Kettle River; Falls above the Sandstone Dam, which were exposed when the dam was removed in 1995. With the removal of the Sandstone Dam, the Kettle River is now 'free-flowing' and is a tributary to the St. Croix River.

Minnesota Stream Quantification Tool and Debit Calculator User Manual (Version 2.0)

US Army Corps of Engineers®
St. Paul District

BOARD OF WATER AND SOIL RESOURCES

StreamMechanics

MINNESOTA POLLUTION CONTROL AGENCY

DEPARTMENT OF NATURAL RESOURCES

ECOSYSTEM PLANNING & RESTORATION

Minnesota Stream Quantification Tool and Debit Calculator User Manual (Version 2.0)

October 2020

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Acknowledgements

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The Minnesota Stream Quantification Tool (MNSQT) is the collaborative result of agency representatives, Stream Mechanics, and Ecosystem Planning and Restoration (EPR), collectively referred to as the MNSQT Steering Committee (MNSQT SC). Members include:

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Jen Oknich, Minnesota Pollution Control Agency (MPCA)

Many others provided valuable contributions to the Minnesota documents, including: Karl Koller (MN DNR) and Ian Chisholm (MN DNR), who provided valuable input, review and comment throughout regionalization and document development; Nathan Mielke (MPCA), who provided input on fish and macroinvertebrate metrics and assemblage data; Jesse Anderson, who provided input on water quality parameter metrics and associated data; and Nick Proulx (MN DNR), David Demmer (MN BWSR), and Mike Miller (WI DNR). Will Harman (Stream Mechanics), Thomas Barrett, Sara Donatich, Amy James, Cidney Jones, and LeeAnne Lutz (EPR) provided technical support and regionalization support under EPA Contract No. EP-C-17-001. Valuable peer review on draft versions of this document were provided by Julia McCarthy (EPA Region 8). Valuable peer review and contract support was provided by Brian Topping (EPA Headquarters).

Table of Contents

List of Figures

List of Tables

List of Examples

Preface

DOCUMENT HISTORY

The Minnesota Stream Quantification Tool (MNSQT) and Debit Calculator were developed from the Wyoming Stream Quantification Tool (WSQT) v1.0. The MNSQT User Manual (this document) was developed using the Colorado Stream Quantification Tool (CSQT) Beta version documentation as a template. All documents have been edited from the WSQT v1.0 and the CSQT Beta version for use in Minnesota.

DOCUMENT AVAILABILITY AND REVISIONS

A digital copy of the MNSQT and associated documents can be obtained on the Regulatory In-lieu fee and Bank Information Tracking System (RIBITS) website under Assessment Tools for Minnesota:

https://ribits.usace.army.mil/

Or at the Stream Mechanics website:

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

A copy may also be requested from any of the USACE Regulatory Offices in Minnesota.

The following spreadsheets and documents are available:

- MNSQT Workbook – Microsoft Excel Workbook described in detail in the User Manual (this document).
- Debit Calculator Workbook – Microsoft Excel Workbook described in detail in the St. Paul District Stream Mitigation Procedures (USACE Date pending) and the User Manual (this document).
- Minnesota Stream Quantification Tool and Debit Calculator Version 2.0 User Manual (User Manual) – This manual describes the MNSQT and Debit Calculator workbooks, all calculations performed by the workbooks, and how to collect data and calculate input for the MNSQT.
- Scientific Support for the MNSQT (MNSQT SC 2020) – A comprehensive review of the function-based parameters and metrics, reference standards, stratification methods, scoring and references used in the MNSQT. The Scientific Support for the MNSQT also includes a list of metrics summarizing this information.
- St. Paul District Stream Mitigation Procedures (USACE Date pending) – USACE procedures for using the MNSQT and Debit Calculator workbooks to calculate credits and debits.

Future versions will be updated and revised periodically as additional data are gathered and reference curves and metrics are refined. Field data supporting refinement of reference curves and evaluation of metrics are appreciated.

The MNSQT architecture is flexible and can accommodate additional parameters and metrics that are accompanied by reference curves. 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 threshold values and index scores that is outlined in the Scientific Support for the MNSQT (MNSQT SC 2020).

Send questions to: Technical Services Section, St. Paul District US Army Corps of Engineers, 108 5th Street East, Suite 700, St. Paul, Minnesota 55101 or call (651) 290-5525; or email StPaulSQT@usace.army.mil. More information on the MNSQT and District mitigation procedures can be found at https://www.mvp.usace.army.mil/Missions/Regulatory/.

DISCLAIMER

The Minnesota Stream Quantification Tool and Debit Calculator, including workbooks and supporting documents, are intended for the evaluation of Clean Water Act Section 404 (CWA 404) and Rivers and Harbors Act Section 10 (RHA Section 10) compensatory mitigation projects and impact sites and their departure from reference conditions in terms of functional loss or lift, respectively. The metrics are scored based on their current condition as compared to a reference standard. Consultation with the local USACE office is recommended prior to the use of this tool related to any CWA 404 or RHA Section 10 activities. The MNSQT can also be applied to restoration projects outside of the CWA 404 or RHA Section 10 regulatory context. Coordination with the appropriate State agency is recommended prior to data collection. In part, or as a whole, the function-based parameters, metrics, and index values are not intended to be used as the basis for engineering design criteria. The U.S. Army Corps of Engineers assumes no liability for engineering designs based on these tools. Designers should evaluate evidence from hydrologic and hydraulic monitoring, modeling, nearby stream morphology, existing stream conditions, sediment transport requirements, and site constraints to determine appropriate restoration designs.

Version

Version	Date finalized	Description
1.0	August 2019	Original version
2.0	October 2020	Various revisions and corrections

Acronyms

BEHI/NBS – Bank Erosion Hazard Index / Near Bank Stress
BHR – Bank height ratio
BMP – Best management practice
CFR – Code of Federal Regulations
Corps – United States Army Corps of Engineers (also, USACE)
CSQT – Colorado Stream Quantification Tool
CWA 404 – Clean Water Act Section 404
DNR – Department of Natural Resources
DO – Dissolved oxygen
ECS – Existing condition score
EPA – United States Environmental Protection Agency (also, USEPA)
ER – Entrenchment ratio
FF – Functional feet
HUC – Hydrologic Unit Code
IBI – Index of biotic integrity
IHA – Indicators of Hydrologic Alteration
LWD – Large woody debris
LWDI – Large woody debris index
MIDS – Minimal Impact Design Standards
MNSQT – Minnesota Stream Quantification Tool
MNSQT SC – Minnesota Stream Quantification Tool Steering Committee
MPCA – Minnesota Pollution Control Agency
MWR – Meander width ratio
NLCD – National Land Cover Database
NRCS – Natural Resource Conservation Service
PCS – Proposed condition score
RHA Section 10 – Rivers and Harbors Act Section 10
R_v – Site runoff coefficient
SEM – Stream evolution model
SFPF – Stream Function Pyramid Framework
TMDL – Total maximum daily load
TSS – Total suspended solids
USACE – United States Army Corps of Engineers (also, Corps)
USEPA – United States Environmental Protection Agency (also, EPA)
USGS – United States Geologic Survey
USDA – United States Department of Agriculture
W/D – Width-to-depth ratio
WHAF – Watershed Health Assessment Framework
WSQT – Wyoming Stream Quantification Tool
WSTT – Wyoming Stream Technical Team

Glossary of Terms

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

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).

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

Colorado Stream Quantification Tool (CSQT) – The CSQT user manual and scientific support documents have been adapted and modified for use in Minnesota.

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

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. (33CFR 332.2)

Condition score – Metric-based index values are averaged to characterize condition for each parameter, functional category, and overall project reach.

ECS = Existing Condition Score

PCS = Proposed Condition Score

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

Debit Calculator workbook – A Microsoft-Excel spreadsheet-based calculator that determines functional loss due to proposed impacts.

Debit Tool worksheet – The debit tool worksheet is included in the Debit Calculator workbook and is used to calculate the functional loss due to proposed impacts.

Effective vegetated riparian area – The portion of the effective riparian area that contains riparian vegetation and is free from utility-related, urban, or other soil disturbing land uses.

Field value – A field measurement or calculation input into the MNSQT 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. (33CFR 332.2)

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

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

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

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

Geomorphic pools – Large pools that remain intact over many years and flow conditions and are associated with planform features. Examples include pools associated with the outside of a meander bend (i.e. streams in alluvial valleys) and downstream of a large cascade or step (i.e. streams in colluvial valleys). All geomorphic pools are significant pools (see significant pool definition).

Index values – Dimensionless values between 0.00 and 1.00 that express the relative condition of a metric field value compared with reference standards. These values are derived from reference curves for each metric. Index values are combined to create parameter, functional category, and overall reach scores.

Impact severity tiers – The Debit Tool 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.

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 values 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).

Minnesota Stream Quantification Tool (MNSQT) – The MNSQT is a spreadsheet-based calculator that scores stream condition before and after restoration or impact activities to determine functional lift or loss, respectively, and can also be used to determine restoration potential, develop monitoring criteria and assist in other aspects of project planning. The MNSQT is comprised of two workbooks, the MNSQT and Debit Calculator. Because both are based on principles and concepts of the SFPF, they have some overlapping components. In addition, references to the MNSQT can describe concepts that are applicable within both the MNSQT and Debit Calculator workbooks.

Minnesota Stream Quantification Tool Steering Committee (MNSQT SC) – The group that worked on the development of the MNSQT and contributed to various aspects of this document.

MNSQT workbook – The Microsoft-Excel workbook file used to evaluate change in condition at a mitigation or restoration site.

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 within the project area.

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 without anthropogenic disturbances. (see 33 CFR 332.2)

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 other forms that best represent the degree of departure from a reference standard 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 functional capacity. In the MNSQT, this condition is considered functioning for the metric being assessed, and ranges from minimally impacted to unaltered to pristine condition.

Representative sub-reach – A length of stream within a project reach that is selected for field data collection of parameters and metrics. The representative sub-reach is typically 20 times the bankfull width or two meander wavelengths (Leopold 1994).

Riffle – Riffles are the river's natural grade control feature (Knighton 1998) and are commonly referred to as fast-water channel units (Hawkins et al. 1993; Montgomery and Buffington 1998). The riffles are shallower than pools and are located between pools. In conventional literature, a riffle is partially defined by bed material size and is limited to gravel bed streams. Sand bed streams are classified by bedforms of ripples, dunes, and antidunes (Knighton 1984). In the SQT, and most other assessment methods that include sand and gravel beds, the section between lateral-scour pools is called a riffle, regardless of bed material size. In this application, the riffle is defined as the crossover between meander bends. It is a straight section of the channel where the thalweg crosses from one side of the channel to the other.

Riparian area width – The area adjacent to and contiguous with the stream channel that supports the geomorphological dynamic equilibrium of the stream. It is typically a corridor associated with a stream reach where under natural conditions the valley bottom is influenced by fluvial processes under the current climatic regime, riparian vegetation characteristic of the region and plants known to be adapted to shallow water tables and fluvial disturbance are present, and the valley bottom is flooded at the stage of the 100-year recurrence interval flow. (Merritt et al. 2017)

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

Significant pools – Pools associated with wood, boulders, convergence, and backwater AND geomorphic pools (see geomorphic pool definition). These pools have a width that is at least one-half the channel bottom width, a water surface slope that is flatter than the riffle, and a concave profile.

Stream Functions Pyramid Framework (SFPF) – 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 SFPF includes the organization of function-based parameters, metrics (measurement methods), and performance standards (reference 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 more broadly in this document to represent multiple stream compensatory mitigation methods including re-habilitation, re-establishment, and enhancement.

Stream/wetland complex – A stream channel or channels with adjacent riverine wetlands located within the floodplain or riparian geomorphic setting, where overbank flow from the channel(s) is the primary wetland water source (Brinson et al., 1995). Stream types may be single-thread or anastomosed. Common stream types for stream/wetland complexes include Rosgen E, Cc-, and D_A.

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 the Performance Standards defined in Harman et al. (2012).

Wyoming Stream Quantification Tool (WSQT) – The SQT and Debit tool developed for use in Wyoming and administered by the Omaha District of the Army Corps of Engineers. The WSQT is the Stream Quantification Tool from Wyoming that has been adapted and modified for use in Minnesota.

Wyoming Stream Technical Team (WSTT) – The group who worked on the development of the WSQT and associated documents.

Overview

The Minnesota Stream Quantification Tool and Debit Calculator (MNSQT) are spreadsheet-based tools designed to inform permitting and compensatory mitigation decisions within the Clean Water Act Section 404 (CWA 404) and Rivers and Harbors Act Section 10 (RHA Section 10) programs. When used within the context of these programs, coordination with the US Army Corps of Engineers and other state or local regulatory authorities on tool use and parameter selection is recommended prior to data collection. The MNSQT can also be applied to restoration projects outside of the CWA 404 or RHA Section 10 regulatory context. Coordination with the appropriate State agency is recommended prior to data collection. These Microsoft Excel Workbooks have been developed to characterize stream ecosystem functions by evaluating a suite of indicators that represent structural or compositional attributes of a stream and its underlying processes. Indicators in the MNSQT represent parameters that are often impacted by authorized projects or affected (e.g. enhanced or restored) by mitigation actions undertaken by restoration providers. The MNSQT has been modified from the Wyoming Stream Quantification Tool Version 1.0 (WSQT v1.0; USACE 2018a) and regionalized for use in Minnesota. Many of the parameters, metrics, and reference curves within the MNSQT Version 2.0 are similar to or identical to those in the WSQT v1.0 (USACE 2018a). Other stream quantification tools and user manuals have been developed for use in other states and regions, including North Carolina (Harman and Jones 2017), Tennessee (TDEC 2018), Georgia (USACE 2018b), and Colorado (CSQT SC 2019). Some metrics from these quantification tools were considered when developing the metrics for the MNSQT.

The MNSQT is an application of the Stream Functions Pyramid Framework (SFPF) and uses function-based parameters and metrics to assess five functional categories: Hydrology, Hydraulics, Geomorphology, Physicochemical, and Biology (Harman et al. 2012). The MNSQT integrates multiple indicators from these functional categories into a reach-based condition score that is used to calculate the change in condition before and after impact or restoration activities are implemented. Restoration refers to 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 compensatory mitigation methods including re-habilitation, re-establishment, and enhancement as defined in the 2008 Compensatory Mitigation for Losses to Aquatic Resources; Final Rule (2008 Rule).

The main goal of the MNSQT is to produce objective, verifiable, and repeatable results by consolidating well-defined procedures for objective and quantitative measures of defined stream variables. The MNSQT includes 24 metrics within 12 parameters that can be evaluated at a project site. A basic set of metrics within 5 parameters is required at all project sites evaluated for CWA 404 or RHA Section 10 purposes to provide consistency between impacts and compensatory mitigation and allow for more consistent accounting of functional change. Users can include additional parameters and metrics on a project-specific basis (see Section 2.3 on Parameter Selection). This User Manual provides data collection methods related to each metric. For some metrics, methods include both rapid and more detailed forms of data collection, allowing the tool to be used for rapid or more comprehensive site assessment.

