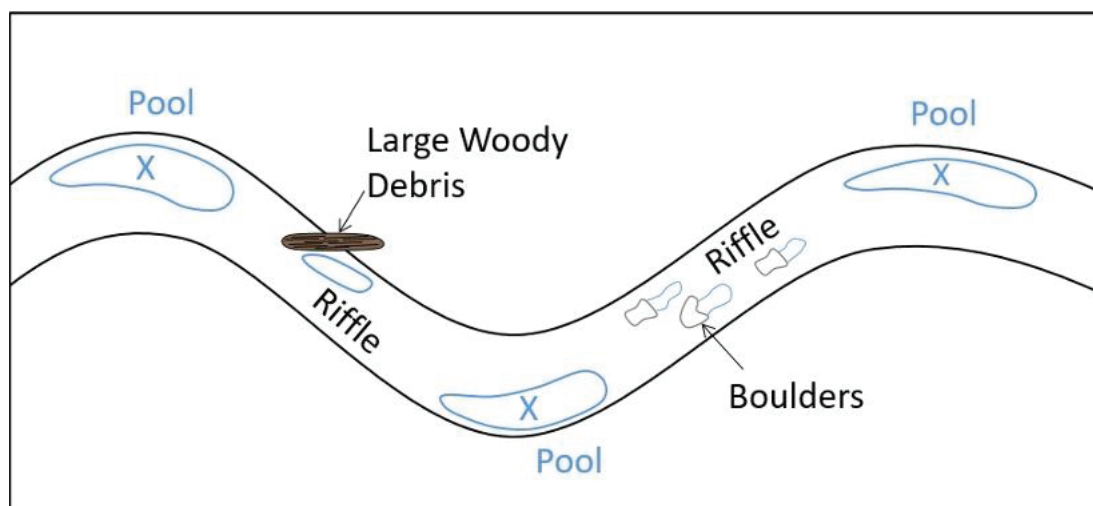


Figure A.5: Pool Spacing for Streams in Alluvial Valleys.

Identifying Geomorphic Pools in Colluvial and V-Shaped Valleys:

Pools in colluvial or v-shaped valleys should only be counted as geomorphic pools if they are downstream of a step, riffle, or cascade. An example of pool spacing in a colluvial or v-shaped valley is shown in Figure A.6. Figure A.6 provides an illustration of what is and is not counted as a geomorphic pool (pools counted are marked with an 'X'). Significant pools (defined above) and micro-pools within a riffle or cascade are not counted as geomorphic, just like pools within a riffle of a meandering stream are not counted as geomorphic.

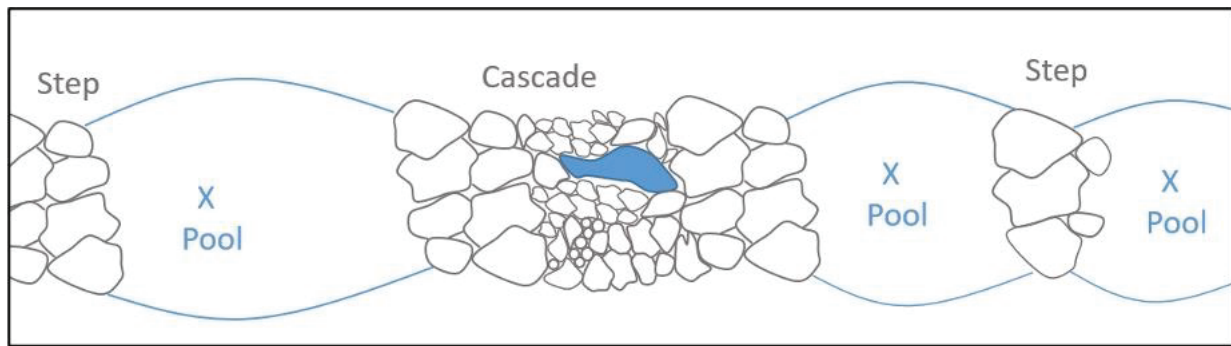


Figure A.6: Pool Spacing for Streams in Colluvial and V-Shaped Valleys.

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Appendix B

Forms: Required and Optional

Required Forms

- Parameter Selection Checklist
- Project Reach Form
- Bankfull Verification
- Field Value Documentation (FVD) Forms
- Riparian Extent Form
- Riparian Vegetation Form

Optional Forms

- Rapid Survey Form

Project Name:
Reach ID(s):

**Wyoming Stream Quantification Tool
Parameter Selection Checklist**

Function-based Parameter		Metric(s)	Applicability
<input checked="" type="checkbox"/>	Reach Runoff*	<input checked="" type="checkbox"/> Land Use Coefficient* (D) AND Concentrated Flow Points* (F)	All streams and flow types.
<input type="checkbox"/>	Baseflow Dynamics	<input type="checkbox"/> Average Velocity AND Average Depth (D/F)	Use INSTEAD OF Bankfull Dynamics where hydraulic conditions during summer/fall baseflow periods should support trout assemblages (coldwater perennial or intermittent streams).
<input checked="" type="checkbox"/>	Bankfull Dynamics*	<input checked="" type="checkbox"/> Width/Depth Ratio State* (D/F)	Use in single-thread channels.
<input checked="" type="checkbox"/>	Floodplain Connectivity*	<input checked="" type="checkbox"/> Bank Height Ratio* AND Entrenchment Ratio (F)	Omit ER in multi-thread channels.
		<input type="checkbox"/> Percent Side Channels (F)	Metric applicable in alluvial valleys with single-thread channels that support side-channels.
<input type="checkbox"/>	Large Woody Debris (LWD)	<input type="checkbox"/> LWD Index (F) or <input type="checkbox"/> No. of LWD Pieces/ 100 meters (F)	Use in systems with forested catchments, riparian gallery forests, or that otherwise naturally have a supply of LWD. This parameter can also be used where LWD is an appropriate element in restoration.
<input checked="" type="checkbox"/>	Lateral Migration*	<input checked="" type="checkbox"/> Dominant BEHI/NBS AND Percent Streambank Erosion (F) or <input type="checkbox"/> Greenline Stability Rating (F) <input type="checkbox"/> Percent Armoring (F)	Use in single-thread channels. Likely more applicable in streams naturally unstable. Use in addition to the other metric(s) when man-made armoring is present or proposed in the project reach.
<input type="checkbox"/>	Bed Material Characterization	<input type="checkbox"/> Percent Fines (F)	Applicable where reach wide d50 > 2mm and fine sediment deposition over coarse bed material is occurring or expected.
<input checked="" type="checkbox"/>	Bed Form Diversity*	<input checked="" type="checkbox"/> Pool Spacing Ratio AND Pool Depth Ratio* AND Percent Riffle* (F)	Applicable in perennial and intermittent single-thread channels. Omit pool spacing ratio in bedrock dominated systems.
<input checked="" type="checkbox"/>	Riparian Vegetation*	<input checked="" type="checkbox"/> Riparian Extent (D/F) AND Woody Vegetation Cover (F) AND Percent Native Cover (F) AND for CWA 404 projects Herbaceous Cover (F). <input type="checkbox"/> Riparian Extent (D/F) AND Herbaceous Vegetation Cover (F) AND Percent Native Cover (F)	Where absolute woody vegetation cover is/should be >20%. Where absolute woody vegetation cover is/should be <20%.
<input type="checkbox"/>	Temperature	<input type="checkbox"/> Maximum Weekly Average Temperature (F)	Use these parameters and metrics for impacts or for projects with goals related to water quality improvements.
<input type="checkbox"/>	Nutrients	<input type="checkbox"/> Chlorophyll (F)	
<input type="checkbox"/>	Macroinvertebrates	<input type="checkbox"/> WSII AND RIVPACs (F)	Use for impacts, for projects with goals related to biological improvements or where project may impact conservation areas or other valuable fish habitats.
<input type="checkbox"/>	Fish	<input type="checkbox"/> Native Fish Species Richness AND SGCN Absent (F) <input type="checkbox"/> Game Species Biomass (F)	
* Include in all assessments (D) indicates metrics are calculated using desktop methods (F) indicates metrics are calculated or verified using field methods			

I.

Site Information

Project Name:		<i>Note: if form is being used for proposed condition scores, do not complete Section IIA or Section III.</i>
Reach ID:		
Drainage Area (sq. mi.):		
Flow Permanence:		
River Basin:		
Valley Type:		
Stream Reach length (ft):		
Upstream Latitude:		
Upstream Longitude:		

Shading Key

Desktop Value

Field Value

Calculation

II.

Reach Walk

A.	Difference between bankfull (BKF) stage and water surface (WS) (ft)							
	Difference between BKF stage and WS (ft) <i>Average or consensus value from reach walk.</i>							
B.	Number Concentrated Flow Points							
	Concentrated Flow Points/ 1,000 L.F.							
C.	Length of Armoring on banks (ft)							
	Total (ft)							
	Percent Armoring (%)							
D.	Length of Side Channels (ft)							
	Total (ft)							
	Percent Side Channels (%)							

III.

Identification of Representative Sub-Reach

Representative Sub-Reach Length At least 20 x the Bankfull Width		20*Bankfull Width	
Latitude of downstream extent:			
Longitude of downstream extent:			

Sub-Reach Survey Method

- ☐ Rapid Survey
- ☐ Detailed - Longitudinal Profile and Cross Sections

IV. Bankfull Verification and Stable Riffle Cross Section

Is Cross Section located within Representative Sub-Reach? ☐ Yes ☐ No

If no, explain why:

A.	Bankfull Width (ft)	
B.	Bankfull Mean Depth (ft) = Average of cross-section depths	
C.	Bankfull Area (sq. ft.) Width * Mean Depth	
D.	Regional Curve Bankfull Width (ft)	
E.	Regional Curve Bankfull Mean Depth (ft)	
F.	Regional Curve Bankfull Area (sq. ft.)	
G.	Curve Used	
H.	Does the the bankfull area fall within the range of scatter from the regional curve?	

NOTE: Space is provided here to survey a cross section using rapid survey methods.

Cross Section Measurements			
Depth measured from bankfull			
Station	Depth	Station	Depth

Cross Section Calculations					
W	Ave D	Area	W	Ave D	Area
-	-	-			

V.

Stream Classification

A.	Width Depth Ratio (ft/ft) Bankfull Width / Bankfull Mean Depth		Average slope from the representative sub-reach will be measured and calculated.
B.	Bankfull Max Riffle Depth		
C.	Floodprone Area Width (ft)		
D.	Entrenchment Ratio (ft/ft) Floodprone Area Width /Bankfull Width		
E.	Slope Estimate (%)		
F.	Channel Material Estimate		
	Stream Length (ft)		
G.	Valley Length (ft)		
	Sinuosity		
H.	Stream Type		

Quick Rosgen Stream Classification Guide (Rosgen, 1996)

ER < 1.4		1.4 < ER < 2.2		ER > 2.2	
WDR < 12	WDR > 12	WDR > 12		WDR < 12	WDR > 12
A or G	F	B		E	C

VI.