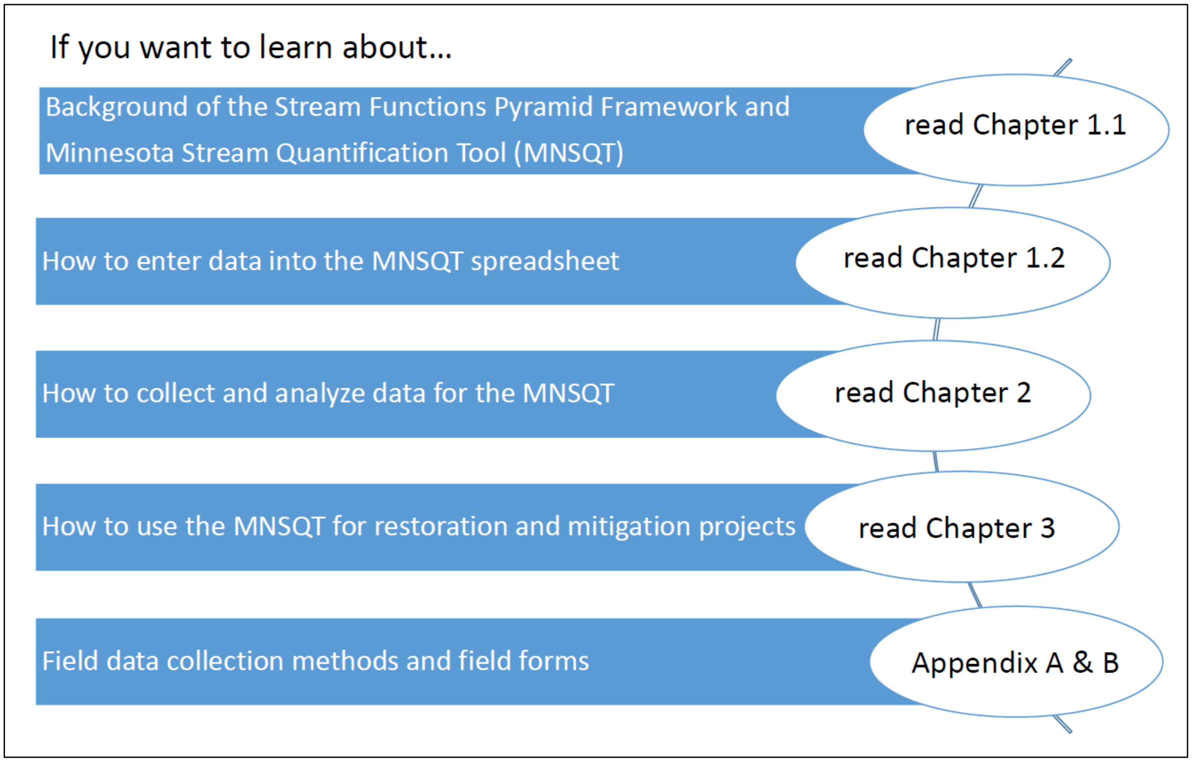
This manual describes the MNSQT and Debit Calculator workbooks and how to collect and analyze data entered into these workbooks. Companion documents include the St. Paul District Stream Mitigation Procedures (USACE Date pending), which provides policy direction for how and when the MNSQT will be used for the CWA 404 or RHA Section 10 regulatory programs and how tool results are translated into credits and debits; and the Scientific Support for the MNSQT, which provides rationale for scoring in the MNSQT and describes how measured stream conditions were converted into dimensionless index scores (MNSQT SC 2020).

Purpose and Use of the MNSQT

The purpose of the MNSQT is to evaluate change in stream ecosystem functions at a mitigation or restoration site and to inform permitting and compensatory mitigation decisions within the CWA 404 and RHA Section 10 programs. The MNSQT can also be applied to restoration projects outside of the CWA 404 or RHA Section 10 regulatory context. The tools are calculators to quantify functional change between an existing and future stream condition. The future stream condition can be a proposed for an active stream restoration project or a proposed stream impact requiring a CWA 404 permit. For a stream restoration project, this functional change can be estimated during the design or mitigation plan phase and verified during post-construction monitoring events in the MNSQT workbook. For a stream impact, functional loss can be estimated several ways using the Debit Calculator workbook. Estimates of functional lift and functional loss can inform CWA 404 and RHA Section 10 permitting and mitigation decisions; the application of the MNSQT in these regulatory programs in Minnesota is outlined in the St. Paul District Stream Mitigation Procedures (USACE Date pending). Debit and credit determination methods are not included in this manual but are outlined in the St. Paul District Stream Mitigation Procedures (USACE Date pending). Users are strongly encouraged to contact the Corps and other state or local regulatory authorities to obtain project-specific direction. Not all portions of the MNSQT or Debit Calculator workbooks will be applicable to all projects.

The MNSQT can also help determine if a proposed site has the potential to be considered for a stream restoration or mitigation project and provides a framework to guide restoration planning. The catchment assessment and restoration potential process accompanying the MNSQT (described in Chapter 3) can be used to help determine factors that limit the potential lift 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 stream functional categories and function-based parameters assessed by the tool. Figure 1 can assist in navigating this User Manual for specific project types.

Figure 1: Manual Directory



KEY CONSIDERATIONS

The MNSQT and supporting documentation have been developed to meet the function-based approaches set forth in the 2008 Rule. Therefore, the following concepts are critical in understanding the applicability and limitations of this tool:

- The parameters and metrics in the tool were selected due to their sensitivity in responding to reach-scale changes associated with the types of activities commonly encountered in the CWA 404 or RHA Section 10 programs and commonly used in stream restoration. These parameters do not comprehensively characterize all structural measures or processes that occur within a stream.
- The MNSQT is designed to assess the same parameters at a site over time, thus providing information on the degree to which the condition of the stream system changes following impacts or restoration activities. We refer to the MNSQT as a change tool for this reason – it is intended to detect change at a site over time. If the same parameters and metrics are not used across all sites, it is inappropriate to compare scores.
- The MNSQT itself does not score or quantify watershed condition. Watershed condition reflects the external elements that influence functions within a project reach and may affect project site selection or restoration potential (see Chapter 3).
- The MNSQT is not a design tool. Many function-based parameters are critical to a successful restoration design but sit outside the scope of the MNSQT. The MNSQT measures the physical, chemical, and biological responses or outcomes related to a project design at a reach scale.

- Not all parameters and metrics in the tool will be applicable to wetland/stream complexes. Practitioners working in these resource types should consult with agencies to determine the most applicable parameters to be used.

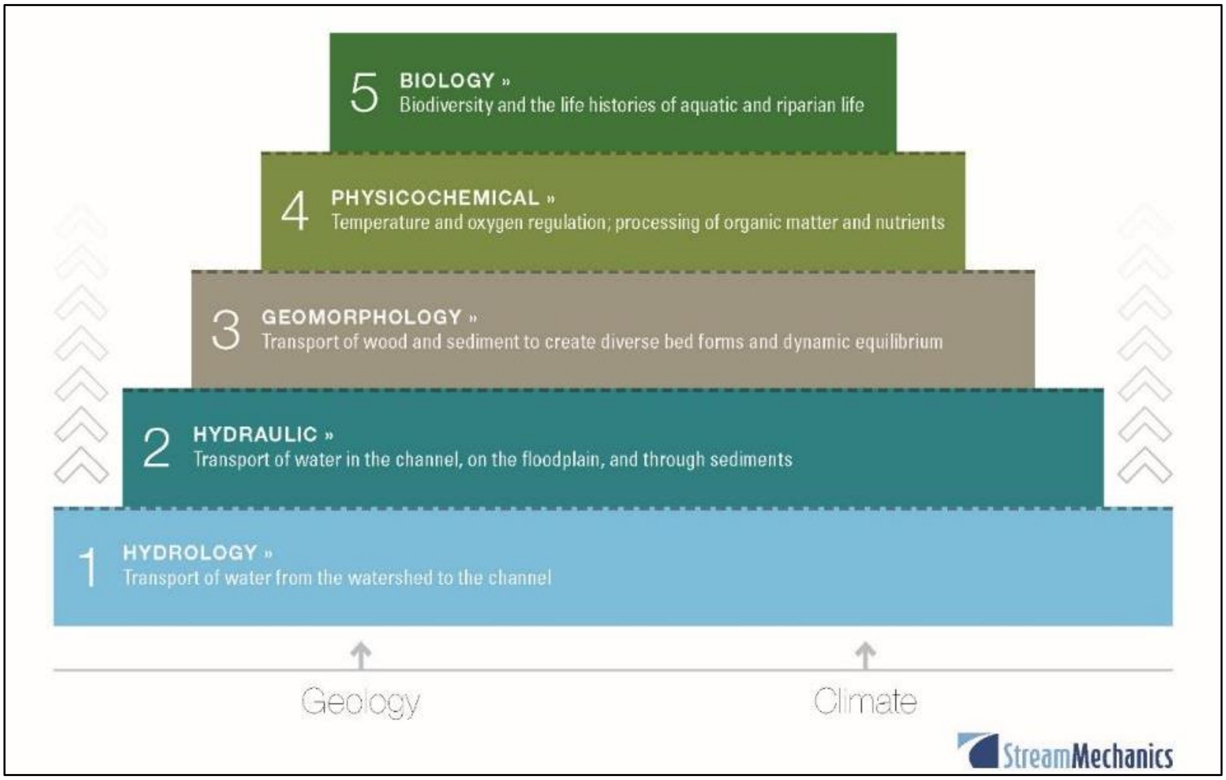
Chapter 1. Background and Introduction

The Minnesota Stream Quantification Tool and Debit Calculator spreadsheets are an application of the Stream Functions Pyramid Framework (SFPF). Therefore, to understand the structure of the MNSQT, it is important to first understand the SFPF. This chapter provides a brief overview of the SFPF followed by an overview of the elements included in the MNSQT and Debit Calculator workbooks.

1.1. Stream Functions Pyramid Framework (SFPF)

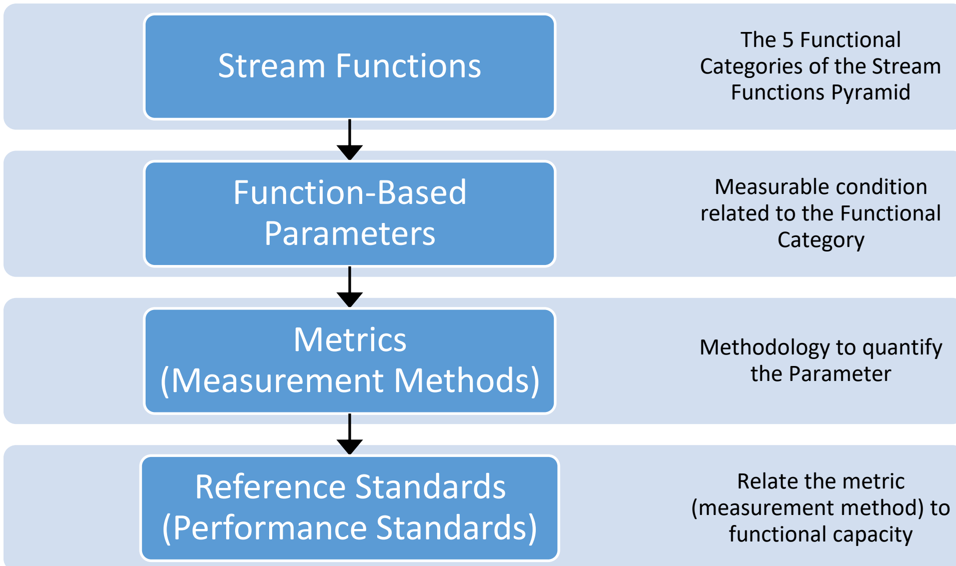
The Stream Functions Pyramid (Figure 2) includes five functional categories: Level 1: Hydrology, Level 2: Hydraulics, Level 3: Geomorphology, Level 4: Physicochemical, and Level 5: Biology. The Pyramid organization recognizes that lower-level functions generally support higher-level functions (although the opposite can also be true) and that all functions are influenced by local geology and climate. Each functional category is defined by a functional statement.

Figure 2: Stream Functions Pyramid (Image from Harman et al. 2012)



The SFPF 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 3 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.

Figure 3: Stream Functions Pyramid Framework



This comprehensive framework includes more detailed forms of analysis to quantify stream functions and functional 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 are used to characterize site condition and inform function-based parameter scores. Reference standards (performance standards) are measurable or observable end points of stream restoration.

1.2. Minnesota Stream Quantification Tool and Debit Calculator (MNSQT)

Following the SFPF, function-based parameters and metrics were selected to quantify stream condition across various ecoregions and stream types. Each metric is linked to reference curves that relate measured field values to a regional reference condition. In the MNSQT, field values for a metric are assigned an index value (0.00 – 1.00) using the applicable reference standards. The numeric index value range was standardized across metrics by determining how field values relate to functional capacity, i.e., functioning, functioning-at-risk, and not functioning conditions (Table 1). The reference standards in the MNSQT are tied to specific benchmarks (thresholds) that represent the degree to which the aquatic resources are functioning and/or the degree to which condition departs from reference standard.[1]

[1] Additional detail on function-based parameters and metrics, along with specific information on stratification and reference curve development is provided in the Scientific Support for the MNSQT (MNSQT SC 2020).

Table 1: ***Functional Capacity Definitions Used to Define Threshold Values and Develop Reference Standards for the MNSQT***

Functional Capacity	Definition	Index Score Range
Functioning	A functioning 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. The reference standard concept aligns with the definition for a reference condition for biological integrity (Stoddard et al. 2006). A score of 1.00 represents an un-altered or pristine condition (native or natural condition). A range of index values (0.70-1.00) is used for characterizing reference standard to account for natural variability, recognizing that reference standard datasets include sites that reflect least disturbed condition (i.e., the best available conditions given current anthropogenic influence per Stoddard et al. 2006).	0.70 to 1.00
Functioning-at-risk	A functioning-at-risk 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 not at a reference standard level. In many cases, this indicates the parameter is adjusting in response to changes in the reach or the catchment towards lower or higher function. This range characterizes a grey area, where a resource is neither achieving a reference standard nor is significantly degraded or impaired.	0.30 to 0.69
Not functioning	A not functioning 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 relative to reference standard, and an index value of 0.00 represents a condition that provides no functional capacity for that metric. Index values of 0.00 were often extrapolated from the best fit lines, and these were reviewed to determine whether field values would reasonably represent no functional support for that metric.	0.00 to 0.29

The MNSQT workbook (MNSQTv2.0.xlsx) is a Microsoft Excel Workbook comprised of 9 worksheets. There are no macros in the workbook, and all formulas are visible, though some worksheets are locked to prevent editing. One workbook should be assigned to each project reach within a project area. Each of the following worksheets is described in this Section.

The MNSQT worksheets include:

- Project Assessment
- Catchment Assessment
- Major Flow Variability Metrics
- Measurement Selection Guide

- Quantification Tool (locked)
- Monitoring Data (locked)
- Data Summary (locked)
- Reference Standards (locked)
- Pull Down Notes – This worksheet is hidden and contains all the inputs for drop down menus throughout the workbook.

The Debit Calculator workbook (MNSQT Debit Calculator v2.0.xlsx) is a Microsoft Excel Workbook comprised of seven worksheets. There are no macros in the workbook, and all formulas are visible, though some worksheets are locked to prevent editing. One workbook can be used to score multiple project reaches within a project area. Each of the following worksheets is described in this Section.