Large Woody Debris (328 ft assessment length within Sub-Reach)

A.	Number of Pieces		NOTE: Complete this section only if the LWDI is not being used. Otherwise complete the LWDI Field Form.
----	------------------	--	--

Date:
Investigators:

EXISTING or PROPOSED or MONITORING
(Select one)

Wyoming Stream Quantification Tool
Project Reach Form

VII. Representative Sub-Reach Sketch

VIII. Notes

Reach ID:

I. Riffle Data (Floodplain Connectivity & Bed Form Diversity)

A. Representative Sub-Reach Length						20*Bankfull Width			
B. Bank Height & Riffle Data: Record for each riffle in the Sub-Reach									
	R1	R2	R3	R4	R5	R6	R7	R8	R9
Begin Station									
End Station									
BKF Width (ft)									
Low Bank Height (ft)									
BKF Max Depth (ft)									
BKF Mean Depth (ft)									
Flood Prone Width (ft)									
Riffle Length (ft) <i>Including Run</i>									
Bank Height Ratio (BHR) Low Bank H / BKF Max D									
Entrenchment Ratio (ER)									
W/D BKF Width/BKF Mean Depth									
BHR * Riffle Length (ft)									
ER * Riffle Length (ft)									
W/D * Riffle Length (ft)									

C. Total Riffle Length (ft)	
D. Weighted BHR $\frac{\sum (Bank\ Height\ Ratio_i \times Riffle\ Length_i)}{\sum Riffle\ Length}$	
E. Weighted ER	
Weighted W/D (Observed; O)	
F. Reference W/D (Expected; E)	
Width/Depth Ratio State (O/E)	
G. Percent Riffle (%)	

Shading Key

Field Value

Calculation

Desktop Value

Date:
Investigators:

EXISTING or MONITORING
(Select one)

Wyoming Stream Quantification Tool
Rapid Survey Form

II. Pool Data (Bed Form Diversity)

A. Pool Data: Record for each pool within the Sub-Reach

	P1	P2	P3	P4	P5	P6	P7	P8	P9
Geomorphic Pool?									
Station									
P-P Spacing (ft)	X								
Pool Spacing Ratio Pool Spacing/BKF Width	X								
Pool Depth (ft) Measured from BKF									
Pool Depth Ratio Pool Depth/BKF Mean Depth									

B. Average Pool Depth Ratio		C. Median Pool Spacing Ratio	
-----------------------------	--	------------------------------	--

III. Slope

	Begin	End	Difference	Slope (ft/ft)
Station along tape (ft)				
Stadia Rod Reading (ft)				

IV. Notes

Project Name:

Reach ID:

**Wyoming Stream Quantification Tool
Bankfull Verification Form**

Bankfull Riffle Values used for WSQT Calculations:

Discharge (CFS):	
Cross-sectional area (SF):	
Width (FT):	
Maximum Depth (FT):	
Mean Depth (FT):	

If field verification was not possible, explain why.

--

(1) Line of Evidence:

- | | |
|--|---------------------------------------|
| <input type="checkbox"/> Surveyed Profile of WSEL and Bankfull | <input type="checkbox"/> H&H Modeling |
| <input type="checkbox"/> Return Interval Analysis | <input type="checkbox"/> Other: _____ |
| <input checked="" type="checkbox"/> Regional Curves | <input type="checkbox"/> Other: _____ |

BKF value calculated from this method:

Description:

--

(2) Line of Evidence:

- | | |
|--|---------------------------------------|
| <input type="checkbox"/> Surveyed Profile of WSEL and Bankfull | <input type="checkbox"/> H&H Modeling |
| <input type="checkbox"/> Return Interval Analysis | <input type="checkbox"/> Other: _____ |
| <input type="checkbox"/> Regional Curves | <input type="checkbox"/> Other: _____ |

BKF value calculated from this method:

Description

--

Project Name:

Reach ID:

**Wyoming Stream Quantification Tool
Bankfull Verification Form**

(3) Line of Evidence:

- | | |
|--|---------------------------------------|
| <input type="checkbox"/> Surveyed Profile of WSEL and Bankfull | <input type="checkbox"/> H&H Modeling |
| <input type="checkbox"/> Return Interval Analysis | <input type="checkbox"/> Other: _____ |
| <input type="checkbox"/> Regional Curves | <input type="checkbox"/> Other: _____ |

BKF value calculated from this method:

Description

(4) Line of Evidence:

- | | |
|--|---------------------------------------|
| <input type="checkbox"/> Surveyed Profile of WSEL and Bankfull | <input type="checkbox"/> H&H Modeling |
| <input type="checkbox"/> Return Interval Analysis | <input type="checkbox"/> Other: _____ |
| <input type="checkbox"/> Regional Curves | <input type="checkbox"/> Other: _____ |

BKF value calculated from this method:

Description

Project Reach Name:

Project Reach Length:

Shading Key
Desktop Value
Field Value
Calculation

DESKTOP DELINEATION					
Aerial imagery mapped extent:		Expected (area):		Observed (area):	
Check Aerial Imagery indicators used to define Expected Area:				Riparian Area %:	
<input type="checkbox"/>	Valley Edge	<input type="checkbox"/>	Slope break/Terrace	Notes:	
<input type="checkbox"/>	Change in Sediment	<input type="checkbox"/>	Meander Width Ratio		
<input type="checkbox"/>	Evidence of Flooding	<input type="checkbox"/>	Other:		
<input type="checkbox"/>	Change in Vegetation	<input type="checkbox"/>			
If Meander Width Ratio approach was used, enter the following information: Explain why MWR had to be used. What resources were evaluated? <div></div>					
Valley Type:		Meander Width Ratio Used:		Additional width (ft):	
Valley Length (ft):		Bankfull width (ft):		Expected Area (ft ²):	
Check Aerial Imagery indicators used to define Observed Area:					
<input type="checkbox"/>	Riparian veg. removed	<input type="checkbox"/>	Berms/levees	Notes:	
<input type="checkbox"/>	Hardening	<input type="checkbox"/>	Underground utilities (e.g., sewer lines)		
<input type="checkbox"/>	Cultivation	<input type="checkbox"/>	Other:		
<input type="checkbox"/>	Intensive land/water use	<input type="checkbox"/>			

FIELD VERIFICATION					
Date of Field visit:					
Field verified extent:		Expected (area):		Observed (area):	
Check indicators observed in the field at Expected Riparian Area extent:				Riparian Area %:	
<input type="checkbox"/>	Valley Edge	<input type="checkbox"/>	Slope break/Terrace	Describe changes to mapped extent based on observations:	
<input type="checkbox"/>	Change in Sediment	<input type="checkbox"/>	Other:		
<input type="checkbox"/>	Evidence of Flooding	<input type="checkbox"/>			
<input type="checkbox"/>	Change in Vegetation	<input type="checkbox"/>			
Check indicators observed in the field at Observed Area:					
<input type="checkbox"/>	Riparian veg. removed	<input type="checkbox"/>	Berms/levees	Notes:	
<input type="checkbox"/>	Hardening	<input type="checkbox"/>	Underground utilities (e.g., sewer lines)		
<input type="checkbox"/>	Cultivation	<input type="checkbox"/>	Other:		
<input type="checkbox"/>	Intensive land/water use	<input type="checkbox"/>			

Aerial Photo of Project Reach with Observed and Expected Riparian Area Extents

Sub-Reach Length:

EXISTING or MONITORING
(circle one)

Wyoming Stream Quantification Tool

Riparian Vegetation Form

#Plots/side:

Random Start #(1-20):

Plot Information		Station ID: Cover Type: Location: L or R bank:	Station ID: Cover Type: Location: L or R bank:	Station ID: Cover Type: Location: L or R bank:	Station ID: Cover Type: Location: L or R bank:	Station ID: Cover Type: Location: L or R bank:	Station ID: Cover Type: Location: L or R bank:
Trees (32x32ft)	N/I	% Cover	% Cover	% Cover	% Cover	% Cover	% Cover
Tree Absolute Cover Subtotal		0	0	0	0	0	0
Shrubs (16x16ft)	N/I	% Cover	% Cover	% Cover	% Cover	% Cover	% Cover
Shrub Absolute Cover Subtotal		0	0	0	0	0	0

N= Native
I = Introduced

Cover Type: H, W
Herbaceous or Woody

Location = Geomorphic Location: I, O, S
Inside meander, Outside meander, Straight/riffle

Investigators:

EXISTING or MONITORING
(circle one)

Wyoming Stream Quantification Tool

Riparian Vegetation Form

[illegible]

N= Native
I = Introduced

Cover Type: H, W
Herbaceous or Woody

Location = Geomorphic Location: I, O, S
Inside meander, Outside meander, Straight/riffle

Project Name:

EXISTING or PROPOSED or MONITORING

Wyoming Stream Quantification Tool

Reach ID:

(Select one)

Field Value Documentation

Reach Hydrology & Hydraulics

Reach Runoff

Land Use Coefficient

Provide the filepath or location of aerial image depicting boundary of LDA and land uses within LDA:

Item	Value		Notes
Lateral Drainage Area (total; Acres)			Source of topographic and land cover data:
Forested, mountain shrub, scrub-shrub, sage brush with grass understory (Acres)		0	
Herbaceous (Acres)		0	
Open Space (Acres)		0	
Impervious Surfaces (Acres)		0	
Pasture, grassland, or range (Acres)		0	
Croplands and Farmsteads (Acres)		0	
FIELD VALUE - Land Use Coefficient (%)			<i>Calculated</i>

Concentrated Flow Points (#/1000 LF)

Provide the filepath or location of aerial image depicting CFP locations and types:

FIELD VALUE - Concentrated Flow Points (#/1,000 LF)		<i>Pulls from project reach form.</i>
--	--	---------------------------------------

Baseflow Dynamics

Provide the filepath or location of time-series plot of gage data or concurrent-discharge data used to calculate baseflow:

Gage Sampling Period (start, stop, and sampling interval)		
Gage number (if applicable)		
Q baseflow (cfs)		
Area wetted (sf) - Riffle A		
Area wetted (sf) - Riffle B		
Area wetted (sf) - Riffle C		
Top width wetted (ft) - Riffle A		
Top Width wetted (ft) - Riffle B		
Top Width wetted (ft) - Riffle C		

Provide the filepath or location of cross-section figures for Riffles A, B, and C with wetted dimension and baseflow discharge labeled:

Project Name:

EXISTING or PROPOSED or MONITORING

Wyoming Stream Quantification Tool

Reach ID:

(Select one)

Field Value Documentation

Average Velocity (fps)

Item	Value	Notes
Average Velocity (fps) - Riffle A		<i>Calculated</i>
Average Velocity (fps) - Riffle B		<i>Calculated</i>
Average Velocity (fps) - Riffle C		<i>Calculated</i>
FIELD VALUE - Average Velocity (fps)		<i>Calculated from data entered above.</i>

Average Depth (ft)

Average depth (ft) - Riffle A		<i>Calculated</i>
Average depth (ft) - Riffle B		<i>Calculated</i>
Average depth (ft) - Riffle C		<i>Calculated</i>
FIELD VALUE - Average Depth (ft)		<i>Calculated from data entered above.</i>

Representative Sub-Reach Geomorphic Survey Method (Select one):

Longitudinal Profile & Cross Section(s) If selected, provide filepath or location of survey data, longitudinal profile & cross-section figures. List survey methods/post processing tools:	OR	Rapid Survey If selected, complete Rapid Survey form. There is no need to re-enter data below.
Riffle lengths - Riffle 1		
Riffle lengths - Riffle 2		
Riffle lengths - Riffle 3		
Riffle lengths - Riffle 4		
Riffle lengths - Riffle 5		

Bankfull Dynamics

Width/Depth Ratio

Describe how reference W/D ratio was determined. If the reference W/D ratio is from a cross section, provide the filepath or location of the cross section figure:		
Reference W/D Ratio		
W/D - Riffle 1		
W/D - Riffle 2		
W/D - Riffle 3		
W/D - Riffle 4		
W/D - Riffle 5		
Weighted W/D		<i>Calculated</i>
FIELD VALUE - Width/Depth Ratio State (O/E)		<i>Calculated from data entered above.</i>

Project Name:

EXISTING or PROPOSED or MONITORING

Wyoming Stream Quantification Tool

Reach ID:

(Select one)

Field Value Documentation

Floodplain Connectivity

Bank Height Ratio

Item	Value	Notes
BHR - Riffle 1		
BHR - Riffle 2		
BHR - Riffle 3		
BHR - Riffle 4		
BHR - Riffle 5		
FIELD VALUE - Weighted Bank Height Ratio (ft/ft)		<i>Calculated from data entered above.</i>

Entrenchment Ratio

ER - Riffle 1		
ER - Riffle 2		
ER - Riffle 3		
ER - Riffle 4		
ER - Riffle 5		
FIELD VALUE - Weighted Entrenchment Ratio (ft/ft)		<i>Calculated from data entered above.</i>

Percent Side Channels (%)

Provide the filepath or location of aerial image depicting side channel locations:

FIELD VALUE - Percent Side Channels (%)		<i>Pulls from project reach form.</i>
--	--	---------------------------------------

Project Name:

EXISTING or PROPOSED or MONITORING

Wyoming Stream Quantification Tool

Reach ID:

(Select one)

Field Value Documentation

Geomorphology

Large Woody Debris

LWD Index

Provide the filepath or location of the LWDI form:

Item

Value

Notes

FIELD VALUE - LWDI

No. of LWD Pieces/ 100 meters

FIELD VALUE - No of LWD Pieces / 100 m

Pulls from project reach form.