The Debit Calculator worksheets include:

- Project Assessment
- Debit Calculator (locked)
- Measurement Selection Guide
- Existing Conditions (locked)
- Proposed Conditions (locked)
- Reference Standards (locked)
- Pull Down Notes – This worksheet is hidden and contains all the inputs for drop down menus throughout the workbook.

1.2.A. Project Assessment Worksheet

The Project Assessment worksheet allows for a description of the project reach, the proposed project, and its effect on the stream within the project area. This worksheet is included in both MNSQT and Debit Calculator workbooks but contains different components, as described below.

In the MNSQT workbook this worksheet will communicate the goals of the project and its associated restoration potential. For projects with multiple reaches (and thus multiple workbooks), the project information on this worksheet may be the same across workbooks except for a unique reach-specific description. Information on delineating project reaches is provided in Chapter 2.

Components of the Project Assessment Worksheet

<u>Programmatic Goals (MNSQT only)</u> – Programmatic goals represent big-picture goals that are often broader than function-based goals and are determined by the project owner or funding entity. A drop-down menu is provided with the following options: Mitigation – Credits, TMDL, Grant, or Other.

Reach Description (MNSQT) – Space is provided to describe the project reach, including the individual reach ID, location (latitude/longitude), and reference stream type. If there are multiple project reaches within the project area, this section should include a description of the characteristics that separate it from other reaches. Guidance on identifying project reaches and selecting reference stream type is provided in Section 2.4.

Reach Description (Debit Calculator) – Space is provided in a table to assign each reach a Stream ID, briefly describe proposed impact for each reach, and identify the location (latitude/longitude) for up to 10 reaches. Information regarding the project name, applicant and project ID and/or permit numbers can be documented on the worksheet.

Aerial Photograph of Project Reach (MNSQT only) – Provide a current aerial photograph of the project reach. The photo could include labels indicating where work is proposed, the project area boundaries and/or proposed/existing easement, and any important features within the project site.

Latitude/Longitude (MNSQT and Debit Calculator) – Provide the latitude and longitude at the downstream limit of the project reach.

Reference Stream Type (MNSQT only) – Provide the reference stream type that should occur in a given landscape setting given the hydrogeomorphic processes occurring at the watershed and reach scales. Channel evolution scenarios should be used to inform the reference stream type.

Restoration Approach (MNSQT only) – In Box 1, the user should explain programmatic goals (see Example 1).

Box 2 should be used to explain the connection between the restoration potential and the programmatic goals. The restoration potential can be classified as partial or full restoration, and this classification comes from the Catchment Assessment worksheet (see below).

Box 3 should be used to describe the function-based goals and objectives of the project. More information on restoration potential and developing goals and objectives is provided in Chapter 3.

Example 1: Restoration Approach

If the programmatic goal is to create mitigation credits, then the first text box could provide more information about the type and number of credits desired.

If the restoration potential is partial restoration, then the second text box would explain how improvements to hydrology and hydraulics, and/or geomorphology would create the necessary credits and identify the constraints and stressors that are limiting restoration of physicochemical and biological functions.

The goals of the project would match the restoration potential, e.g., target reference standard habitat condition and partial restoration of biological condition. Accompanying objectives could identify parameters to be restored and which metrics will be used to monitor restoration progress.

1.2.B. Catchment Assessment Worksheet

This worksheet is included within the MNSQT workbook but not the Debit Calculator workbook. The Catchment Assessment worksheet assists in characterizing watershed processes and stressors that exist outside of the project reach but affect functions within the reach. It also highlights factors necessary to consider or address during the project design to maximize the likelihood of a successful project. This worksheet contains 15 categories to be rated as Good, Fair, or Poor. Fourteen of the categories are related to specific Minnesota Department of

Natural Resources (DNR) Watershed Health Assessment Framework (WHAF) Index Scores or values that can be obtained from WHAF Charts and Reports. The specific WHAF index or value that relates to each category is listed in Column I. Information on the WHAF and index descriptions are provided at the DNR WHAF website (https://www.dnr.state.mn.us/whaf/index.html).

Most of the categories describe potential stressors upstream of the project reach since the contributing catchment has the most influence on the project reach's hydrology, water quality, and biological condition. Based on the category ratings, the user should provide an overall watershed condition and determine the restoration potential for the reach. The user should refer to Section 3.2.a for determining the Restoration Potential for the reach.

1.2.c. Major Flow Variability Metrics

This worksheet is present in the MNSQT workbook but not the Debit Calculator workbook. This worksheet is a reference that provides the Flow Variability Rate and Frequency of Change metric and the Frequency and Duration of High/Low Pulses metric for the HUC-8 watershed in which the stream restoration project is located. These two metrics are evaluated for the Flashiness Index (Hydrology) category IHA analysis. *This worksheet is included for reference purposes and does not require any data entry.*

1.2.d. Measurement Selection Guide

This worksheet is present in the MNSQT workbook and the Debit Calculator workbook. The measurement selection guide is included to assist users in selecting the appropriate parameters and metrics for the project reach.

1.2.e. Quantification Tool Worksheet (SQT) & Existing Conditions and Proposed Conditions Worksheet (Debit Calculator)

The Quantification Tool worksheet is included in the MNSQT workbook and serves a similar purpose to the Existing Conditions and Proposed Conditions Debit worksheets within the Debit Calculator workbook. In both workbooks, the quantification tool calculates the condition score based on data entry describing the existing and proposed conditions of the project reach. In the MNSQT workbook, the Quantification Tool worksheet contains three areas for data entry: Site Information and Reference Selection, Existing Condition Assessment field values, and Proposed Condition Assessment field values.

In the Debit Calculator workbook, the user can score the existing and proposed conditions for 10 reaches in the Existing Conditions and Proposed Conditions worksheets, respectively. The user provides site information for each reach in the Reach Information and Reference Standard Stratification table above each condition assessment.

Cells that allow input are shaded gray, and all other cells are locked. Each section of the MNSQT Quantification Tool worksheets is discussed below.

Site Information and Reference Selection

In the MNSQT workbook Quantification Tool worksheet, 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 4).

Information on each input field and guidance on how to select values are provided in Section 2.4.

In the Debit Calculator workbook, the corresponding section is located above each reach condition assessment in the Existing Conditions and Proposed Conditions workbook and is called Reach Information and Reference Selection. Similar general site information and classifications that determine which reference curve(s) apply are input in this section for each reach. Four inputs (outstanding resource waters, proposed BMPs, stream/wetland complex and presence of armoring) are specific to the Debit Calculator. The Debit Calculator also requires more specific location information (latitude and longitude of the upstream and downstream extent of the reach) in lieu of the drainage area input.

In the MNSQT workbook, Quantification Tool worksheet, the restoration potential field is linked to the input cell on the Catchment Assessment worksheet, and the reference stream type is linked to the input cell on the Project Assessment worksheet.

Figure 4:   Example Site Information and Reference Selection Input Fields

Site Information and Reference Selection	
Project Name:	Restoration Project
Reach ID:	1
Restoration Potential:	Full
Existing Stream Type:	F
Reference Stream Type:	Bc
Woody Vegetation Natural Component:	Yes
Use Class:	2A
River Nutrient Regions:	North
Drainage Area (sq.mi.):	10
Proposed Bed Material:	Gravel
Existing Stream Length (ft):	1000
Proposed Stream Length (ft):	1200
Macroinvertebrate IBI Class:	Northern Forest Rivers
Fish IBI Class:	Northern Rivers
Valley Type:	Confined Alluvial
Flow Permanence:	Perennial
Strahler Stream Order:	Third

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 5).

A user will rarely input data for all metrics or parameters within the tool. Guidance on parameter selection is provided in Chapter 2.3. The function-based parameters and metrics are listed by functional category, starting with Hydrology. Multiple tables in the MNSQT are color-coded to show the delineation between functional categories: light blue for hydrology, dark blue for hydraulics, orange for geomorphology, yellow for physicochemical, and green for biology.

The Existing Condition Assessment field values are derived from data collection and analysis methods outlined in Chapter 2 and Appendix A. An existing condition score relies on baseline data collected from the project reach before any work is completed. 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 comprehensive site assessment.

The Proposed Condition Assessment field values should consist of reasonable values for restored conditions. For the Proposed Condition Assessment, the user should rely on available data to estimate the proposed condition field values. Proposed field values that describe the physical post-project condition of the stream reach should be based on project design studies and calculations, drawings, field investigations, and best available science. Parameters and metrics that are assessed in the Existing Condition Assessment must also be used to determine the proposed post-impact condition score. (Note: field value, as used here, refers to the location in the condition assessment table of the worksheet where data are entered and not the actual collection of field data to yield a field value).

Figure 5: Example Field Value Data Entry in the Condition Assessment Table

Functional Category	Function-Based Parameter	Metric	Field Value
Hydrology	Reach Runoff	Land Use Coefficient	80
		BMP MIDS Rv Coefficient	
		Concentrated Flow Points / 1,000 feet	3
Hydraulics	Floodplain Connectivity	Bank Height Ratio	1.2
		Entrenchment Ratio	3
Geomorphology	Large Woody Debris	LWD Index	184
		No. of LWD Pieces / 100 meters	
	Lateral Migration	Dominant BEHI/NBS	H/M
		Percent Streambank Erosion (%)	20
		Percent Armoring (%)	
	Bed Material Characterization	Size Class Pebble Count Analyzer (p-value)	
	Bed Form Diversity	Pool Spacing Ratio	2.4
		Pool Depth Ratio	2.1
		Percent Riffle (%)	30
		Aggradation Ratio	1.2
	Riparian Vegetation	Effective Vegetated Riparian Area (%)	60
		Canopy Cover (%)	50
		Herbaceous Strata Vegetation Cover (%)	40
		Woody Stem Basal Area (sqm/hectare)	50
Physicochemical	Temperature	Summer Average (°C)	14
	Dissolved Oxygen	DO (mg/L)	7
	Total Suspended Solids	TSS (mg/L)	11
Biology	Macroinvertebrates	Macroinvertebrate IBI	55
	Fish	Fish IBI	40

SCORING FUNCTIONAL LIFT AND LOSS

Scoring occurs automatically as field values are entered into the Existing Condition Assessment or Proposed Condition Assessment tables. A metric field value will correspond to an index value ranging from 0.00 to 1.00. Where more than one metric is used per parameter, these index values are averaged to calculate parameter scores. Similarly, multiple parameter scores within a functional category are averaged to calculate functional category scores. Functional category scores are weighted and summed to calculate overall scores that are used to calculate functional change.

Index Values – The reference curves available for each metric are visible in the Reference Curves worksheet. When a field value is entered for a metric on the Quantification Tool worksheet, the reference curves are used to calculate an index value.

As a field value is entered in the Quantification Tool worksheet, the neighboring index value cell should automatically populate with an index value (Example 2a). If the index value cell returns FALSE instead of a numeric index value, the Site Information and Reference Selection section may be missing data. In Example 2b, the proposed stream type was not selected in the Site Information and Reference Selection causing the Index Value to return FALSE because the tool could not determine which reference curve to use.

Example 2: Populating Index Values in the MNSQT

(a) Index values automatically populate when field values are entered.

Metric	Field Value	Index Value
Pool Spacing Ratio	5	1.00
Pool Depth Ratio		
Percent Riffle (%)	60	1.00
Aggradation Ratio		

(b) If FALSE, check the Site Information and Reference Selection section of the worksheet.

Metric	Field Value	Index Value
Pool Spacing Ratio	5	FALSE
Pool Depth Ratio		
Percent Riffle (%)	60	FALSE
Aggradation Ratio		

If the worksheet does not return a numeric 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.

However, simply because a numeric index value populates does not guarantee data integrity. Index value calculations will be compromised if incorrect information is input into the Site Information and Reference Selection section.

Scoring – In the MNSQT, scores are averaged within each level of the stream functions pyramid framework. Metric index values are averaged to calculate parameter scores; parameter scores are averaged to calculate category scores (Figure 6). The category scores are then weighted and summed to calculate overall scores; overall score weighting by category is shown in Table 2. Category scores are additive, so a maximum overall score of 1.00 is only possible when parameters within all five categories are evaluated. For example, if only Hydrology, Hydraulics, and Geomorphology parameters are evaluated, the maximum overall score is 0.60.

- There are three metrics for lateral migration, including a metric that reflects the amount of artificial bank hardening present (percent armoring; refer to Section 2.3 for direction on metric selection). Where percent armoring exceeds 75% of the total bank length, the parameter as a whole will score a 0.00 regardless of any other metric field values entered.

In the Debit Calculator, scores for metrics that are not determined from studies, field investigations, or best available science will default to a score of 0.90 for [US] state-listed outstanding resource waters (prohibited or restricted) or 0.80 for all other waters. The tool assumes these metrics are functioning to acknowledge the possibility that some metrics may function at a high capacity while other metrics may function at a lower capacity.

Figure 6: Scoring Example

Functional Category	Function-Based Parameter	Parameter	Category	Category
Hydrology	Reach Runoff	0.58	0.58	Functioning At Risk
Hydraulics	Floodplain Connectivity	0.57	0.57	Functioning At Risk
Geomorphology	Large Woody Debris	0.42	0.52	Functioning At Risk
	Lateral Migration	0.60		
	Bed Material Characterization			
	Bed Form Diversity	0.55		
	Riparian Vegetation	0.50		
Physicochemical	Temperature	0.21	0.31	Functioning At Risk
	Dissolved Oxygen	0.21		
	Total Suspended Solids	0.50		
Biology	Macroinvertebrates	0.00	0.00	Not Functioning
	Fish	0.00		

Table 2: Functional Category Weights

Functional Category	Weight
Hydrology	0.20
Hydraulics	0.20
Geomorphology	0.20
Physicochemical	0.20
Biology	0.20

Calculating Functional Feet – The change at an impact or mitigation site is the difference between the existing (pre-project) and proposed (post-project) overall scores. Existing and proposed condition scores are multiplied by stream length to calculate the change in functional feet (ΔFF).

The Quantification Tool worksheet calculates change in units of functional feet (FF) using stream length and the existing and proposed reach condition scores (ECS and PCS respectively) as follows:

1. $Existing\ FF = ECS * Existing\ Stream\ Length$
2. $Proposed\ FF = PCS * Proposed\ Stream\ Length$
3. $Change\ in\ FF\ (\Delta FF) = Proposed\ FF - Existing\ FF$

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.

Color Coded Scoring – When index values are populated in the Quantification Tool worksheet, cell colors will automatically change color to identify where on the reference curve the field value lies (Figure 6). Green coloring indicates field values and index scores that represent a functioning (reference standard) range of condition; yellow indicates field values and index scores that represent a functioning-at-risk range of condition; and, red indicates field values and index scores that represent a not-functioning range of condition (see Table 1 for definitions). This color-coding is provided as a communication tool 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 when reviewing the summary tables and monitoring data included in the MNSQT workbook (both are described below). Note that color coding is not provided for the overall score as the overall score is not representative of an overall site condition unless parameters within all categories are evaluated. For example, if only Hydrology, Hydraulics and Geomorphology parameters are evaluated, the maximum overall score will be 0.60.

FUNCTIONAL LIFT AND LOSS SUMMARY TABLES

The Quantification Tool worksheet in the MNSQT workbook summarizes the scoring at the top of the worksheet, next to and under the Site Information and Reference Selection section. There are four summary tables: Functional Change Summary, Mitigation Summary, Functional Category Report Card, and Function-Based Parameters Summary.

Functional Change Summary – This summary (Figure 7) provides the overall scores from the Existing Condition Assessment and Proposed Condition Assessment sections, calculates the functional change occurring at the project site, and incorporates the length of the project to calculate the overall change in functional feet (∆FF).

The change in functional condition is the difference between the proposed condition score (PCS) and the existing condition score (ECS). It is a measure of the quality difference between existing and proposed condition irrespective of stream length. The summary includes the existing and proposed stream lengths to calculate and communicate functional feet (FF). A functional foot is the product of a condition score and the stream length (see equations in Calculating Functional Feet above). Because the condition score is 1.00 or less, the functional feet of a stream reach are always less than or equal to the actual stream length.

The change in functional feet (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 can be summed to calculate the total change in functional feet for an entire project. This value can be used as a credit. Functional change is also expressed as the percent change in functional feet for a project reach:

$$Percent\ Change\ in\ FF = \frac{Proposed\ FF - Existing\ FF}{Existing\ FF} * 100$$

Percent change is provided for the functional feet scores. For stream restoration activities creating functional lift, the percent change will be positive. If functional loss occurs, the percentage will be negative. Stream restoration projects that increase stream length as part of a restoration activity will have a greater percent increase in functional feet.

The final summary value shown is the Functional-Foot Yield (FF Yield) (FF/FT). This value is calculated as:

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

This value 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 FF Yield equals the Proposed Condition Score minus the Existing Condition Score.

Figure 7: Example Functional Change Summary Table

FUNCTIONAL CHANGE SUMMARY	
Existing Condition Score (ECS)	0.45
Proposed Condition Score (PCS)	0.65
Change in Functional Condition (PCS - ECS)	0.20
Existing Stream Length (ft)	1000
Proposed Stream Length (ft)	1200
Change in Stream Length (ft)	200
Existing Functional Feet (FF)	450
Proposed Functional Feet (FF)	780
Proposed FF - Existing FF	330
Percent Change in FF (%)	73%
FF Yield	0.28

Functional Category Report Card – This summary presents a side-by-side comparison of the functional category scores based on the existing and proposed condition scores from the Condition Assessment sections of the worksheet (Figure 8). This table provides a general overview of the functional changes pre- and post-project to illustrate where the change in condition is anticipated. The color coding within this table is described in the Scoring Functional Lift and Loss Section above.

Figure 8: Example Functional Category Report Card

FUNCTIONAL CATEGORY REPORT CARD			
Functional Category	ECS	PCS	Functional Change
Hydrology	0.47	0.85	0.38
Hydraulics	0.65	0.99	0.34
Geomorphology	0.64	0.76	0.12
Physicochemical	0.49	0.67	0.18
Biology	0.00	0.08	0.08

Function-Based Parameters Summary – This summary provides a side-by-side comparison of the individual parameter scores (Figure 9). Values are pulled from the Condition Assessment sections of the worksheet. This table can be used to better understand how the category scores are determined and serves as a quality control check to see if a parameter was assessed for both the existing and proposed condition assessments. For example, the parameter summary table illustrates which parameters within the geomorphology functional category were assessed and contributing to the overall lift at the site. The color coding within this table is described in the Scoring Functional Lift and Loss Section above.

Figure 9: Example Function-Based Parameters Summary Table

FUNCTION BASED PARAMETERS SUMMARY			
Functional Category	**Function-Based Parameters**	**Existing Parameter**	**Proposed Parameter**
Hydrology	Reach Runoff	0.47	0.85
Hydraulics	Floodplain Connectivity	0.65	0.99
Geomorphology	Large Woody Debris	0.40	0.64
	Lateral Migration	0.66	0.99
	Bed Material Characterization	0.00	0.65
	Bed Form Diversity	0.60	0.75
	Riparian Vegetation	0.44	0.66
Physicochemical	Temperature	0.70	0.97
	Dissolved Oxygen	0.21	1.00
	Total Suspended Solids	0.00	0.00
Biology	Macroinvertebrates	0.00	0.00
	Fish	0.12	0.21

1.2.F. MONITORING DATA WORKSHEET

This worksheet is included in the MNSQT workbook but not the Debit Calculator workbook. The Monitoring Data worksheet contains 11 condition assessment tables identical to the Existing and Proposed Condition Assessment sections in the Quantification Tool worksheet (Figure 5, page 18). The first table on the Monitoring Data worksheet is identified as the As-Built condition followed by 10 condition assessment tables for monitoring. The user can enter the monitoring date and year at the top of each condition assessment table, e.g., 1 for the first growing season post-project. The methods for calculating index values and scoring are identical to the Quantification Tool worksheet (Section 1.2.e).

To calculate functional change, the same parameters and the same metrics must be included in each condition assessment. If a value is entered for a metric in the Existing Condition Assessment, a field value must also be entered for the As-Built Condition and for each monitoring event in the Monitoring Data worksheet. Field values in the Monitoring Data worksheet should be entered for each monitoring event as they occur. A condition assessment is not likely to be completed every calendar year.

1.2.G. DATA SUMMARY WORKSHEET

This worksheet is included in the MNSQT workbook but not the Debit Calculator. This worksheet provides a summary of project data from the existing condition, proposed condition, as-built condition, and monitoring assessments, as pulled from the Quantification Tool and Monitoring Data worksheets. The Data Summary worksheet features a function-based parameter summary, a functional category report card, and four plots showing this information graphically. *This worksheet is included for information purposes and does not require any data entry.*

1.2.H. REFERENCE CURVES WORKSHEET

The Reference Curves worksheet contains the reference curves used to convert metric field values into index values in the Quantification Tool and Monitoring Data worksheets. This worksheet is present in both the MNSQT and Debit Calculator workbooks. For information on reference curves, refer to Section 1.2. *This worksheet is included for information purposes and does not require any data entry. This worksheet is locked to protect the calculations used to convert field values to index values.*

The numeric index value range (0.00 to 1.00) was standardized across metrics by determining how field values relate to functional capacity, i.e., functioning, functioning-at-risk and not-functioning conditions (Table 1, page 13). Reference curves are tied to specific benchmarks (thresholds) that represent the degree to which the reach condition departs from reference standard as described in Table 1. On this worksheet, reference curves are organized into columns based on functional category and appear in the order they are listed on the Quantification Tool worksheet. One metric can have multiple curves depending on how the reference curves were stratified. For example, the dissolved oxygen (DO) metric is stratified by use class. All reference curves and their stratification are described in the Scientific Support for the MNSQT (MNSQT SC 2020).

There may be instances where better data to inform reference standard and index values are available for a project. The Corps can approve an exception to using the reference curves and index values for a metric within the MNSQT where sufficient data are available to identify reference standards.

1.2.I. DEBIT CALCULATOR WORKSHEET

This worksheet is only present in the Debit Calculator workbook, and not in the MNSQT workbook. The Debit Calculator worksheet is where users enter data describing the impacts to each reach by selecting an impact severity tier. Functional loss is then quantified. 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 worksheet within the Debit Calculator workbook. Cells that allow input are shaded grey and most other cells are locked. Each section of the Debit Calculator worksheet is discussed below.

COMPONENTS OF THE DEBIT CALCULATOR WORKSHEET

<u>Permit Number</u> – Provide the name of the project and any permit or application number assigned. This information will be automatically populated from the Project Assessment worksheet.

The Debit Tool Table (Figure 10) is the calculator where users enter data, describe the impact type and severity, and establish the existing condition for each stream reach in the project. This information, along with stream length is how resource value functional loss is quantified.

Figure 10: Debit Calculator Table Example

Stream ID by Reach	Impact Description	Debit Option	Existing Stream Length	Existing Condition Score	Proposed Length	Impact Severity Tier	Proposed Condition Score	Change in Functional Feet
STRM 1 R1	100 LF Minor channelization	3	500	0.27	400	Tier 3	0.14	-79.0
STRM 1 R2	75 LF Arch culverts	2	390	0.79	400	Tier 4	0.18	-236.1
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
							Total Functional Loss (Debits in FF):	**-315.1**

Stream ID by Reach – Applicants enter each impact site by reach. This information will be automatically populated from the Project Assessment worksheet. The user can score up to 10 reaches within each Debit Calculator workbook. If the project contains more than 10 reaches, more than one Debit Calculator workbook will need to be used.

Impact Description – Describe the impact proposed. This activity can range from culvert installations to bank armoring, or full channel fill and replacement. This information will automatically be populated from the Project Assessment worksheet.

Debit Option – There are three options for determining the existing and proposed site conditions. Users should select Debit Option 1, 2 or 3 from the dropdown menu. The existing and proposed conditions scores from the Existing Conditions and Proposed Conditions worksheets are automatically summarized in the ECS and PCS Summary Table. For projects that involve the complete removal or piping of a stream, the proposed condition score is 0.00.

For all Debit Options, it is important that any reach names used in the Existing Conditions and Proposed Conditions worksheets match the reach names used in the Project Assessment worksheet. These options are described below and summarized in Table 3; additional detail is provided in the St. Paul District Stream Mitigation Procedures (USACE Date pending).

1. Option 1 requires the applicant to use the Existing Conditions and Proposed Conditions worksheets of the Debit Calculator workbook to calculate the existing and proposed condition scores by quantitatively assessing required parameters. Parameter selection should be determined based on coordination with the appropriate regulatory agencies. The user will enter the existing scores for each reach into the Debit Tool Table. The proposed score will automatically populate with the proposed conditions score from the ECS and PCS Summary Table.

2. Option 2 is for permit applicants that choose to use the Existing Conditions worksheet with existing conditions data collected or modeled for the site for selected parameters and use the standard score for all other parameters. The parameter selection and standard score selection will be determined based on coordination with the appropriate regulatory agencies.

The proposed condition score will be calculated by the Debit Tool based on the Impact Severity Tier that is selected.

3. Option 3 allows permit applicants to use a standard existing condition score for all required parameters. The existing conditions score will default to 0.90 for state listed outstanding resource waters (prohibited or restricted) or 0.80 for all other waters. The proposed condition score will be calculated by the Debit Tool based on the Impact Severity Tier that is selected.

For all options, if the existing scores calculated from the Existing Condition worksheet are less than 0.30, the user will enter 0.30 into the Existing Conditions Score column of the Debit Tool table. The minimum allowable existing condition score is 0.30 and the debit calculator will highlight the cell if the existing score entered is less than 0.30.

Table 3: Summary of Debit Options

Debit Option	Existing Condition Score (ECS)*	Proposed Condition Score (PCS)
1	Assess existing condition using Existing Conditions worksheet for required parameters	Estimate proposed condition using Proposed Conditions worksheet for required parameters
2	Assess existing condition using Existing Conditions worksheet for selected parameters and use standard scores for all other parameters	Use Debit Calculator
3	Assess existing condition using Existing Conditions worksheet using standard scores for all parameters (0.90 for state listed outstanding resource waters (prohibited or restricted) and 0.80 for other waters as a default value)	Use Debit Calculator
** ECS cannot be below 0.30 for any of the options.*		

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

Proposed Stream Length – Calculate the length of stream channel after the impact has occurred. 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 length will be less than the existing 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 debit calculator will highlight the cell if the existing stream length is shorter than the proposed stream length.

Impact Severity Tier – Determination of an impact severity tier is needed to calculate a proposed condition score. The impact severity tier is a categorical determination of the amount of adverse impact to stream functions, ranging from no loss to total loss from a proposed activity. 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.

Impact Severity Tiers range from 0 – 5 where 0 represents no appreciable permanent loss of stream functions and therefore would not require compensatory mitigation, while a 5 would result in total loss of stream functions. Table 4 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.

Once the Impact Severity Tier has been selected, the proposed condition score and proposed functional feet will automatically calculate in the Debit Calculator. A description of how functional feet are calculated can be found in Section 1.2.e The absolute value of the total change in functional feet is equal to the base debits required to offset the proposed impacts. However, it is not the only information needed to determine the total amount of debits assessed in a project. This information is detailed in the St. Paul District Stream Mitigation Procedures (USACE Date pending), or the most recent applicable guidance.

Multiple stream impacts can be reported on a single spreadsheet. The spreadsheet will automatically total the base debits.

<u>ECS and PCS Summary Table</u> – Summarizes the overall existing condition scores and overall proposed condition scores of all stream reaches from the Existing Conditions and Proposed Conditions worksheets in a table located below the Debit Tool Table. If the existing condition score calculated from the Existing Conditions worksheet is less than 0.30, the score in the Summary Table will default to 0.30. Therefore, applicants can easily transfer overall existing condition scores from the summary table to the Debit Tool Table. The overall proposed conditions score will automatically populate in the Debit Tool Table when Debit Option 1 is selected.

Table 4: Impact Severity Tiers and Example Activities

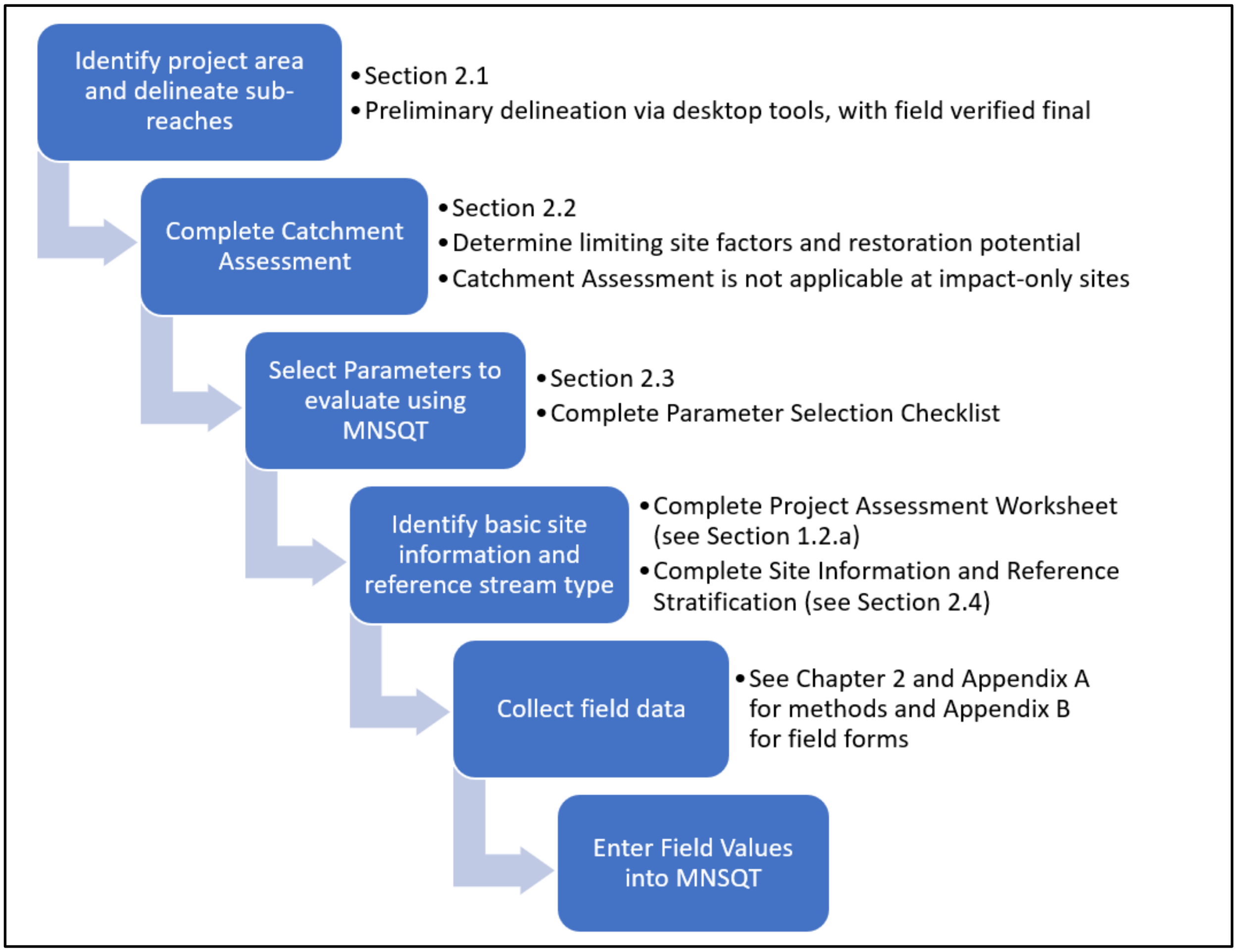
Tier	Description (Impacts to function-based parameters)	Example Activities
0	No permanent impact on any of the key function-based parameters	Bio-engineering of streambanks, stream restoration
1	Impacts to riparian vegetation and/or lateral migration	Bank stabilization, two-stage ditch, utility crossings
2	Impacts to riparian vegetation, lateral migration, and bed form diversity	Utility crossing, two-stage ditch, bridges, bottomless arch culverts
3	Impacts to riparian vegetation, lateral migration, bed form diversity, and floodplain connectivity	Bottomless arch culverts, minor channelization
4	Impacts to riparian vegetation, lateral migration, bed form diversity, and floodplain connectivity. Potential	Channelization, box culverts, short length pipe culverts,

	impacts to temperature, processing of organic matter, and macroinvertebrate and fish communities	weirs/impoundments/flood, and minor relocations
5	Removal of all aquatic functions	Piping, relocation, removal, or complete fill of channel