Lateral Migration

Dominant BEHI/NBS

Provide the filepath or location of the figure depicting BEHI/NBS banks and ratings:

Total Length of Bank Assessed (ft)

BEHI/NBS Category 1

Total Bank Length for Category 1 (ft)

BEHI/NBS Category 2

Total Bank Length for Category 2 (ft)

BEHI/NBS Category 3

Total Bank Length for Category 3 (ft)

BEHI/NBS Category 4

Total Bank Length for Category 4 (ft)

BEHI/NBS Category 5

Total Bank Length for Category 5 (ft)

BEHI/NBS Category 6

Total Bank Length for Category 6 (ft)

FIELD VALUE - Dominant BEHI/NBS

If this information is provided elsewhere, provide filepath or location; do not re-enter data.

Percent Streambank Erosion (%)

Length of Eroding Streambanks

Representative Sub-reach Length (ft)

FIELD VALUE - Percent Streambank Erosion (%)

Pulls from project reach form.

Calculated

Project Name:

EXISTING or PROPOSED or MONITORING

Wyoming Stream Quantification Tool

Reach ID:

(Select one)

Field Value Documentation

Lateral Migration

Greenline Stability Rating

If GSR forms were completed; provide the filepath or location of the form; do not re-enter data below. List sampling method and note the species:

Item	Value	Notes
% Composition of Stability Class 1		
% Composition of Stability Class 2		
% Composition of Stability Class 3		
% Composition of Stability Class 4		
% Composition of Stability Class 5		
% Composition of Stability Class 6		
% Composition of Stability Class 7		
% Composition of Stability Class 8		
% Composition of Stability Class 9		
% Composition of Stability Class 10		
FIELD VALUE - Greenline Stability Rating		

Lateral Migration

Percent Streambank Armoring (%)

Provide the filepath or location of image depicting armoring locations and types:

FIELD VALUE - Percent Streambank Armoring (%)		<i>Pulls from project reach form.</i>
--	--	---------------------------------------

Bed Material Characterization

Percent Fines (%)

Note filepath or location of bed material data:

Total number of particles sampled		
Number of Particles <2mm		
FIELD VALUE - Percent Fines (%)		<i>Calculated</i>

Project Name:

EXISTING or PROPOSED or MONITORING

Wyoming Stream Quantification Tool

Reach ID:

(Select one)

Field Value Documentation

Bed Form Diversity
Pool Spacing Ratio

If the Rapid Survey Form was used, do not
re-enter data here.

Item	Value	Notes
Number of Geomorphic Pools		
Bankfull Riffle Width (ft)		
Pool Spacing Ratio 1		
Pool Spacing Ratio 2		
Pool Spacing Ratio 3		
Pool Spacing Ratio 4		
FIELD VALUE - Pool Spacing Ratio		<i>Calculated</i>

Pool Depth Ratio

If the Rapid Survey Form was used, do not
re-enter data here.

Mean Riffle Depth		
Number of pools measured		
Pool Depth Ratio 1		
Pool Depth Ratio 2		
Pool Depth Ratio 3		
Pool Depth Ratio 4		
Pool Depth Ratio 5		
Pool Depth Ratio 6		
FIELD VALUE - Pool Depth Ratio		<i>Calculated</i>

Percent Riffle (%)

If the Rapid Survey Form was used, do not
re-enter data here.

Representative Sub-Reach Length	0	<i>Pulls from project reach form.</i>
Total Riffle Length in Representative Sub-Reach		<i>Calculated</i>
FIELD VALUE - Percent Riffle (%)		<i>Calculated</i>

Project Name:

EXISTING or PROPOSED or MONITORING

Wyoming Stream Quantification Tool

Reach ID:

(Select one)

Field Value Documentation

Riparian Vegetation - Field Forms Required, values calculated from those forms.

Riparian Extent (%)

Item	Value	Notes
FIELD VALUE - Riparian Extent (%)		<i>Pulls from Riparian Extent form</i>

Woody Vegetation Cover (%)

Number of riparian plots		
Plot 1		
Plot 2		
Plot 3		
Plot 4		
Plot 5		
Plot 6		
Plot 7		
Plot 8		
Plot 9		
Plot 10		
Plot 11		
Plot 12		
Plot 13		
Plot 14		
Plot 15		
Plot 16		
FIELD VALUE - Absolute Woody Cover (%)		<i>Calculated</i>

Herbaceous Vegetation Cover (%)

Number of riparian plots		
Plot 1		
Plot 2		
Plot 3		
Plot 4		
Plot 5		
Plot 6		
Plot 7		
Plot 8		
Plot 9		
Plot 10		
Plot 11		
Plot 12		
Plot 13		
Plot 14		
Plot 15		
Plot 16		
FIELD VALUE - Absolute Herbaceous Cover (%)		<i>Calculated</i>

Project Name:

EXISTING or PROPOSED or MONITORING

Wyoming Stream Quantification Tool

Reach ID:

(Select one)

Field Value Documentation

Percent Native Cover (%)

Item	Value	Notes
Number of riparian plots		
Plot 1		
Plot 2		
Plot 3		
Plot 4		
Plot 5		
Plot 6		
Plot 7		
Plot 8		
Plot 9		
Plot 10		
Plot 11		
Plot 12		
Plot 13		
Plot 14		
Plot 15		
Plot 16		
FIELD VALUE - Relative Native Cover (%)		<i>Calculated</i>

Project Name:

EXISTING or PROPOSED or MONITORING Wyoming Stream Quantification Tool

Reach ID:

(Select one)

Field Value Documentation

Physicochemical

Temperature

Item	Value	Notes
Date & Time First Sensor Reading		
Date & Time Last Sensor Reading		
Sampling Interval		

MWAT (°C)

Provide the filepath or location of a time-series plot of temperature data here:		
Date range of MWAT value		
FIELD VALUE - Maximum Weekly Average Temperature (°C)		

Nutrients

Chlorophyll α (mg/m²)

Provide the filepath or location of laboratory results here:		
Sampling date(s)		
FIELD VALUE - Average Chlorophyll α (across all samples [mg/m²])		

Biology

Macroinvertebrates

Provide the filepath or location of laboratory results here:		
Sampling date(s)		

WSII

FIELD VALUE - WSII		
---------------------------	--	--

RIVPACS

FIELD VALUE - RIVPACS		
------------------------------	--	--

Project Name:

EXISTING or PROPOSED or MONITORING Wyoming Stream Quantification Tool

Reach ID:

(Select one)

Field Value Documentation

Fish

Provide the expected list of native species or the location of the list here. Also provide the names of any aquatic biologists consulted in developing the list.

Describe sampling methods here:

Item	Value	Notes
Date of Sample 1		
Date of Sample 2		

Native Fish Species Richness (% of Expected)

Expected # native fish species		
Observed # native fish species - Sample 1		
Observed # native fish species - Sample 2		
# native fish species in Sample 2 but not Sample 1		
FIELD VALUE - Native Fish Species Richness (%)		<i>Calculated</i>

SGCN Absent Score

No. of Tier 1 SGCN species expected		
No. of Tier 2 SGCN species expected		
No. of Tier 3 SGCN species expected		
No. of Tier 1 SGCN species observed		
No. of Tier 2 SGCN species observed		
No. of Tier 3 SGCN species observed		
FIELD VALUE - Weighted SGCN species Absent		<i>Calculated</i>

Project Name:

EXISTING or PROPOSED or MONITORING Wyoming Stream Quantification Tool

Reach ID:

(Select one)

Field Value Documentation

Game Species Biomass (% Change)

Provide the filepath or location of aerial image depicting control site location:

Describe sampling methods here (if different than above):

Baseline data:

Item	Value	Notes
Date of control site Sample 1		
Date of control site Sample 2		
Average Biomass (Sample 1&2) - Control Site		
Date of project site Sample 1		
Date of project site Sample 2		
Average Biomass (Sample 1&2) - Project Site		

Post-project data:

Year 1: Date of control site sample		
Year 1: Biomass - Control Site		
Year 1: Date of project site sample		
Year 1: Biomass - Project site		
Year 2: Date of control site sample		
Year 2: Biomass - Control Site		
Year 2: Date of project site sample		
Year 2: Biomass - Project site		
FIELD VALUE - Game Species Biomass (% Change)		<i>Calculated. Note: existing condition field value is always 0</i>

Appendix C

Fish Community Assemblage Lists by Basin

Wyoming Game and Fish Department (WGFD). 2017. State Wildlife Action Plan. Wyoming Game and Fish Department, Habitat Program, Cheyenne, WY.

The following lists the fish community assemblages for three stream types in each Wyoming River Basin. The idea behind this list is that they could represent the expected community assemblage in a pristine or even best-attainable system. Assemblages are included for coldwater-high gradient systems, transitional systems (either transitional in slope or temperature), and warmwater-low gradient systems. The species lists are derived from the 2017 Draft State Wildlife Action Plan (WGFD 2017). These species were assigned to cold, transitional or warm assemblages based on professional judgment. Fish species that normally exist in lakes and only occasionally occur in flowing water (and do not depend on flowing water) in Wyoming (lentic species) are not included. Those species include: Black Crappie, Bluegill, Emerald Shiner, Freshwater Drum, Gizzard Shad, Green Sunfish, Goldfish, Golden Shiner, Golden Trout, Grass Carp, Grayling, Kokanee Salmon, Lake Trout, Largemouth Bass, Northern Pike, Pumpkinseed, Rock Bass, Smallmouth Bass, Spottail Shiner, Walleye, White Crappie, and Yellow Perch.

Table C.1. Wyoming stream fish species occurrence in major basins (SWAP 2017). “N” denotes native to the basin and “P” indicates present but not native to the basin. An “E” indicates a fish species that has been historically extirpated from the basin. Extirpated species should not be included in assembling the best attainable fish community assemblage.