Chapter 2. Data Collection and Analysis

This chapter provides instruction on how to collect and analyze data used in the MNSQT and Debit Calculator workbooks. Figure 11 provides a flow chart of the typical process. Individuals collecting and analyzing these data should have experience and expertise in botany, ecology, hydrology, and geomorphology. Interdisciplinary teams with a combination of these skill sets are beneficial to ensure consistent and accurate data collection and analysis. Field training in the methods outlined herein, as well as the Stream Functions Pyramid Framework, are recommended to ensure that the methods are executed correctly and consistently. Additionally, the analysis for the BMP Minimal Impact Design Standards (MIDS) R_v Coefficient requires training and experience with hydrologic modeling and analyses, although this is an optional metric within the MNSQT.

Figure 11: MNSQT Process Flow Chart



This chapter includes methods for metrics that can be evaluated in the office, steps for calculating metrics, as well as a summary of field methods. For some metrics, multiple field methods are provided that will allow for either rapid or more comprehensive site assessment. Detailed field procedures are provided in Appendix A. Few metrics are unique to the MNSQT, and data collection procedures are generally 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 MNSQT.

2.1. Reach Delineation and Representative Sub-Reach Selection

The MNSQT is informed by reach-based assessment methods, and each reach is input into the tool separately. A large project may be subdivided into multiple project reaches (each requiring their own workbook), as stream condition or character can vary widely from the upstream end of a project to the downstream end.

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 reach to assess various metrics. The processes to define project reaches and representative sub-reaches are described in detail below in Sections 2.1.a and 2.1.b respectively.

2.1.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 valley morphology, stream type (Rosgen 1996), stability condition, riparian vegetation type, and bed material composition. Reaches within a project site may vary in length depending on the variability of the physical stream characteristics within the project area.

Practitioners can use aerial imagery, National Hydrography Dataset, and other desktop tools to determine preliminary reach breaks; however, these delineations should be verified in the field. Practitioners should provide justification for the final reach breaks in the Reach Description section of the Project Assessment worksheet. Specific guidance is provided below to assist in making consistent reach identifications:

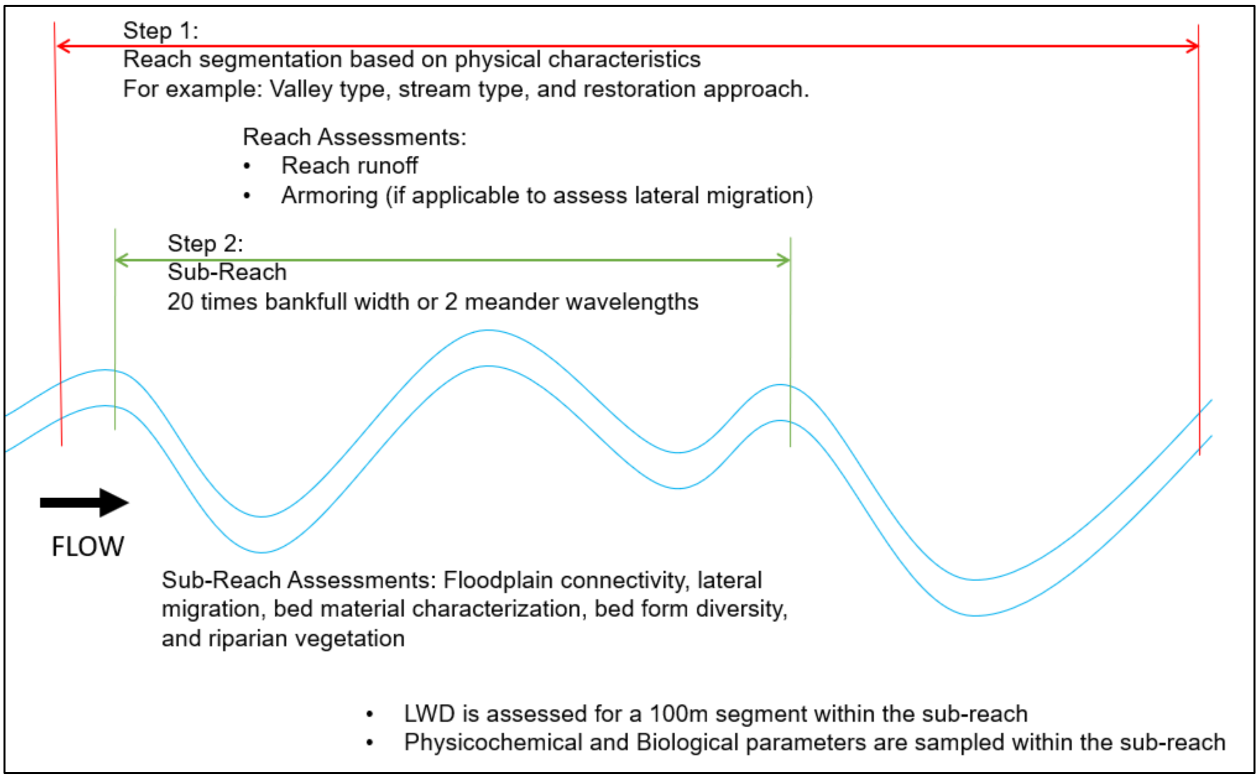
- Separate streams, e.g. tributaries vs. main stem, are considered separate project reaches.
- A tributary confluence should lead to a reach break. Where a tributary enters the main stem, the main stem should be split into two project reaches - one upstream and one downstream of the confluence. Small 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 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 separate reaches upstream and downstream of the structure. The diversion dam or structure would also be its own 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, dams, stabilization, 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 versus bank stabilization activities.

2.1.B. Representative Sub-Reach Determination

Some metrics will be evaluated along an entire project reach length, some will be evaluated at a specific point within the project reach and other metrics will be evaluated in a representative sub-reach (Figure 12). Selecting a representative sub-reach is necessary to avoid having to quantitatively assess very long stream lengths with similar physical conditions. The representative-sub reach is 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. Guidelines are provided below for each functional category.

Figure 12: Reach and Sub-Reach Segmentation



<u>Hydrology Functional Category</u>:

- Reach runoff metrics are evaluated within the entire project reach.

<u>Hydraulics Functional Category</u>:

- Floodplain connectivity is assessed within the representative sub-reach.

Geomorphology Functional Category:

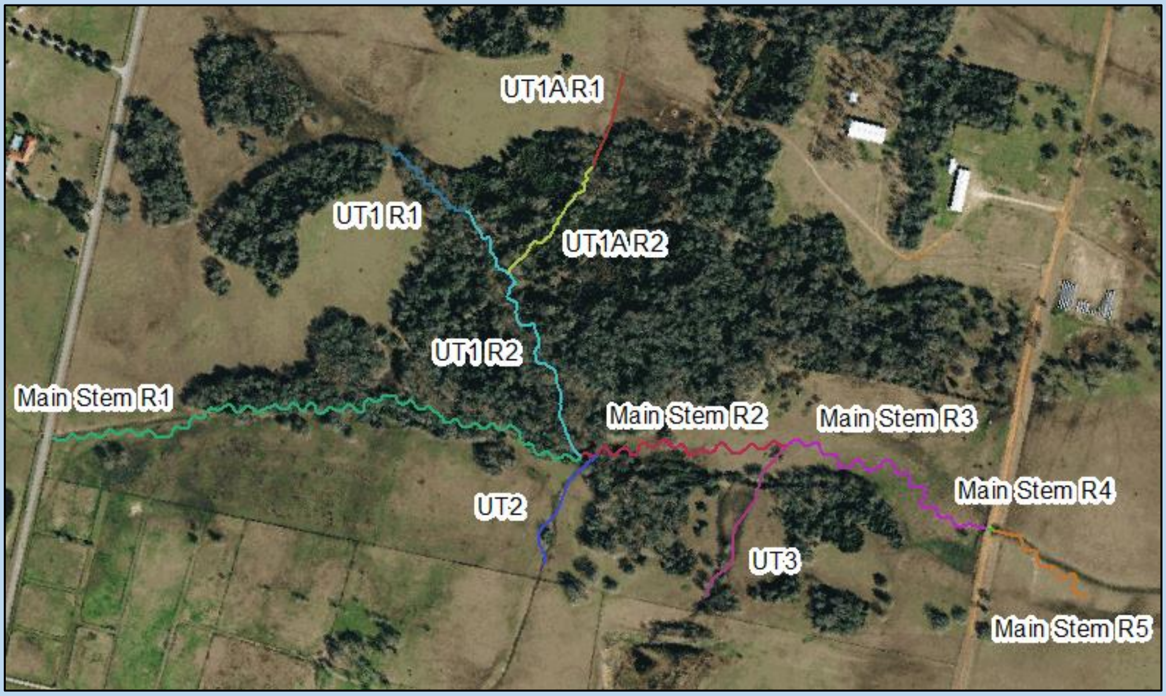
- Large woody debris (LWD) is assessed within a 328-foot (100 meter) segment located, whenever possible, within the representative sub-reach. If the project reach is less than 328 feet, the LWD assessment should extend proportionally into the adjacent upstream and downstream segments to achieve the required stream length.
- Lateral migration, bed material characterization, bed form diversity, and riparian vegetation are assessed within the representative sub-reach. There is one exception. Armoring, which is a metric under lateral migration, is assessed along the entire project reach.

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 and in Appendix A.

Example 3: 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. This project has a total of 11 project reaches and an MNSQT Excel Workbook would need to be completed for each.



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.
Main Stem R3	To culvert. Bed material is finer and bed form 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.

2.2. Catchment Assessment

The primary purpose of the Catchment Assessment is to assist in determining restoration potential for restoration and mitigation projects (described in Section 3.2.a.). It is a decision-support tool rather than a quantitative scoring tool. Therefore, results from the Catchment Assessment are not scored in the MNSQT but are used to help inform a restoration potential decision. The Catchment Assessment worksheet is included in the MNSQT workbook, but not the Debit Calculator workbook.

The Catchment Assessment worksheet includes descriptions of processes and stressors that exist outside of the project reach or conservation easement and may limit functional lift. The Catchment Assessment does not pertain to stressors occurring within the project reach/easement area that can be addressed as part of the restoration activities. The Catchment Assessment evaluates conditions primarily upstream, but sometimes downstream of the project reach. Instructions for collecting data and describing each process and stressor are provided in this section.

There are 14 defined categories, with space for an additional user-defined category to identify and document any stressor observed in the catchment that could limit the restoration potential or impair the functioning of the project reach. There are three choices to rate the catchment condition for each category: Good, Fair, and Poor.

The Catchment Assessment relies on data available from the MN DNR's WHAF. The specific WHAF index or value that relates to each category is listed in Column I. Information on the WHAF and index descriptions are provided at the DNR WHAF website (https://www.dnr.state.mn.us/whaf/index.html).

The score for the indicators of hydrologic alteration (IHA) analysis used in the Flashiness Index (Hydrology) category is derived from the Rate and Frequency of Change metric and the Frequency and Duration of High/Low Pulses metric (metric values are listed in the Major Flow Variability Metrics worksheet provided in the MNSQT).

The data used to evaluate each category should be documented and provided as supporting data. Once all categories of the Catchment Assessment are completed, the user should provide an overall watershed condition, based on their best professional judgement, and determine the restoration potential for the reach. The user should refer to Section 3.2.a for determining the Restoration Potential for the reach.

2.3. Parameter Selection

The MNSQT and Debit Calculator workbooks include 24 metrics used to quantify 12 parameters. Not all metrics and parameters will need to be evaluated at each site. The user should consider landscape setting, function-based goals/objectives and restoration potential when selecting parameters.

IMPORTANT CONSIDERATIONS:

- For CWA 404 and RHA Section 10 projects, the Corps has discretion over which field methods, metrics, and parameters are used for a project; therefore, users should consult with the Corps prior to data collection on a project. In addition, the Corps strongly encourages applicants or bank sponsors to consult with the District and other state or local regulatory authorities prior to data collection on a project to avoid costly delays and unnecessary data collection. Not all field methods, metrics, and parameters may be required for all projects.

- The same parameters must be used in the existing condition and all subsequent condition assessments (i.e., proposed, as-built, and monitoring) within a project reach, otherwise the relative weighting between metrics and parameters changes and the overall scores are not comparable over time.
- For metrics that are not selected (i.e., a field value is not entered), the metric is not included in the scoring. It is NOT counted as a zero.
- The overall scores should not be compared or contrasted between sites when parameters and metric selection vary between project sites. To evaluate multiple sites, the same suite of parameters and metrics would need to be collected at all sites.
- The reach runoff, floodplain connectivity, lateral migration, riparian vegetation, and bed form diversity parameters must be evaluated at all sites. These parameters are important indicators of the stability and resiliency of stream systems. If data are not entered for these parameters, the Quantification Tool worksheet in the MNSQT workbook will display a warning message above the Functional Category Report Card reading, *“WARNING: Data are not provided for Reach Runoff, Floodplain Connectivity, Lateral Migration, Riparian Vegetation, and Bed Form Diversity Parameters.”*
- Field methods in Appendix A are generally focused on single-thread wadeable streams, except for fish, which can be sampled in wadeable and non-wadeable streams. Some metrics may be difficult to sample in non-wadeable or stream/wetland complexes and may require alternate field methodologies. For CWA 404 or RHA Section 10 projects, sampling plans in these systems should be discussed with the Corps and other state or local regulatory authorities prior to data collection efforts.
- Reference curves to assign index values have been primarily derived from data within perennial, wadeable, single-thread stream systems. Thus, when applying metrics in other stream situations, such as stream/wetland complexes (Figure 13) or ephemeral channels, the user should note this and select only applicable parameters and metrics (Table 5). While a parameter and associated metrics may be applicable to ephemeral and stream/wetland complexes, the user should understand that the reference curves are not from these systems. Therefore, more focus should be placed on the difference in stream condition rather than the absolute value.