Species	Tier	Cold	Transitional	Warm	Bear	Green	Platte	Snake/Salt	Yellowstone	NE Missouri
Bigmouth Shiner	III		X	X			N			
Black Bullhead				X			N		P	N
Bluehead Sucker	I		X	X	N	N		N		
Bonneville Cutthroat	II	X	X		N	P	P	P	P	
Brassy Minnow	III		X	X			N		N	N
Brook Stickleback			X	X			P		P	P
Brook Trout		X	X		P	P	P	P	P	P
Brown Trout			X		P	P	P	P	P	P
Burbot	II					P			N	
Central Stoneroller			X	X			N			N
Channel Catfish			X	X		P	N		N	N
Colorado Pikeminnow				X		E				
Colorado River Cutthroat	II	X				N	P		P	
Common Carp			X	X	P	P	P		P	P
Common Shiner	III		X	X			N			
Creek Chub			X	X		P	N		N	N
Fathead Minnow			X	X	P	P	N	P	N	N
Finescale Dace	II									N
Flannelmouth Sucker	I		X	X		N				
Flathead Chub	III		X	X			N		N	N
Goldeye	II			X			N		N	N
Greenback Cutthroat		X					E			
Hornyhead Chub	I		X				N			
Iowa Darter	II		X	X		P	N			N

Species	Tier	Cold	Transitional	Warm	Bear	Green	Platte	Snake/Salt	Yellowstone	NE Missouri
Johnny Darter			X	X			N		P	
Kendall Warm Springs Dace	I		X			N				
Lake Chub			X	X		P	N		N	N
Longnose Dace		X	X		N	P	N	N	N	N
Longnose Sucker		X	X	X		P	N		N	P
Mottled Sculpin		X	X		N	N		N	P	
Mountain Sucker		X	X		N	N	N	N	N	N
Mountain Whitefish			X		N	N		N	N	
Northern Leatherside Chub	II		X		N	P		N		
Northern Plains Killifish	II		X	X			N		P	P
Northern Pearl Dace	II			X						N
Orangethroat Darter	II			X			N			
Paiute Sculpin		X	X		N			N		
Plains Minnow	II			X			E		N	N
Plains Topminnow	II			X			N			N
Quillback				X			N			
Rainbow Trout		X	X		P	P	P	P	P	P
Redside Shiner			X	X	N	P		N		
Red Shiner			X	X			N			N
River Carpsucker				X			N		N	N
Roundtail chub	I		X	X		N				
Sand Shiner			X	X		P	N		N	N
Sauger	II		X	X			N		N	
Shorthead Redhorse				X			N		N	N
Shovelnose Sturgeon	II			X			E		N	
Speckled Dace			X	X	N	N		N		
Snake River Cutthroat ¹	II	X	X		P	P	P	N	P	P
Stonecat			X	X			N		N	N
Sturgeon Chub	II			X			E		N	
Suckermouth Minnow	II			X			N			
Utah Chub			X	X	N	P		N		
Utah Sucker			X	X	N	P		N		
Western Silvery Minnow	II			X					N	N
Western Mosquitofish				X			P			
White Sucker			X	X		P	N	P	N	N
Yellowstone Cutthroat ¹	II	X	X			P	P	N	N	

¹ Snake River Cutthroat trout and Yellowstone cutthroat trout are managed separately but considered variants of the same subspecies in Wyoming.

Appendix D

Bankfull Verification Examples

This appendix is reproduced from CSQT Checklist.

USACE. 2021. Colorado Stream Quantification Tool and Debit Calculator Review Checklist.
U.S. Army Corps of Engineers, Albuquerque District, Pueblo Regulatory Office.

Appendix 4: Bankfull Verification Examples

The bankfull verification process is described in Section 2.6 of the CSQT User Manual (UM; USACE 2020). This appendix provides examples for the bankfull verification methods from the UM and are shown here in Figure 1. Bankfull identification (described in Appendix A of the UM) should be performed by professionals with a background in geomorphology and the necessary experience to accurately complete the methods described in the UM. Bankfull discharge modeling and return interval calculations should be performed by engineers or hydrologists with experience with hydrologic and hydraulic modeling in Colorado, including the modeling of water diversions and withdrawals.

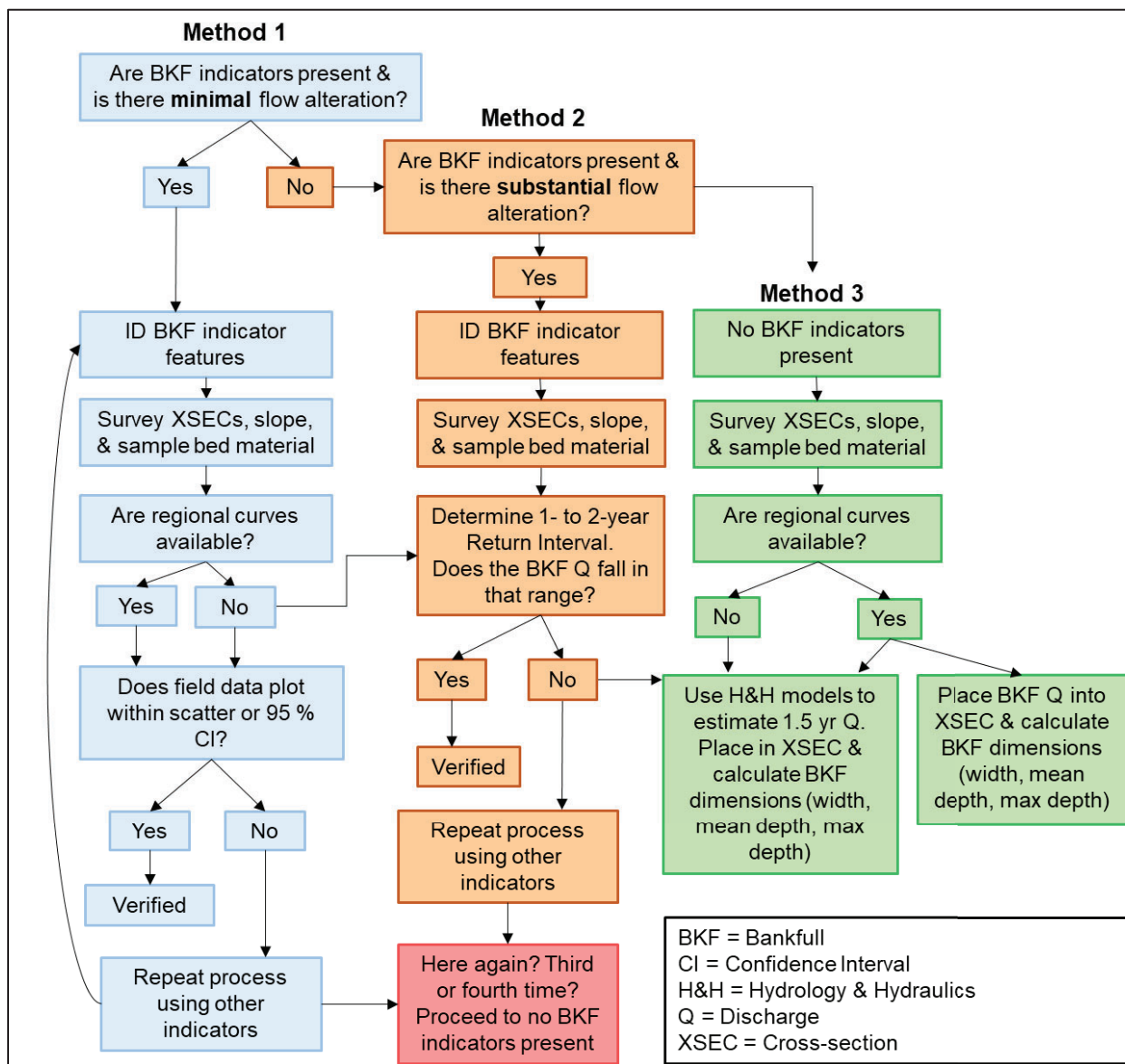


Figure 1. Bankfull verification flow chart duplicated from the CSQT User Manual.

Practitioners and regulators should always start with the field identification of geomorphic features: inner berm, bankfull, and the terrace. Bankfull indicators should be sought for all sites following the instructions provided in UM Appendix A, Section 3. These instructions include quality control and descriptions of primary and secondary field indicators. If these features are identified, they should be tested and verified with Methods 1 and 2. This is often an iterative process. If geomorphic features are not present due to urban or other impacts, then Method 3 can be used. Use of Method 3 as shown in Figure 1 requires sufficient explanation and rationale demonstrating no field indicators were present or those identified were insufficient.

The general process of bankfull identification and verification is provided below using an example.

1. Identify bankfull indicators at the site.

Following the checklist format from UM Appendix A, Section 3, field indicators of bankfull throughout the reach are recorded. Field notes for the difference between water surface elevation and suspected bankfull indicators are recorded on the required Project Reach Form (Figure 2). The difference between water surface and bankfull should be similar among all measurements. Note, the difference between water surface and other geomorphic features, such as the inner berm or terrace, might differ from that of the bankfull feature. For example, it is common for the difference between water surface and the inner berm to be half of the difference between water surface and bankfull. The difference between water surface and a terrace will be greater than the difference between water surface and bankfull.

II.		Reach Walk						
A.	Difference between bankfull (BKF) stage and water surface (WS) (ft)	1.1	1.2	1.0	1.1	1.1	1.2	
	Difference between BKF stage and WS (ft) <i>Average or consensus value from reach walk.</i>		1.1					

Figure 2. Project Reach Form difference between bankfull and water surface example.

Where detailed survey methods were implemented, the difference between water surface and bankfull should be consistent between the surveyed cross-sections and the longitudinal profile. This can be visually observed by comparing the slope of the best-fit-line through bankfull indicators in the longitudinal profile and compare that slope to the water surface slope for the reach. These two lines should be parallel, as shown in the longitudinal profile (e.g., Figure 4, Appendix 2 of this document).

For this example, an incised channel is being used; a photo of the channel and geomorphic indicators is provided in Figure 3. There are three geomorphic indicators present at this site: inner berm, bankfull, and terrace. The back of a floodplain bench is identified as being the most

likely bankfull feature. The inner berm is the front of the bench, and the terrace is the top of bank. Note, all three features could be tested against the regional curve; however, since the back of the bench in a small, incised channel is often the bankfull feature, it is tested first. The difference between water surface and the potential bankfull feature was measured at several places along the reach. The measured values and the average were recorded in Figure 2.