Figure 13: Example of a stream/wetland complex within a single thread stream corridor

Table 5 shows which parameters are applicable to different stream flow and channel types. Additionally, modifications to sampling methods may be needed to accommodate data collection in stream/wetland complexes or non-wadable streams.

Table 5: Applicability of metrics across flow type and in stream/wetland complexes

Applicable Parameters	Perennial	Intermittent	Ephemeral	Stream/Wetland Complexes (Anastamosed, DA)	Stream/Wetland Complexes (Single thread, E/Cc-)
Reach Runoff	x	x	x	x	x
Floodplain Connectivity	x	x	x	x[1]	x
Large Woody Debris	x	x	x	x	x
Lateral Migration	x	x	x	x	x
Bed Material Characterization	x	x	x	x	x
Bed Form Diversity	x	x			x
Riparian Vegetation	x	x	x	x	x
Temperature	x	Where baseflows extend through sampling period		x	x
Dissolved Oxygen	x			x	x
TSS	x			x	x
Macroinvertebrates	x			x	x
Fish	x			x	x

An 'x' denotes that one or more metrics within a parameter is applicable within these streams

1 - ER not applicable for stream/wetland complexes with D_A stream types.

SPECIFIC GUIDANCE ON PARAMETER SELECTION:

Reach Runoff Parameter: This parameter should be evaluated at all project sites. Users should evaluate the land use coefficient metric and the concentrated flow points metric together. These two metrics are used in rural environments and urban environments without stormwater best management practices (BMPs). The BMP MIDs R_v coefficient is an optional metric that should be used only when BMPs are proposed on land adjacent to the stream restoration project. If the BMP MIDS R_v coefficient is used, the land use coefficient and concentrated flow points metrics are not used.

Floodplain Connectivity: This parameter should be evaluated at all project sites. The BHR and ER metrics are complementary, as each of these metrics contributes differently to an overall understanding of floodplain connectivity; therefore, they should be applied together. The only exception is in stream/wetland complexes with D_A stream types, where the BHR should be applied but not the ER.

Large Woody Debris (LWD) Parameter: This parameter should be evaluated at project sites where trees/wood is a natural component of the riparian corridor. 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.

Lateral Migration Parameter: This parameter should be evaluated at all project sites. Users should evaluate the dominant BEHI/NBS and percent streambank erosion metrics together. Additional guidance on metric selection follows:

1. The dominant BEHI/NBS and percent erosion metrics are applicable in single-thread channels. These metrics are not recommended in systems that are naturally in disequilibrium, like some braided streams, ephemeral channels, alluvial fans, or other systems with naturally high rates of bank erosion.
2. The percent armoring metric is applicable only when armoring techniques are present or proposed in the project reach. **However, if more than 75% of the reach is armored, it is recommended that the other metrics in the lateral migration parameter not be measured.** At this magnitude, the armoring is so pervasive that lateral migration processes would likely have no functional value. If a user is proposing to armor an eroding bank, the user would substitute this metric for dominant BEHI/NBS in calculating the proposed condition score; the user would not apply the BEHI/NBS metric to an armored bank.

Bed Material Characterization Parameter: This parameter is optional and 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 parameter is only applicable in gravel and cobble bed streams. Selection and sampling of a reference reach is required.

Bed Form Diversity Parameter: This parameter should be evaluated at all single-thread perennial and intermittent project sites. Users must evaluate pool spacing ratio, pool depth ratio, and percent riffle metrics together. The aggradation ratio metric is optional. Additional guidance on metric selection follows:

1. The pool spacing ratio metric should be evaluated at all sites except natural bedrock systems, ephemeral streams, or stream/wetland complexes with DA stream types, where the metric is not applicable.
2. The pool depth ratio and percent riffle metrics should be evaluated together at all sites except ephemeral streams or stream/wetland complexes with DA stream types.
3. The aggradation ratio metric is recommended for meandering single-thread stream types where the riffles are exhibiting signs of aggradation.

Riparian Vegetation Parameter: This parameter should be evaluated at all project sites. However, the woody stem basal area metric should only be used if woody vegetation is determined to be a natural component of the riparian buffer.

Temperature, Dissolved Oxygen, and Total Suspended Solids[2]: These parameters are optional and are recommended for projects with goals and objectives related to water quality

[2] Without evaluating the physicochemical and biological parameters, the maximum overall score in the MNSQT will be 0.60. Selecting and assessing parameters in both of these functional categories will increase the maximum overall score to 1.0 in the MNSQT.

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.

Macroinvertebrates Parameter: This parameter is optional for all partial restoration potential projects and is recommended for wadeable perennial and intermittent stream projects with goals and objectives related to biological improvements or projects where improvements in biological condition are anticipated based on restoration potential.

Fish Parameter: This parameter is optional for all partial restoration potential projects and is recommended for wadeable and non-wadeable perennial projects with goals and objectives related to biological improvements or projects where improvements in biological condition are anticipated based on restoration potential.

2.4. Data Collection for Site Information and Reference Selection

The Quantification Tool worksheet quantifies the change in condition using reference curves to translate measured field values into index scores. For some metrics, these curves are stratified by physical stream characteristics like stream type and vegetation attributes. The Site Information and Reference Selection section of the Quantification Tool worksheet consists of general site information and classifications to determine which reference curves are used to calculate index values for relevant metrics. It may not be necessary to complete all fields in this section, depending on parameter selection. Metrics will not be scored or may be scored incorrectly if necessary data are not provided in this section.

In the Debit Calculator workbook, similar information for each reach is included in the Reach Information and Reference Selection section above each condition assessment in the Existing Conditions and Proposed Conditions worksheets. Metrics will not be scored or may be scored incorrectly if necessary data are not provided in this section.

Information on each field and guidance on how to select values is described below.

For fields with drop-down menus, if a certain variable is not included in the drop-down menus, then data to inform stratified index values for a specific physical stream characteristic is not yet available for Minnesota. Additional information on how reference curves are stratified is included in the Scientific Support for the MNSQT (MNSQT SC, 2020).

Project Name – Enter the name of the project.

Reach ID – Each project reach within a project area should be assigned a unique identifier (see Section 2.1 for guidance on delineating project reaches).

Restoration Potential (restoration and mitigation projects only) – Restoration potential should be determined for the reach (not the sub-reach) using the stepwise process described in Section 3.2.a. This cell is automatically populated by the restoration potential selected by the user on the Catchment Assessment worksheet.

Existing Stream Type – The existing stream type is determined through a field survey of the project reach. This stream classification system and the basic fluvial landscapes in which the different stream types typically occur are described in detail in *Applied River Morphology* (Rosgen 1996). The broad-level stream type is determined using entrenchment ratio (ER), width depth ratio, sinuosity, and slope (Figure 14). In the MNSQT, the existing stream type is used for communication and informs channel evolution scenarios and restoration potential (see section

3.2). The existing stream type is **not** used to select the appropriate reference curve or determine index values in the MNSQT or Debit Calculator (see reference stream type below).

Figure 14: Rosgen Stream Classification Summary (Rosgen 1996)

<table>
<tr><th colspan="6">Quick Rosgen Stream Classification Guide (Rosgen 1996)</th></tr>
<tr><td colspan="3">ER < 1.4</td><td>1.4 < ER < 2.2</td><td colspan="2">ER > 2.2</td></tr>
<tr><td colspan="2">WDR < 12</td><td>WDR > 12</td><td>WDR > 12</td><td>WDR < 12</td><td>WDR > 12</td></tr>
<tr><td>K<1.2</td><td>K>1.2</td><td>F</td><td>B</td><td>E</td><td>C</td></tr>
<tr><td>A</td><td>G</td><td colspan="4">ER = Entrenchment Ratio; WDR = Width Depth Ratio; K = Sinuosity</td></tr>
</table>

<u>Reference Stream Type</u> – The MNSQT and Debit Calculator rely on the reference stream type to stratify reference curves for the entrenchment ratio, pool spacing ratio, and percent riffle metrics.

Reference stream type is the stream type that should occur in a given landscape setting given the hydrogeomorphic processes occurring at the watershed and reach scales. Channel evolution scenarios should be used to inform the reference stream type in the MNSQT and Debit Calculator, and this information can be further supported with information from the design process, where available (see Example 4). The Rosgen Channel Succession Scenarios (Rosgen 2006) or other stream evolution models (Cluer and Thorne 2013) can be used as a guide for determining the reference stream type. In the MNSQT workbook, this cell is automatically populated by the reference stream type selected by the user on the Project Assessment worksheet. Space is provided on the Project Assessment worksheet to describe the rationale used to select the reference stream type.

Example 4: Reference Stream Type Identification

Existing stream type: Gc
This stream type will often evolve into an F and then a C stream type (Table 14). If the reach is in a wide alluvial valley, the reference stream type would likely be a C, E, or DA. These are all common in wide, low gradient, alluvial valleys.

However, it may sometimes evolve into a Bc stream type if the forces resisting lateral migration are greater than the driving forces of water and sediment discharge.

Historic, geomorphic, and even stratigraphic evidence and research may be needed to determine reference stream type. For example, DA (stream/wetland) complexes were historically common in alluvial valleys with low energy and sediment supply (Cluer and Thorne 2013) while alluvial valleys with gravel/cobble bed streams and sediment supply were likely single-thread C or E stream types (Rosgen 2006). Information from the design process (e.g., fluvial landscape, historic channel conditions, watershed hydrology, sediment transport, and/or anthropogenic constraints) can also be used to inform reference stream type. It will require experience and expertise from a multi-disciplinary team to determine the reference stream type.

Woody Vegetation Natural Component – The MNSQT uses this stratifier to select the correct reference curves for the Canopy Cover and Woody Stem Basal Area metrics. Methodology for determining if trees and shrubs are a natural component of the riparian zone is described in the Canopy Cover Data Collection section in Appendix A. In cases where woody vegetation is a natural component of the riparian zone, the user will select yes from the drop-down menu. This condition should represent the vegetation community that would naturally occur at the site if the reach were free of anthropogenic alteration and impacts.

Use Class – A water body's use class is determined by the Minnesota Pollution Control Agency (MPCA) based on the best usage and the need for water quality protection in the interest of the public. The use classifications are shown below:

- Class 2A. Aquatic life and recreation beneficial use. Waters that support or may support cold water aquatic biota, bathing, boating, or recreational purposes and for which quality control is or may be necessary to protect aquatic or terrestrial life. This class of surface waters is also protected as a source of drinking water.
- Class 2B. Aquatic life and recreation beneficial use. Waters that support or may support cold or warm water aquatic biota, bathing, boating, or recreational purposes and for which quality control is or may be necessary to protect aquatic or terrestrial life.
- Class 2Bd. Aquatic life and recreation beneficial use. Waters that support or may support cold or warm water aquatic biota, bathing, boating, or recreational purposes and for which quality control is or may be necessary to protect aquatic or terrestrial life. This class of surface waters is also protected as a source of drinking water
- Class 2D. Wetlands.
- Class 7. Limited resource value waters. The quality of Class 7 waters shall protect aesthetic qualities, secondary body contact use, and groundwater for use as potable water supply.

The use class is used to stratify the reference curves for both the DO and Total Suspended Solids (TSS) parameters. Use classes are provided in Minnesota Administrative Rules[3,4].

River Nutrient Regions – The river nutrient region is used to stratify reference curves for the TSS parameter. Figure 15 shows the nutrient regions delineated for MN and Table 6 sets out standards for TSS developed by the MPCA by nutrient region or reach.

[3] https://www.revisor.mn.gov/rules/7050.0470/
[4] https://www.revisor.mn.gov/rules/7050.0430/ (unlisted waters)

Figure 15: River Nutrient Regions in Minnesota (MPCA 2019)

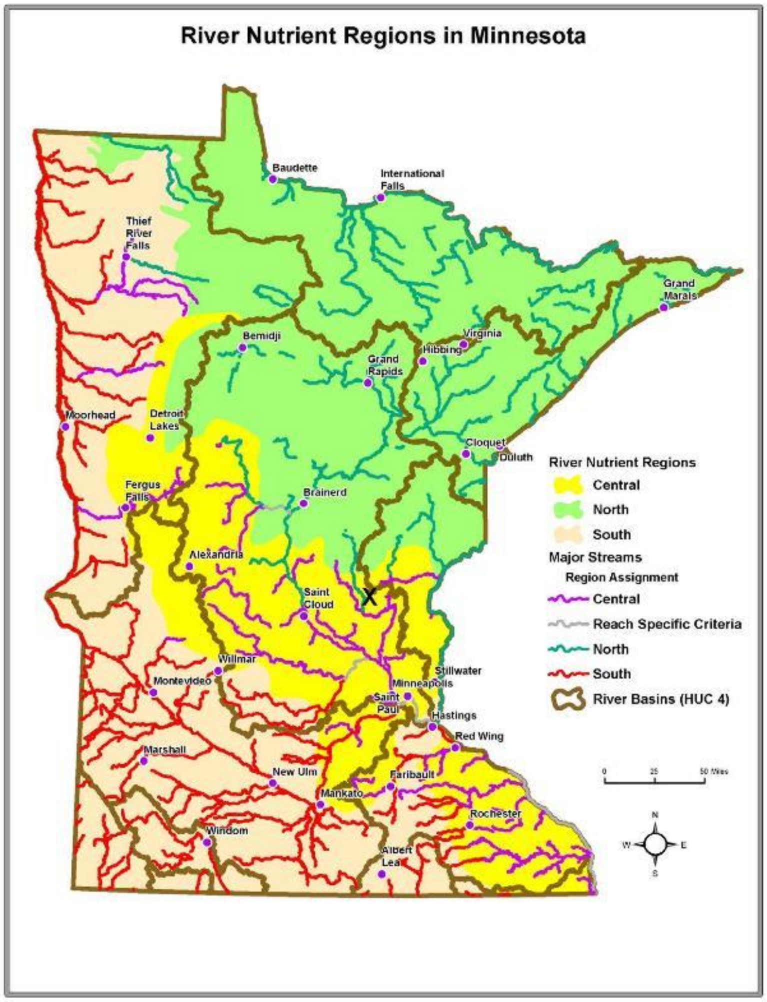


Table 6: Minnesota's TSS, Secchi tubes (S-tube), and site-specific standards for named river reaches

Region or River	TSS (mg/L)	S-tube (cm) Exceeds	S-tube (cm) Meets
All Class 2A Waters	10	55	95
Northern River Nutrient Region as Modified for TSS	15	40	55
Central River Nutrient Region as Modified for TSS	30	25	35
Southern River Nutrient Region as Modified for TSS	65	10	15
Red River Nutrient Region as Modified for TSS	100	5	10
(Assessment season for above waters is April through September)			
Lower Mississippi Mainstem – Pools 2-4	32		
Lower Mississippi Mainstem below Lake Pepin	30		
(Assessment season for Lower Mississippi is June through September)			
Adapted from MPCA 2019			

Drainage Area (sq.mi.) – The drainage area is the land area draining water to the downstream end of a project reach and is delineated using available topographic data (e.g., StreamStats, USGS maps, LiDAR or other digital terrain data). The drainage area is not used to stratify any reference curves but is important information to include for a project site. This input is not included in the Debit Calculator workbook.