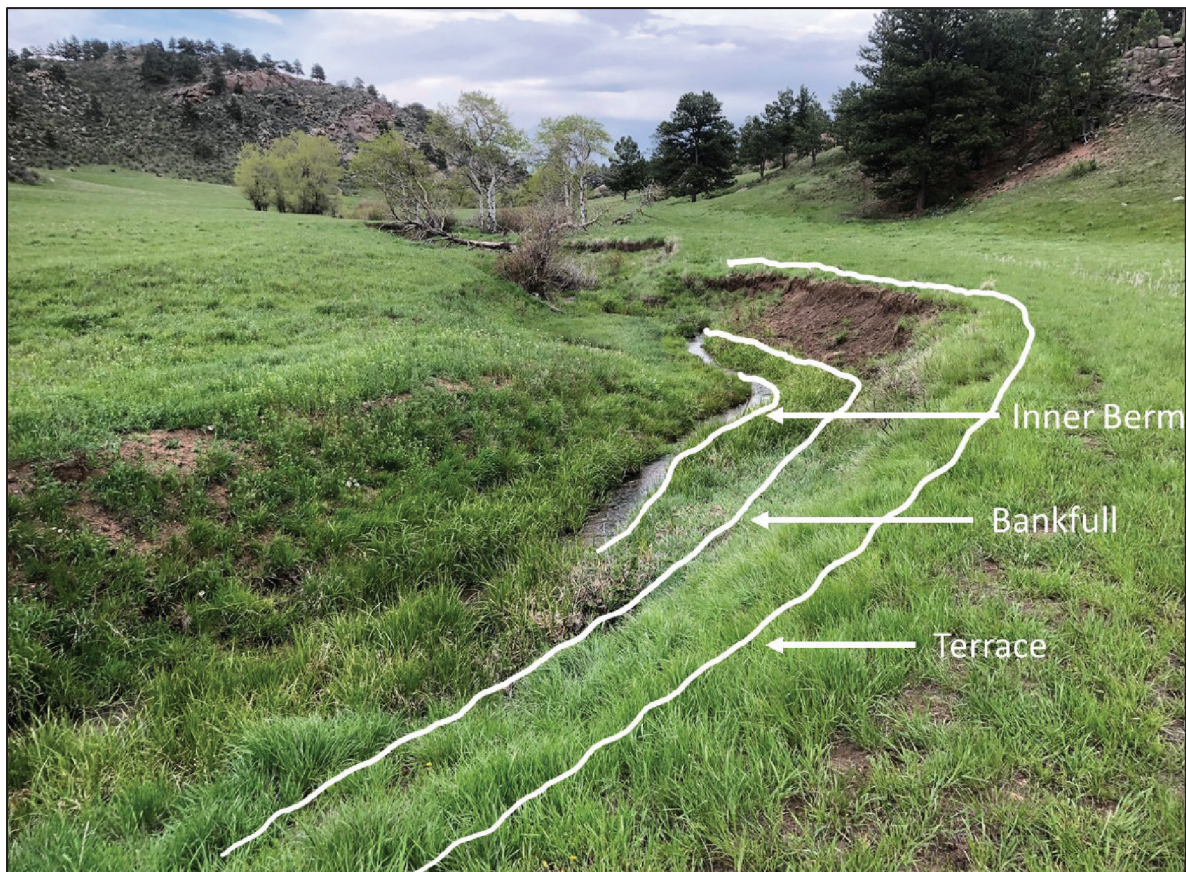


Figure 3. Bankfull identification example showing inner berm, bankfull, and terrace geomorphic features.

Differences between water surface and both inner berm and terrace elevations were also recorded in case they were needed for bankfull verification. The inner berm averaged 0.5 feet above water surface elevation on the day of the survey and the terrace was 4.0 feet above water surface elevation. The next steps include:

2. Survey riffle cross-sections and slope, and sample bed material.
3. Process cross-section data.

A rapid survey was performed for a riffle cross-section with a strong bankfull indicator.¹ The cross-sectional area, width, and mean depth associated with each of the features identified

¹ Rapid survey instructions are provided in UM Appendix A.

Colorado Stream Quantification Tool and Debit Calculator Review Checklist

Appendix 4

(suspected bankfull, inner berm, and terrace) were calculated. The slope for the reach was measured across a riffle-pool sequence as 1.8% and the D84 was 90mm. This information was used to make the following calculations:

$$\text{Inner Berm Area} = 3 \text{ ft}^2$$

$$\text{Bankfull Area} = 10 \text{ ft}^2$$

$$\text{Terrace Area} = 80 \text{ ft}^2$$

$$\text{Bankfull Discharge} = 40 \text{ cfs}$$

This information can now be used with a bankfull regional curve (Method 1 in Figure 1) and/or flood frequency analysis (Method 2 in Figure 1) to verify the bankfull feature.

Method 1

Method 1 from the flow chart uses bankfull regional curves, preferably watershed-specific regional curves, to verify the field-identified feature. Regional curves are relationships derived from sites with well-formed bankfull features that relate bankfull dimensions (most often bankfull cross-sectional area at a riffle) to drainage area. A watershed-specific regional curve is preferable for validating field indicators because it ensures that the sites used to develop the regional curve are under the same climatic, geologic, and anthropogenic influences as the project. Watershed-specific regional curves require field identification of bankfull at sites in the same watershed as the project, preferably sites with similar drainage area and then within ± 1 log scale of the project drainage area. For example, a project with a drainage area of around 7 sq. mi., surveys of bankfull should occur at sites ranging from about 1 to 100 square miles.

Using Method 1, the data from the example project were overlayed onto a watershed-specific curve shown in Figure 4. The graph shows the inner berm feature, bankfull, and terrace cross-sectional areas overlayed onto the regional curve data. The dashed lines represent the range of scatter and were added by hand as an aid in visualizing the upper and lower range of scatter. Some regional curves are published with 95% confidence limits or intervals. If the regional curve includes statistically produced confidence limits, they should be used rather than a hand drawn line. The overlay shows that the inner berm plots well below, and the terrace plots well above the range of scatter. The cross-sectional area for the bankfull feature falls within the range of scatter and is therefore confirmed as the bankfull feature. An example bankfull verification form is provided at the end of this appendix.

Published regional curves are shown in Table 1, note that Blackburn-Lynch (2017) provides additional equations for hydrologic landscape units. Refer to the source material to determine applicable range of drainage area, standard error, or range of scatter associated with calculated values.

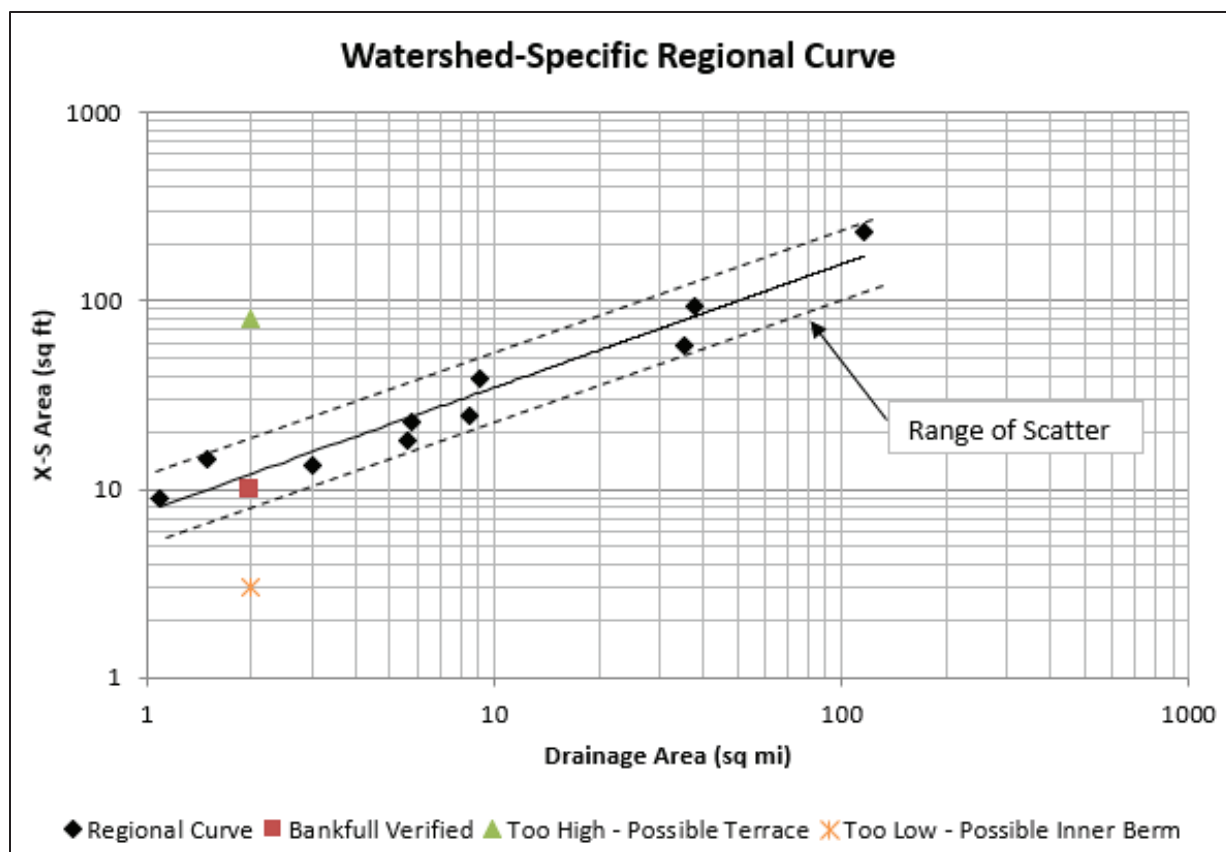


Figure 4. Example watershed-specific regional curve showing features surveyed at a project site that corresponded to inner berm (below the range of scatter), bankfull (verified), and a terrace (above the range of scatter).

Table 1. Published Regional Curves applicable to various areas of Colorado.

$$A_{BKF} = a(\text{Drainage Area})^b$$

Physiographic Province	Units	a	b	R2	Reference
Great Plains	Metric	0.36	0.54	0.63	Blackburn-Lynch (2017)
Middle Rocky Mountains	Metric	0.69	0.50	0.57	Blackburn-Lynch (2017)
Southern Rocky Mountains	Metric	0.41	0.50	0.63	Blackburn-Lynch (2017)
Wyoming Basin	Metric	0.06	0.84	0.83	Blackburn-Lynch (2017)
Rocky Mountain Hydrologic Region in Wyoming	S.I.	8.6	0.62	0.85	Foster (2012)

Method 2

If a regional curve for the cross-sectional area is not available and cannot be developed, then a flood frequency analysis can be used to check the field-derived bankfull value. This method can also be used to further verify the bankfull determination made in Method 1. Note, Method 1 should not be skipped; Method 2 follows Method 1 per the flow chart.

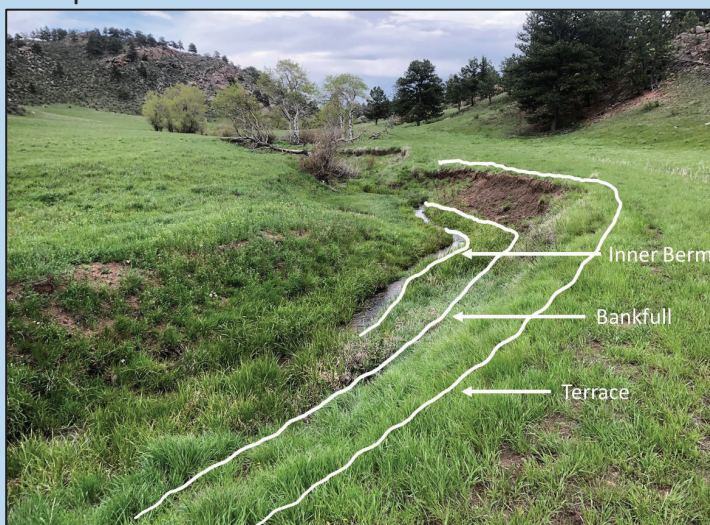
Flood frequency analysis is based on discharge rather than area and it is important to remember that unless velocity is measured in the field (average velocity for a cross-section using a flow meter) then the calculated discharge value for a cross-section is a coarse estimate.

In the absence of a regional curve, the USGS published regression equations, and statistical hydrologic models implemented in an application called StreamStats can be used for bankfull verification. StreamStats is the most likely source of flood frequency data.² The practitioner should determine whether values from StreamStats are reasonable for the site. Generally, the extent of flow alteration for the project area may mean different methods for estimating return interval discharge are needed (e.g., hydrologic process modeling). This section provides two examples to show how Method 2 can be used with the data provided by StreamStats.

- Example A uses the data from the example above to further verify the bankfull determination.
- Example B uses a new example, where a bankfull regional curve was not available to make the verification.

² <https://streamstats.usgs.gov>

Example A: Further verification



Cross-sectional area (A) = 10 ft²

Slope (S) = 1.8%

Riffle D84 = 90mm used to estimate roughness value "n"

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} = 40 \text{ CFS}$$

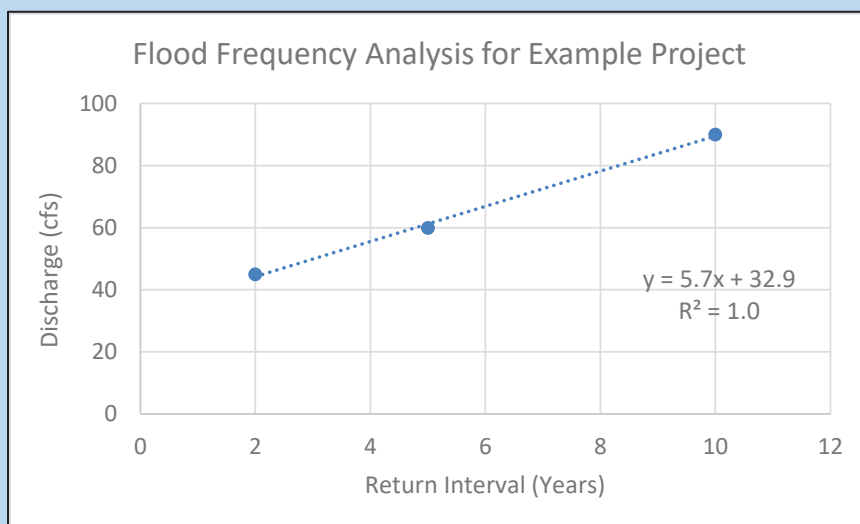
Where R is the hydraulic radius calculated from the cross-section data.

StreamStats was used to calculate discharge values for the 2-, 5-, and 10-year return intervals. StreamStats calculates higher return intervals, but these are not needed (or preferred) for this analysis. Relationships are not linear and thus, including higher return interval events will affect the interpolation of the 1.5-year return interval.

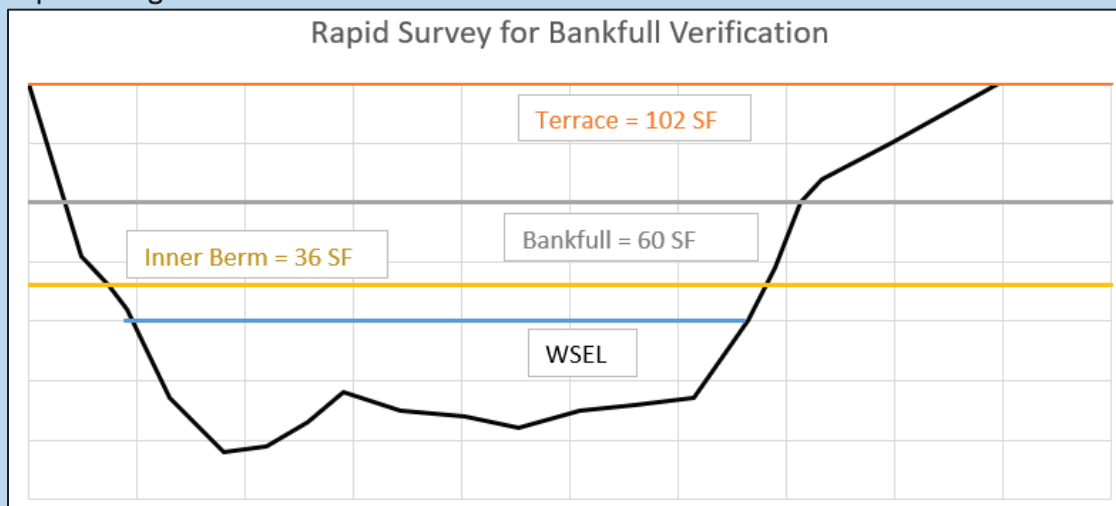
The StreamStats data were used to create the graph below. A linear regression line and equation were created from the data. The equation was then used to estimate the 1.5-year return interval discharge, as shown in equation (1).

$$\begin{aligned} (1) \text{ Discharge (cfs)} &= 5.7 (RI) + 32.9, \text{ where: } RI \text{ equals the 1.5-year return interval.} \\ &= 5.7(1.5) + 32.9 = 41 \text{ cfs} \end{aligned}$$

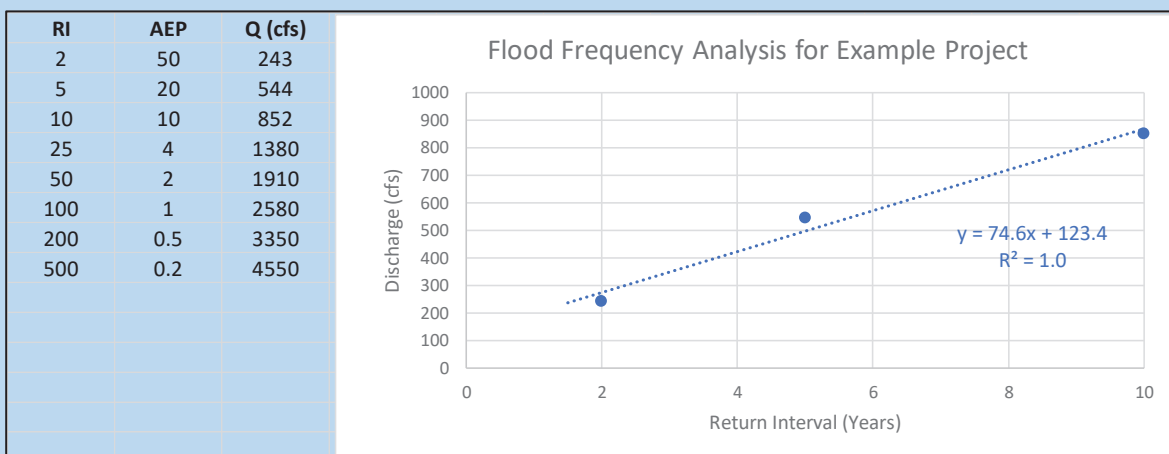
This value is very close to the 40 cfs estimated from the field data and further verifies that the back of the floodplain bench represents the bankfull feature.



Example B: Regional curve is not available



For this site, bankfull indicators were identified throughout the reach, the bankfull stage was associated with a bankfull cross-sectional area of 60 ft², which was used to calculate a bankfull discharge of 180 cfs. There were no regional curve data for the site, so a flood frequency analysis was performed to verify bankfull. Values from StreamStats and the USGS references for the flood frequency prediction equations are shown below. The 1.5-year return interval discharge is calculated as 235 cfs which is close to the 180 cfs estimated from the field data. This analysis verifies the bankfull feature that corresponds to 60 ft² cross-sectional area at the cross-section above.



Capesius, J.P., and Stephens, V. C., 2009, Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado: U. S. Geological Survey Scientific Investigations Report 2009-5136, 32 p.

Kohn, M.S., Stevens, M.R., Harden, T.M., Godaire, J.E., Klinger, R.E., and Mommandi, A., 2016, Paleoflood investigations to improve peak-streamflow regional-regression equations for natural streamflow in eastern Colorado, 2015: U.S. Geological Survey Scientific Investigations Report 2016-5099, 58 p.

Method 3

Method 3 should only be used after following the flow chart through Methods 1 and 2. Bankfull indicators should be sought for all sites following the instructions provided in UM Appendix A, Section 3. Use of Method 3 requires sufficient explanation and rationale demonstrating no field indicators were present or those identified were unable to be verified (e.g., Figure 5). Without field indicators of the discharge that forms, maintains, and shapes channel dimensions, bankfull can be determined using Method 3, which relies solely on desktop methods. A bankfull discharge value is calculated and applied to a surveyed cross-section (Figure 6).



Figure 5. Urban channel devoid of bankfull indicators.

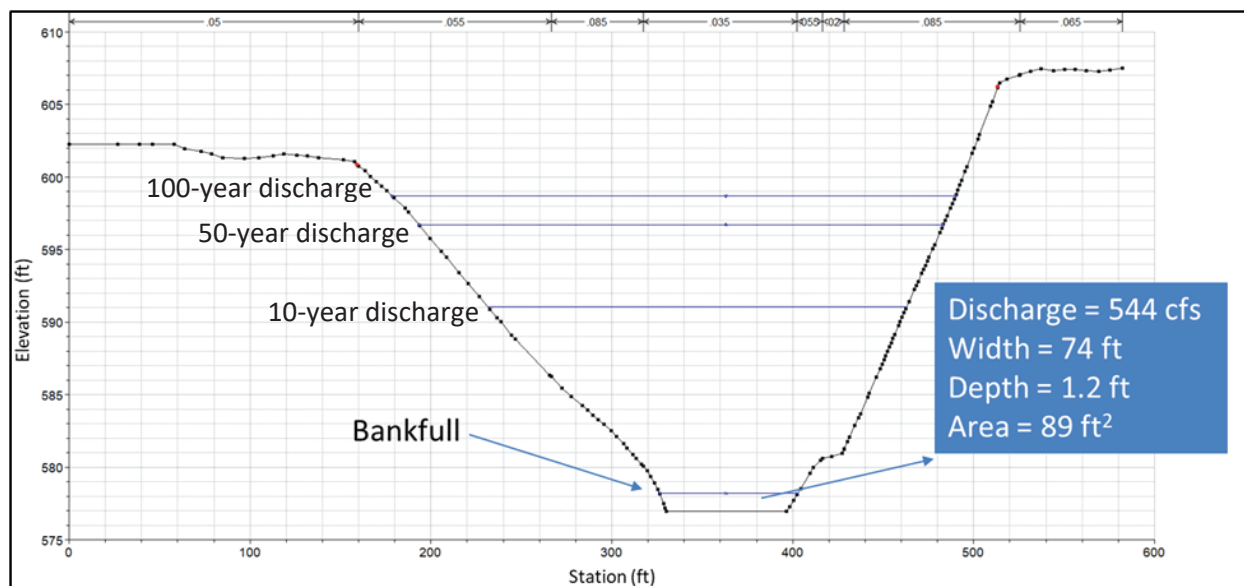


Figure 6. Bankfull discharge and other return interval flows shown on a cross-section using HEC-RAS.

Where regional curve data are available and applicable to the project area or project reach, the regional curve is used to calculate a discharge value. The discharge is then input into a hydraulic model, e.g., a single-section analyzer or HEC-RAS, to determine the corresponding dimensions (bankfull area, width, and mean depth). Figure 6 shows the example output from a HEC-RAS model with bankfull dimensions and calculated discharge. The bankfull, 10-year, 50-year, and 100-year discharges were input into HEC-RAS. The output is the cross-section showing the stage of bankfull and each return interval flow.

Where regional curves are not available, the practitioner may rely on hydrologic modeling to estimate the 1.5-year discharge (bankfull). Revisiting the discharge values reported by Stream Stats (Example B on page 8) and considering standard error (Figure 7), the bankfull discharge at the site may range from 100 to 300 cfs. This discharge is then placed in the cross-section using the same method as described in the paragraph above. This method results in a high level of uncertainty around the bankfull value. While this may be acceptable **for impact activities**, additional analyses and a discussion of risk will be needed when this method is used for restoration designs.