Proposed Bed Material – The bed material characterization metric in the MNSQT is only applicable to gravel or cobble bed streams. Otherwise, the proposed bed material is not used to stratify any reference curves but is important information to include for a project site. Instructions for performing a pebble count is provided in Appendix A.

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. Note the user provides this input in the Debit Calculator worksheet of the Debit Calculator workbook rather than the Site Information and Reference Selection section.

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 Project Reach Stream Length above. Where stream length does not change post-project, the same value can be entered for the Existing and Proposed Project Stream Length. Stream length is used to calculate the functional feet, so both existing and proposed stream length must be recorded. Note the user provides this input in the Debit Calculator worksheet of the Debit Calculator workbook rather than the Site Information and Reference Selection section.

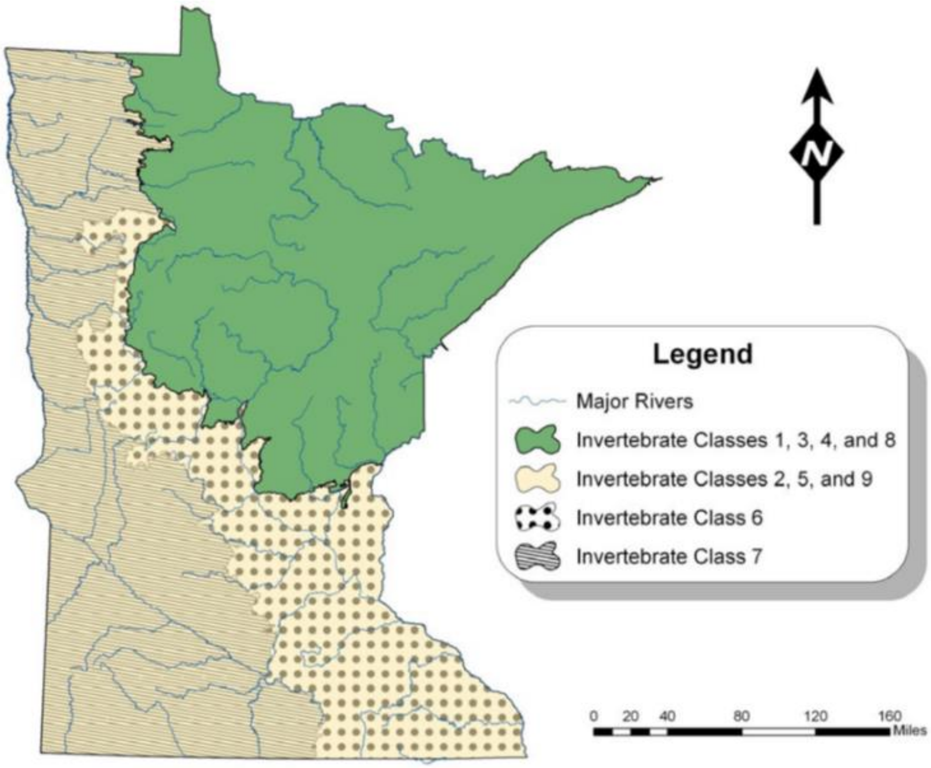
Macroinvertebrate Index of Biological Integrity (IBI) Class – The MPCA recognizes nine different macroinvertebrate IBI classes based on stream type and the expected natural macroinvertebrate community associated with each. Stream types are defined using drainage area, geographic region, thermal regime, and gradient. Table 7 presents the different classes and their criteria while Figure 16 shows the geographic distribution of each class.

Table 7: Macroinvertebrate IBI Classes in Minnesota

Stream Type/Class	Description	Drainage Area
1 - Northern Forest Rivers	Rivers in the Laurentian Mixed Forest province	>=500 Sq. Miles
2 - Prairie and Southern Forest Rivers	Rivers in the Eastern Broadleaf Forest, Prairie Parklands, and Tall Aspen Parklands ecological provinces	>=500 Sq. Miles
3 - Northern Forest Streams, Riffle-Run (RR)	High gradient streams in the Laurentian Mixed Forest ecological province	< 500 Sq. Miles
4 - Northern Forest Streams, Glide-Pool (GP)	Low gradient streams in the Laurentian Mixed Forest ecological province	< 500 Sq. Miles
5 – Southern Streams, RR	High gradient Streams in the Eastern Broadleaf Forest, Prairie Parklands, and Tall Aspen Parklands ecological provinces, as well as streams in HUC 07030005	< 500 Sq. Miles
6 – Southern Forest Streams, GP	Low gradient streams in the Eastern Broadleaf Forest, as well as streams in HUC 07030005	< 500 Sq. Miles
7 – Prairie Streams, GP	Low gradient Streams in the Prairie Parklands, and Tall Aspen Parklands ecological provinces	< 500 Sq. Miles

Stream Type/Class	Description	Drainage Area
8 – Northern Coldwater	Coldwater streams in northern portions of Minnesota characterized by the Laurentian Mixed Forest ecological province	N/A
9 – Southern Coldwater	Coldwater streams in southern portions of Minnesota characterized by the Eastern Broadleaf Forest, Prairie Parklands, and Tall Aspen Parklands ecological provinces	N/A
Adapted from MPCA 2014a		

Figure 16: Map of Macroinvertebrate IBI Classes in Minnesota (MPCA 2014a)



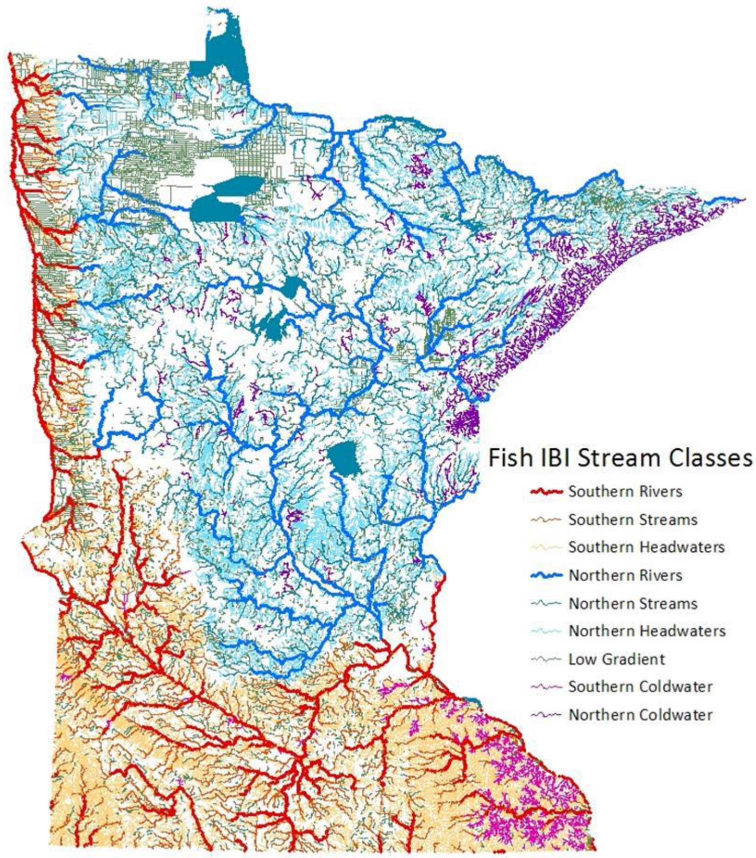
Fish IBI Class – Similar to macroinvertebrates, the MPCA has developed a comprehensive, statewide IBI to assess the biological integrity of riverine fish communities in Minnesota. IBI classes were first defined using watershed lines that reflect post-glacial barriers to movement, resulting in ‘north’ and ‘south’ streams (Figure 17). These two classes were further refined into nine total classes based on stream/watershed size, thermal regime, and gradient (Table 8). Figure 18 shows the general geographic distribution of each class. It is important to note that the map is for display purposes only; classification of individual sampling locations should utilize site-specific attributes as outlined in Table 8.

Figure 17: Map of 'north' and 'south' streams defined for the MN fish IBI (MPCA 2014b)

Table 8: Fish IBI Classes in Minnesota

<table>
<tr><th>Fish IBI Class*</th><th>Drainage Area</th><th>Gradient</th></tr>
<tr><td>Northern Rivers</td><td>>500 sq. miles^{+}</td><td rowspan="2">N/A</td></tr>
<tr><td>Northern Streams</td><td>>50 sq. miles</td></tr>
<tr><td>Northern Headwaters</td><td><50 sq. miles</td><td>>0.50 m/km</td></tr>
<tr><td>Northern Coldwater</td><td>N/A</td><td rowspan="3">N/A</td></tr>
<tr><td>Southern Rivers</td><td>>300 sq. miles</td></tr>
<tr><td>Southern Streams</td><td>>30 sq. miles</td></tr>
<tr><td>Southern Headwaters</td><td><30 sq. miles</td><td>>0.50 m/km</td></tr>
<tr><td>Southern Coldwater</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Low Gradient</td><td><50 sq. miles (north)
<30 sq. miles (south)</td><td><0.50 m/km (north)
<0.30 m/km (south)</td></tr>
<tr><td colspan="3">Adapted from MPCA 2014b
*All classes are warmwater, except for northern and southern coldwater classes
$^{+}$Drainage area cutoff for rivers in the Red River basin is >350 sq. miles</td></tr>
</table>

Figure 18: Map of fish IBI classes in Minnesota (MPCA 2014b)



<u>Valley Type</u> – Valley type is used to stratify reference curves for riparian width. 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 and anastomosed stream types (e.g., 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). **Note:** For purposes of the MNSQT, lacustrine valley types are considered unconfined alluvial valleys.
>
> *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 and 4.
>
> *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.

Flow Permanence – Select whether the stream reach is Perennial, Intermittent, or Ephemeral. Flow permanence is not used for reference standard stratification but can be used to inform parameter selection and to provide context to the change in functional feet in the Mitigation Summary Table. Consult with the Corps regarding the current definition of these terms.

Strahler Stream Order – Stream order as defined by Strahler (1957) is a classification based on stream/tributary relationships. Headwater streams are first order; a stream is second order downstream of the confluence of two first order streams; a stream is third order downstream of the confluence of two second order streams; and so on. Stream order is not used for reference curve stratification but is used to provide context to the change in functional feet in the Mitigation Summary Table.

Outstanding Resource Waters – Outstanding resource waters determination information is provided in Minnesota Administrative Rules[5]. This input is only in the Debit Calculator workbook and is not included in the MNSQT workbook. This input is not used to stratify any reference curves but impacts the default standard scores associated with metrics in the Debit Calculator.

Proposed BMPs – Enter yes if the project includes BMPs to treat runoff from the lateral drainage area. This input is only in the Debit Calculator workbook and is not included in the MNSQT workbook. This input is not used to stratify any reference curves but impacts which metric(s) are used to assess reach runoff in the Debit Calculator.

Stream/Wetland Complex – This input is only in the Debit Calculator workbook and is not included in the MNSQT workbook. This input impacts which metrics are used to assess bed form diversity in the Debit Calculator.

Presence of Armoring – This input is only in the Debit Calculator workbook and is not included in the MNSQT workbook. This input is not used to stratify any reference curves but impacts whether a default standard score is included for the percent armoring metric.

Latitude/Longitude – In the Debit Calculator workbook, enter the latitude and longitude of the upstream and downstream extent of the reach.

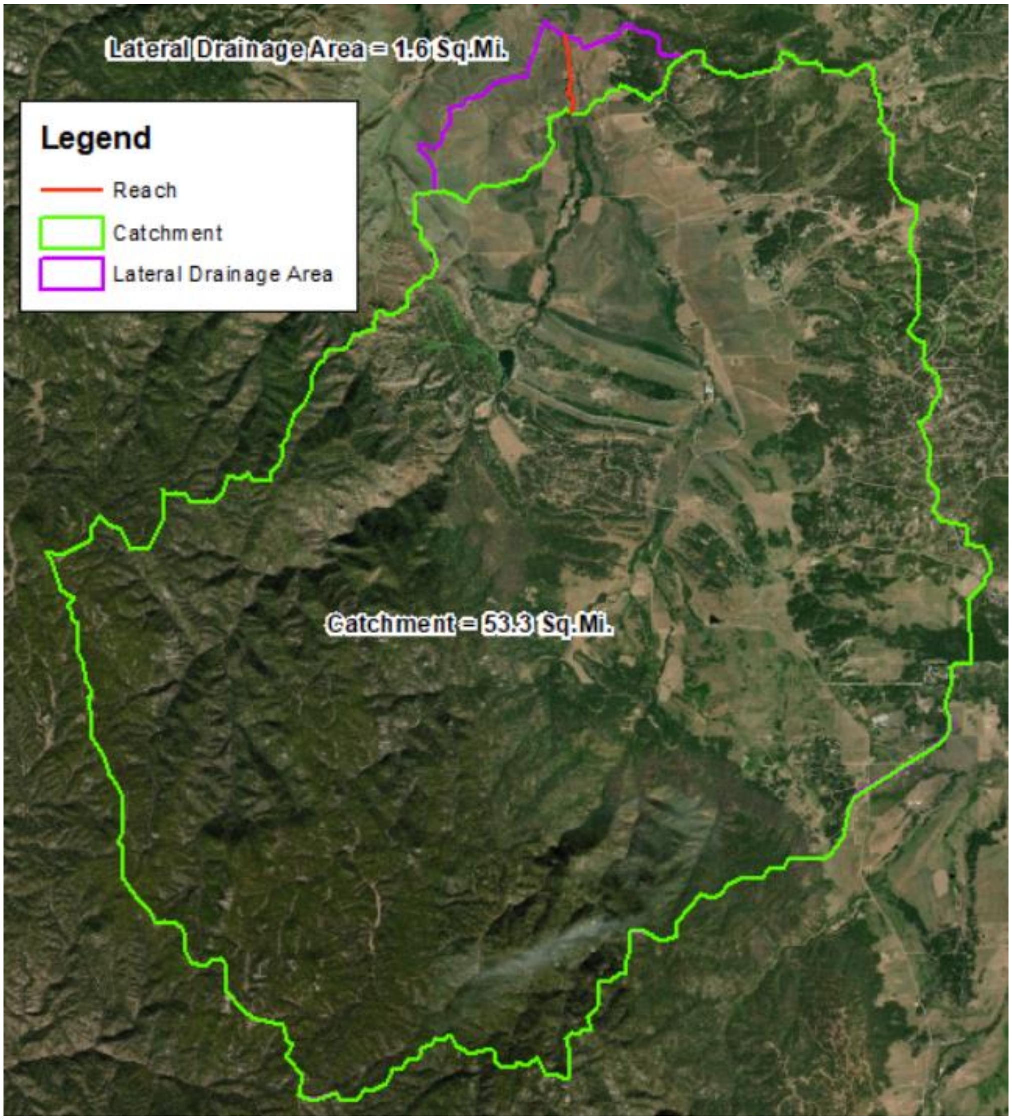
2.5. Hydrology Functional Category Parameters and Metrics

There is one function-based parameter to assess reach-scale hydrology functions: reach runoff. There are three metrics to assess reach runoff: land use coefficient, BMP MIDS R_v coefficient, and concentrated flow points. The land use coefficient and concentrated flow are used together to assess Reach Runoff. The BMP MIDS R_v coefficient metric is used in urban environments when BMPs are applied to adjacent uplands. The land use coefficient and concentrated flow points are not measured if the BMP MIDS R_v coefficient is used.