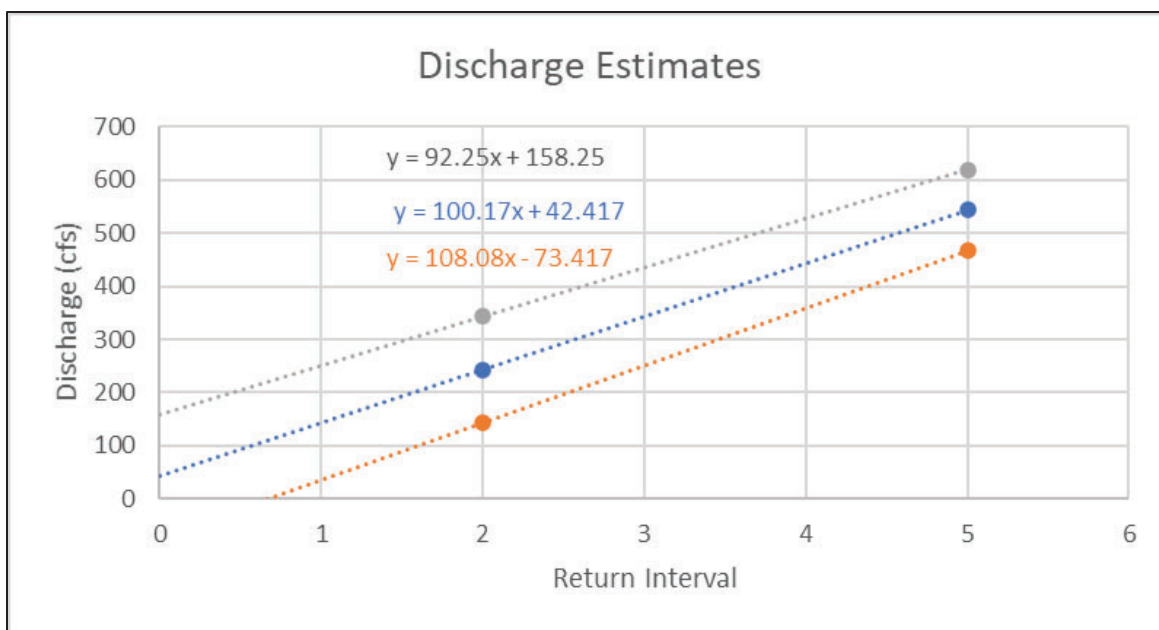


Figure 7. Example extrapolation using 2- and 5-year known discharges to estimate bankfull discharge. Standard error is depicted by the top (gray) and bottom (orange) linear relationships. References for the flood frequency analysis and standard error are provided in Example B, page 8.

Method 3 as preparation for a site visit

Method 3 provides a desktop method that can be used before going in the field to get an idea of where to look for bankfull at a project site. It is highly recommended to determine approximate expected bankfull dimensions before going into the field. Alternatively, the Torizzo and Pitlick (2004) equations (provided below) can be used to quickly estimate width and depth from estimated bankfull discharge.

$$Width = 3.25 Q^{0.56}$$

$$Mean Depth = 0.31 Q^{0.26}$$

Note, mean depth is not the same as the maximum depth measured to the thalweg elevation. It can be coarsely measured in the field between bankfull and the bottom edge of channel (the break in slope between the channel bottom and start of the streambank).

References

Blackburn-Lynch W, Agouridis CT, Barton CD. 2017. Development of regional curves for hydrologic landscape regions (HLR) in the contiguous United States. Journal of American Water Resources Association (JAWRA). 53(4):903-928. <https://doi.org/10.1111/1752-1688.12540>

Foster, K. 2012. Bankfull-Channel Geometry and Discharge Curves for the Rocky Mountains Hydrologic Region in Wyoming. Scientific Investigations Report 2012-5178, U.S. Geological Survey.

Torizzo M, Pitlick J. 2004. Magnitude-frequency of bed load transport in mountain streams in Colorado. Journal of Hydrology. 290(1-2):137-151.

U.S. Army Corps of Engineers (USACE). 2020. Colorado Stream Quantification Tool (CSQT) User Manual and Spreadsheets. Version 1.0. U.S. Army Corps of Engineers, Albuquerque District, Pueblo Regulatory Office.

Appendix E

Savery Creek WSQT Workbook and Select Forms

Function-based Parameter		Metric(s)	Applicability
<input checked="" type="checkbox"/>	Reach Runoff*	<input checked="" type="checkbox"/> Land Use Coefficient* (D) AND Concentrated Flow Points* (F)	All streams and flow types.
<input type="checkbox"/>	Baseflow Dynamics	<input type="checkbox"/> Average Velocity AND Average Depth (D/F)	Use INSTEAD OF Bankfull Dynamics where hydraulic conditions during summer/fall baseflow periods should support trout assemblages (coldwater perennial or intermittent streams).
<input checked="" type="checkbox"/>	Bankfull Dynamics*	<input checked="" type="checkbox"/> Width/Depth Ratio State* (D/F)	Use in single-thread channels.
<input checked="" type="checkbox"/>	Floodplain Connectivity*	<input checked="" type="checkbox"/> Bank Height Ratio* AND Entrenchment Ratio (F)	Omit ER in multi-thread channels.
		<input type="checkbox"/> Percent Side Channels (F)	Metric applicable in alluvial valleys with single-thread channels that support side-channels.
<input type="checkbox"/>	Large Woody Debris (LWD)	<input type="checkbox"/> LWD Index (F)	Use in systems with forested catchments, riparian gallery forests, or that otherwise naturally have a supply of LWD. This parameter can also be used where LWD is an appropriate element in restoration.
		<i>or</i>	
		<input type="checkbox"/> No. of LWD Pieces/ 100 meters (F)	
<input checked="" type="checkbox"/>	Lateral Migration*	<input checked="" type="checkbox"/> Dominant BEHI/NBS AND Percent Streambank Erosion (F)	Use in single-thread channels.
		<i>or</i>	
		<input type="checkbox"/> Greenline Stability Rating (F)	Likely more applicable in streams naturally unstable.
		<input type="checkbox"/> Percent Armoring (F)	Use in addition to the other metric(s) when man-made armoring is present or proposed in the project reach.
<input type="checkbox"/>	Bed Material Characterization	<input type="checkbox"/> Percent Fines (F)	Applicable where reach wide d50 > 2mm and fine sediment deposition over coarse bed material is occurring or expected.
<input checked="" type="checkbox"/>	Bed Form Diversity*	<input checked="" type="checkbox"/> Pool Spacing Ratio AND Pool Depth Ratio* AND Percent Riffle* (F)	Applicable in perennial and intermittent single-thread channels. Omit pool spacing ratio in bedrock dominated systems.
<input checked="" type="checkbox"/>	Riparian Vegetation*	<input checked="" type="checkbox"/> Riparian Extent (D/F) AND Woody Vegetation Cover (F) AND Percent Native Cover (F) AND for CWA 404 projects Herbaceous Cover (F).	Where absolute woody vegetation cover is/should be >20%.
		<input type="checkbox"/> Riparian Extent (D/F) AND Herbaceous Vegetation Cover (F) AND Percent Native Cover (F)	Where absolute woody vegetation cover is/should be <20%.
<input type="checkbox"/>	Temperature	<input type="checkbox"/> Maximum Weekly Average Temperature (F)	Use these parameters and metrics for impacts or for projects with goals related to water quality improvements.
<input type="checkbox"/>	Nutrients	<input type="checkbox"/> Chlorophyll (F)	
<input type="checkbox"/>	Macroinvertebrates	<input type="checkbox"/> WSII AND RIVPACs (F)	Use for impacts, for projects with goals related to biological improvements or where project may impact conservation areas or other valuable fish habitats.
<input type="checkbox"/>	Fish	<input type="checkbox"/> Native Fish Species Richness AND SGCN Absent (F)	
		<input type="checkbox"/> Game Species Biomass (F)	
* Include in all assessments (D) indicates metrics are calculated using desktop methods (F) indicates metrics are calculated or verified using field methods			

I. Site Information

Project Name:	Savery Creek Restoration
Reach ID:	Reach 11-12
Drainage Area (sq. mi.):	107 (pre-dam), 28.5 (post-dam)
Flow Permanence:	Perennial
River Basin:	Green River
Valley Type:	Alluvial
Stream Reach length (ft):	1010
Upstream Latitude:	41.28639
Upstream Longitude:	-107.32037

Note: if form is being used for proposed condition scores, do not complete Section IIA or Section III.

Shading Key
Desktop Value
Field Value
Calculation

II. Reach Walk

A.	Difference between bankfull (BKF) stage and water surface (WS) (ft)	1.3	1	1.2	1.2	1.1	1.1	
	Difference between BKF stage and WS (ft) <i>Average or consensus value from reach walk.</i>		1.2					
B.	Number Concentrated Flow Points	0						
	Concentrated Flow Points/ 1,000 L.F.	0.0						
C.	Length of Armoring on banks (ft)	15	10	22	19			
	Total (ft)	66.0						
	Percent Armoring (%)	3.3%	Armoring by weir on each side					
D.	Length of Side Channels (ft)	0						
	Total (ft)	0.0						
	Percent Side Channels (%)	0%						

III. Identification of Representative Sub-Reach

Representative Sub-Reach Length At least 20 x the Bankfull Width	753	20*Bankfull Width	560.0
Latitude of downstream extent:	41 15.784		
Longitude of downstream extent:	107 19.700		

Sub-Reach Survey Method

- ☐ Rapid Survey
☐ Detailed - Longitudinal Profile and Cross Sections

IV. Bankfull Verification and Stable Riffle Cross Section

Is Cross Section located within Representative Sub-Reach?

☐ Yes ☐ No

If no, explain why:

A.	Bankfull Width (ft)	27.9
B.	Bankfull Mean Depth (ft) = Average of cross-section depths	1.2
C.	Bankfull Area (sq. ft.) Width * Mean Depth	32.5
D.	Regional Curve Bankfull Width (ft)	
E.	Regional Curve Bankfull Mean Depth (ft)	
F.	Regional Curve Bankfull Area (sq. ft.)	
G.	Curve Used	
H.	Does the the bankfull area fall within the range of scatter from the regional curve?	

Cross Section Measurements Depth measured from bankfull			
Station	Depth	Station	Depth
4	0.8	22	1.5
7	1.4	25	0.8
9	1.35	27	0.3
12	1.7	27.9	0
13	1.8		
15	1.9		
17	1.8		
19	1.6		

NOTE: Space is provided here to survey a cross section using rapid survey methods.

Cross Section Calculations					
W	Ave D	Area	W	Ave D	Area
-	-	-	3	1.55	4.65
3	1.1	3.3	3	1.15	3.45
2	1.375	2.75	2	0.55	1.1
3	1.525	4.575	0.9	0.15	0.135
1	1.75	1.75			
2	1.85	3.7			
2	1.85	3.7			
2	1.7	3.4			

V. Stream Classification

A.	Width Depth Ratio (ft/ft) Bankfull Width / Bankfull Mean Depth	24.0	<i>Average slope from the representative sub-reach will be measured and calculated.</i>
B.	Bankfull Max Riffle Depth	1.9	
C.	Floodprone Area Width (ft)	101	
D.	Entrenchment Ratio (ft/ft) Floodprone Area Width / Bankfull Width	3.6	
E.	Slope Estimate (%)	0.4	
F.	Channel Material Estimate	32	
	Stream Length (ft)	5552	
G.	Valley Length (ft)	3361	
	Sinuosity	1.65	
H.	Stream Type	C4	

Quick Rosgen Stream Classification Guide (Rosgen, 1996)

ER < 1.4		1.4 < ER < 2.2	ER > 2.2	
WDR < 12	WDR > 12	WDR > 12	WDR < 12	WDR > 12
A or G	F	B	E	C

VI. Large Woody Debris (328 ft assessment length within Sub-Reach)

A.	Number of Pieces	4	<i>NOTE: Complete this section only if the LWDI is not being used. Otherwise complete the LWDI Field Form.</i>
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VII. Representative Sub-Reach Sketch

VIII. Notes

Reach ID: Reach 11

I. Riffle Data (Floodplain Connectivity & Bed Form Diversity)

A. Representative Sub-Reach Length	756	20*Bankfull Width	558.0
------------------------------------	-----	-------------------	-------

B. Bank Height & Riffle Data: Record for each riffle in the Sub-Reach

	R1	R2	R3	R4	R5	R6	R7	R8	R9
Begin Station	74	108	225	267	460	507	600	663	724
End Station	100	162	236	327	469	574	624	669	756
BKF Width (ft)	47	27.9	29	21	26	25	29	32	33
Low Bank Height (ft)	3.15	1.9	2.85	1.8	2.75	1.6	2.4	1.6	2.2
BKF Max Depth (ft)	3.15	1.9	2.85	1.8	2.75	1.6	2.4	1.6	2.2
BKF Mean Depth (ft)	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Flood Prone Width (ft)	120	101	115	93	71	47	213	197	182
Riffle Length (ft) <i>Including Run</i>	26	54	11	60	9	67	24	6	32
Bank Height Ratio (BHR) Low Bank H / BKF Max D	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Entrenchment Ratio (ER)	2.6	3.6	4.0	4.4	2.7	1.9	7.3	6.2	5.5
W/D BKF Width/BKF Mean Depth	39.2	23.3	24.2	17.5	21.7	20.8	24.2	26.7	27.5
BHR * Riffle Length (ft)	26.0	54.0	11.0	60.0	9.0	67.0	24.0	6.0	32.0
ER * Riffle Length (ft)	66.4	195.5	43.6	265.7	24.6	126.0	176.3	36.9	176.5
W/D * Riffle Length (ft)	1018.3	1255.5	265.8	1050.0	195.0	1395.8	580.0	160.0	880.0

C. Total Riffle Length (ft)	289.0
D. Weighted BHR $\frac{\sum(Bank\ Height\ Ratio_i \times Riffle\ Length_i)}{\sum Riffle\ Length}$	1.0
E. Weighted ER	3.8
Weighted W/D (Observed; O)	23.5
F. Reference W/D (Expected; E)	20.0
Width/Depth Ratio State (O/E)	1.2
G. Percent Riffle (%)	38%

Shading Key

Field Value

Calculation

Desktop Value

II. Pool Data (Bed Form Diversity)**A. Pool Data: Record for each pool within the Sub-Reach**

	P1	P2	P3	P4	P5	P6	P7	P8	P9
Geomorphic Pool?		G	G				G	G	
Station	61	105	204	251	376	490	590	635	670
	0.0	105.0	204.0	204.0	204.0	204.0	590.0	635.0	635.0
P-P Spacing (ft)	X		99.0				386.0	45.0	
Pool Spacing Ratio Pool Spacing/BKF Width	X		3.5				13.8	1.6	
Pool Depth (ft) Measured from BKF	6.25	3.55	4.35	4.25	4.65	4.25	5.05	4.85	4.15
Pool Depth Ratio Pool Depth/BKF Mean Depth	5.4	3.0	3.7	3.6	4.0	3.6	4.3	4.2	3.6

B. Average Pool Depth Ratio	3.9	C. Median Pool Spacing Ratio	3.5
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III. Slope

	Begin	End	Difference	Slope (ft/ft)
Station along tape (ft)				
Stadia Rod Reading (ft)				

IV. Notes

Date: 6/30/2020

Investigators: Dey, McCoy, Mead

Sub-Reach Name: 11

Sub-Reach Length: 756

MONITORING

Wyoming Stream Quantification Tool
Riparian Vegetation Form

#Plots/side: 4

Random Start #(1-20):

14

Plot Information

Plot Information		Station ID: 14	Station ID: 164	Station ID: 314	Station ID: 464
		Cover Type: S	Cover Type: S	Cover Type: S	Cover Type: S
		Location: IM	Location: OM	Location: S	Location: S
		L or R bank: L	L or R bank: L	L or R bank: L	L or R bank: L
Trees (32x32ft)	N/I	% Cover	% Cover	% Cover	% Cover
Tree Absolute Cover Subtotal		0	0	0	0
Shrubs (16x16ft)	N/I	% Cover	% Cover	% Cover	% Cover
Booth's Willow (<i>Salix boothi</i>)	N	55	10	10	5
Narrowleaf Willow (<i>Salix exigua</i>)	N	1	5	15	40
Shrub Absolute Cover Subtotal		56	15	25	45

Herbaceous (3x3ft)	Species	N/I	14 L			164 L			314 L			464 L		
			Plot 1	Plot 2	AVG	Plot 1	Plot 2	AVG	Plot 1	Plot 2	AVG	Plot 1	Plot 2	AVG
	Fowl Manna Grass (<i>Glyceria striata</i>)	N	5		2.5	50		25		0	0			
	Nodding Beggars Tick (<i>Bidens</i>)	N	2		1	5		2.5	1		0.5			
	Juncus (<i>Juncus equisetinus</i> Proskur)	N		60	30				20		10			
	Nebraska Sedge (<i>Carex nebrascensis</i>)	N		40	20	15	45	30	5		2.5			
	Licorice (<i>Glycyrrhiza glabra</i>)	N		5	2.5				5		2.5			
	Red Top (<i>Lebeotropheus trewavasae</i>)	I				10		5						
	Upland Wild Rye (<i>Elymus canadensis</i>)	I				10	25	17.5						
	Wild Mint (<i>Mentha arvensis</i>)	N				2		1						
	Equisetum (<i>Equisetum Hyemale</i>)	N					2	1						
	Small Rip Forb (<i>Sanguisorba</i>)	I					1	0.5						
	Aster (<i>Symphyotrichum puniceum</i>)	N										0	10	5
	Yarrow (<i>Achillea millefolium</i>)	N											5	2.5
	Tiny Trumpet (<i>Collomia linearis</i>)	N											1	0.5
	Upland Grass (<i>Barbarea verna</i>)	N											1	0.5
	Absolute Herb Cover (%)		7	105	56	92	73	82.5	31	0	15.5	0	17	8.5

N= Native

I = Introduced

Cover Type: H, S, F

Herbaceous, Scrub-shrub, Forested

Location = Geomorphic Location: I, O, S

Inside meander, Outside meander, Straight/riffle

Date: 6/30/2020

Investigators: Dev, McCoy, Mead

Sub-Reach Name: 11

Sub-Reach Length: 756

MONITORING

Wyoming Stream Quantification Tool
Riparian Vegetation Form

#Plots/side: 4

Random Start #(1-20): 14

Plot Information

Station ID: 14		Station ID: 164		Station ID: 314		Station ID: 464	
Cover Type: S		Cover Type: S		Cover Type: H		Cover Type: H	
Location: OM		Location: IM		Location: S		Location: S	
L or R bank: R		L or R bank: R		L or R bank: R		L or R bank: R	
Trees (32x32ft)	N/I	% Cover	% Cover	% Cover	% Cover	% Cover	% Cover
Tree Absolute Cover Subtotal		0	0	0	0	0	0
Shrubs (16x16ft)	N/I	% Cover	% Cover	% Cover	% Cover	% Cover	% Cover
Booths Willow (<i>Salix boothii</i>)	N	45	60	70	45		
Narrowleaf Willow (<i>Salix exigua</i>)	N	20	15	20	15		
River Birch (<i>Betula nigra</i>)	N		20				
Sagebrush (<i>Artemisia tridentata</i>)	N	7					
Shrub Absolute Cover Subtotal		72	95	90	60		

Herbaceous (3x3ft)		14 R			164 R			314 R			464 R		
Species	N/I	Plot 1	Plot 2	AVG	Plot 1	Plot 2	AVG	Plot 1	Plot 2	AVG	Plot 1	Plot 2	AVG
Fowl Manna Grass (<i>Glyceria striata</i>)	N												
False Lily of The Valley (<i>Maianthemum dilatatum</i>)	N	5	5	5		10	5		20	10			
Juncus (<i>Juncus equisetinus Proskur</i>)	N												
Nebraska Sedge (<i>Carex nebrascensis</i>)	N	95	10	52.5	0	60	30	15	40	27.5	0	85	42.5
Equisetum (<i>Equisetum Hyemale</i>)	N		15	7.5		5	2.5						
Absolute Herb Cover (%)		100	30	65	0	75	37.5	15	60	37.5	0	85	42.5

N= Native

I = Introduced

Cover Type: H, S, F

Herbaceous, Scrub-shrub, Forested

Location = Geomorphic Location: I, O, S

Inside meander, Outside meander, Straight/riffle

MONITORING

Wyoming Stream Quantification Tool Riparian Vegetation Summary

Date: 6/30/2020 Reach 11 Savery Creek Veg Data

Plot Information	Station ID: 14 L or R bank: L	Station ID: 164 L or R bank: L	Station ID: 314 L or R bank: L	Station ID: 464 L or R bank: L
<u>Plot Summary</u>	% Cover	% Cover	% Cover	% Cover
Absolute Woody Cover (%)	56	15	25	45
Absolute Herbaceous Cover (%)	56	83	16	9
Relative Native Cover (%)	100%	76%	100%	100%
Plot Information	Station ID: 14 Cover Type: S Location: OM L or R bank: R	Station ID: 164 Cover Type: S Location: IM L or R bank: R	Station ID: 314 Cover Type: H Location: S L or R bank: R	Station ID: 464 Cover Type: H Location: S L or R bank: R
<u>Plot Summary</u>	% Cover	% Cover	% Cover	% Cover
Absolute Woody Cover (%)	72	95	90	60
Absolute Herbaceous Cover (%)	65	38	38	43
Relative Native Cover (%)	100%	100%	100%	100%

N= Native
I = Introduced

Cover Type: H, S, F
Herbaceous, Scrub-shrub, Forested

Location = Geomorphic Location: I, O, S
Inside meander, Outside meander, Straight/riffle

Item

Value(s) Notes

Riparian Vegetation - Field Forms Required, values calculated from those forms.

Riparian Extent (%)

FIELD VALUE - Riparian Extent (%)*Pulls from Riparian Extent form*

Woody Vegetation Cover (%)

Number of riparian plots

8

Plot 1

56

Plot 2

15

Plot 3

25

Plot 4

45

Plot 5

72

Plot 6

95

Plot 7

90

Plot 8

60

Field data sheets, vegetation forms and a summary form are provided.

FIELD VALUE - Absolute Woody Cover (%)**57***Calculated*

Herbaceous Vegetation Cover (%)

Number of riparian plots

8

14 L

56

164 L

83

314 L

16

464 L

8

14 R

65

164 R

38

314 R

38

464 R

43

Field data sheets, vegetation forms and a summary form are provided.

FIELD VALUE - Absolute Herbaceous Cover (%)**43***Calculated*

Percent Native Cover (%)

Number of riparian plots

8

Plot 1

100

Plot 2

76

Plot 3

100

Plot 4

100

Plot 5

100

Plot 6

100

Plot 7

100

Plot 8

100

Field data sheets, vegetation forms and a summary form are provided.

FIELD VALUE - Relative Native Cover (%)**97***Calculated*