Reach runoff metrics are assessed in the lateral drainage area for the project reach. The lateral drainage area (Figure 19) is the portion of the reach catchment that drains directly to the reach from adjacent land uses. The purple line delineates the upgradient extent of the land draining to the project reach (i.e., 1.6 mi^2).

[5] https://www.revisor.mn.gov/rules/7050.0335/

Figure 19: Lateral Drainage Area for Reach Runoff



LAND USE COEFFICIENT

The land use coefficient metric evaluates the infiltration and runoff processes of the land that drains laterally into the stream reach. This metric, an area weighted land use coefficient, serves as an indicator of runoff potential from land uses draining into the project reach between the upstream and downstream end points. Land use coefficients are shown in Table 9. Higher values, nearer 100, indicate more runoff potential while lower values, nearer 0, indicate less runoff.

Table 9: Land Use Descriptions and Associated Land Use Coefficients

Land Use Description (From TR-55)	Land Use Coefficient
Urban Areas Land Uses	
Open Space (lawns, parks, golf courses, cemeteries, etc.)	61
Impervious areas	98
Gravel Roads	85
Dirt Roads	82
Commercial and business districts	92
Industrial districts	88
Residential districts by average lot size: 1/8 acre or less (town houses) 1/4 acre 1/3 acre 1/2 acre 1 acre 2 acres	 85 75 72 70 68 65
Agricultural Lands/Natural Land Cover	
Pasture, grassland, or range – continuous forage for grazing	61
Meadow – continuous grass, protected from grazing and generally mowed for hay	58
Brush – brush-weed-grass mixture with brush major element	48
Woods – grass combination (orchard or tree farm)	58
Farmsteads – buildings, lanes, driveways, and surrounding lots	74
Woods – disturbed by heavy grazing	66
Woods – forested areas protected from grazing and w/adequate litter and brush covering the soil	55
Adapted from Natural Resource Conservation Service (NRCS) 1986	

Data Collection Method:

1. Delineate the lateral drainage area between the upstream and downstream project reach limits. This will include land area on both sides of the stream (see Figure 19).
2. Using the USGS National Land Cover Database (NLCD), delineate the different land use types within the lateral drainage area and calculate the area occupied by each type.
3. Using Table 9, assign each land use type a land use coefficient value.
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).

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

Concentrated Flow Points

Anthropogenic impacts can lead to concentrated flows that erode soils and transport sediment into receiving stream channels. This metric assesses the number of concentrated flow points that enter the project reach per 1,000 linear feet of stream. For this metric, concentrated flow points are defined as erosional features, such as swales, gullies or other channels, that are created by anthropogenic impacts. Anthropogenic causes of concentrated flow may include agricultural drainage ditches, impervious surfaces, storm drains, and others (see Example 5).

Example 5: Concentrated Flow Points

An agricultural ditch draining water from an adjacent field into a project reach.

Stream restoration projects can reduce concentrated flow entering the channel by dispersing flow in the floodplain and increasing ground cover near the channel. Combining multiple concentrated flow points into a single concentrated flow point does not count as an improvement. The restoration activity must diffuse or capture the runoff. Example activities include filling ditches, removing pipes, routing concentrated flow into created oxbow ponds, and stormwater BMP's.

Development can negatively impact stream channels by creating concentrated flow points such as stormwater outfalls. Proposed grading and stormwater management plans for development should be consulted to determine whether, and how many, concentrated flow points are likely to result from the proposed development.

<u>Data Collection Method</u>:

Concentrated flow points are evaluated in the field; methods are outlined in Appendix A.

BMP MIDS R_V Coefficient

The BMP MIDS R_v coefficient is assessed for projects that will include stormwater BMPs adjacent to the stream restoration project. The MPCA MIDS calculator accounts for percent impervious in the site runoff coefficient (R_v). The site runoff coefficient is a weighted coefficient based on user input of land use and soil type (Table 10). The R_V is used to calculate annual volume. To assess BMP runoff, the user must use the MIDS calculator[6] to calculate the existing runoff coefficient (R_v) and then calculate the effective R_v for the proposed condition.

[6] The MIDS calculator, web-based manual, and supporting information is available at https://www.pca.state.mn.us/water/enhancing-stormwater-management-minnesota

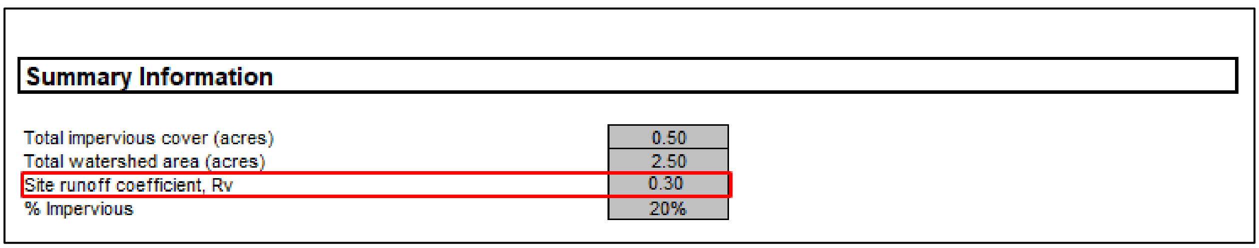
Table 10: R_v Coefficients by Land Use and Soil Type

R_v coefficients	A soils	B soils	C soils	D soils
Forest/Open space	0.02	0.03	0.04	0.05
Managed turf (disturbed soils)	0.15	0.20	0.22	0.25
Impervious cover	0.95	0.95	0.95	0.95
Adapted from MPCA 2014c				

<u>Data Collection Method</u>:

1. Determine the existing land use and impervious cover for the area that drains to the proposed BMP(s).
2. Using the MIDS calculator, the user inputs existing land use and impervious cover. The Existing R_v coefficient is not displayed in the MIDS GUI interface but can be found in the Site Information and Summary worksheet in the associated MIDS calculator Excel workbook (Figure 20). The Existing R_v coefficient is entered into MNSQT for existing conditions.

Figure 20: R_v coefficient in MIDS calculator Excel workbook



Summary Information

Total impervious cover (acres)	0.50
Total watershed area (acres)	2.50
Site runoff coefficient, Rv	0.30
% Impervious	20%

The red box highlights the Existing R_v coefficient in the example below.

3. The user will run MIDs with proposed BMP(s) using the existing land use and impervious cover to determine the Proposed Annual Volume.
4. The user will use the calculated Proposed Annual Volume and the equation below to back-calculate the effective Rv. The equation below is the Annual Volume equation from the MIDS calculator that has been rearranged to solve for the Effective Rv. The effective RV is entered into the MNSQT for proposed conditions.

$$Effective\ R_V = \left(\frac{Proposed\ Annual\ volume(acft)}{0.9 \times Total\ Area\ (acres)}\right) \times \left(\frac{12\ ^{in}/_{ft}}{Annual\ Rainfall(in)}\right)$$

Equation inputs:

- Annual Rainfall determined by project zip code (determined by MIDS calculator)
- 0.9 = Fraction of annual rainfall events that produce runoff (constant)
- Proposed Annual Volume (determined by MIDS calculator from Step 3)
- Total Area (acres) area that drains to the BMP(s)

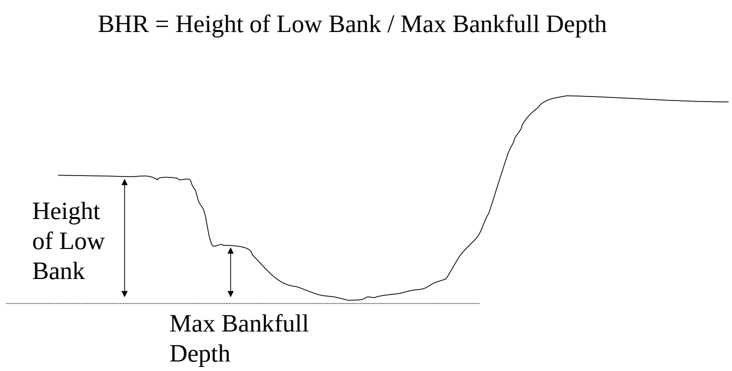
2.6. Hydraulics Functional Category Parameter and Metrics

There is one function-based parameter to assess hydraulic functions: floodplain connectivity. There are two metrics to assess floodplain connectivity: bank height ratio (BHR) and entrenchment ratio (ER). Entrenchment ratio characterizes the horizontal extent of the floodplain while BHR indirectly characterizes the frequency of floodplain inundation. Entrenchment ratio is not applicable to stream/wetland complexes. Every single-thread project reach must assess floodplain connectivity using bank height ratio and entrenchment ratio.

Bank Height Ratio (BHR)

The BHR is a measure of channel incision and an indicator of whether flood flows can access and inundate the floodplain. This metric is described in detail by Rosgen (2014). The bank height ratio compares the low bank height (measured from the thalweg to top of low bank) to the maximum bankfull riffle depth (distance from thalweg to bankfull elevation) (Figure 21. Measuring Bank Height Ratio). The lower the ratio, the lower the flood frequency/magnitude that accesses the floodplain. The low bank height is defined as the left or right streambank that has a lower elevation, indicating the minimum water depth necessary to inundate the floodplain. The most common calculation for the BHR, and the one used in the MNSQT, is low bank height divided by the maximum bankfull riffle depth (D_{max}). Typically, the minimum bank height ratio is 1.0 meaning that the top of the streambank is the bankfull elevation.

Figure 21. Measuring Bank Height Ratio



$$BHR = \frac{Low\ Bank\ Height}{Dmax}$$

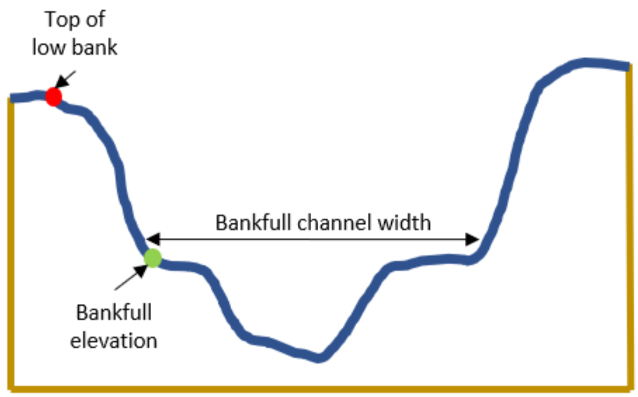
At every riffle within the representative sub-reach:

1. Measure the length of the riffle (refer to glossary for the definition of a riffle).
2. Identify the bankfull and top of low bank features. Use the bankfull verification process to help identify the bankfull feature. If a physical indicator is present, that has been verified, use that feature. For top of low bank, use the break between the channel and a floodplain or terrace that has a lower elevation.

In incised channels with a bankfull bench, determining when bankfull and the top of bank are equal to each other can be challenging. There are two common scenarios detailed below:

Scenario 1: If bankfull is identified as the back of the bench, then the top of the low bank is the top of the left or right bank which break onto the terrace (Figure 22).

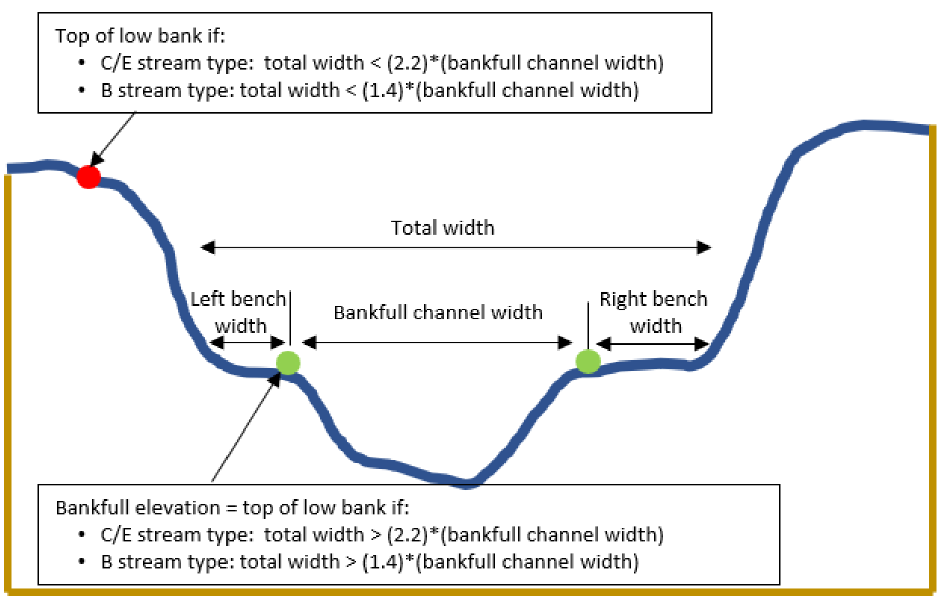
Figure 22: Scenario 1, where bankfull and top of low bank are not equal



Scenario 2: If bankfull elevation is identified as the front of the bench, then the width that expands the left and right bench plus the bankfull channel width (Figure 23) must be measured before the top of low bank can be determined.

- For C/E proposed/reference stream types, if the total width (left bench + bankfull channel + right bench) is greater than 2.2 times the channel width in Rosgen E and C reference stream types, then the top of low bank is equal to bankfull.
- For B proposed/reference stream types, if the total width (left bench + bankfull channel + right bench) is 1.4 times greater than the channel width, then the top of low bank is equal to bankfull.
- If values are lower than the 2.2 for C/E proposed/reference stream types and 1.4 for B proposed/reference stream types, then the top of the low bank is the top of the left or right bank which break onto the terrace (Figure 23).

Figure 23: Scenario 2, where top of low bank must be determined via calculations



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 top of low bank and the bankfull feature are the same, the BHR equals 1.0.
4. Record the difference between the bankfull stage and the thalweg elevation.
5. Calculate the BHR for that riffle.
6. Using the BHR and riffle length for every riffle feature within the representative sub-reach, calculate the weighted BHR using the equation below (also see Example 7). The weighted BHR should then be entered in the MNSQT.

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

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

Example 6: 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			

<u>Data Collection Methods</u>:

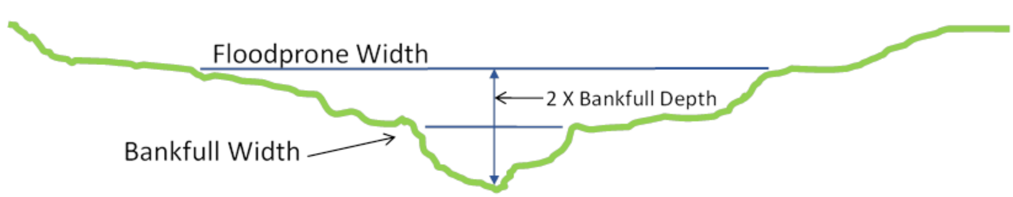
BHR data are collected within the representative sub-reach using the longitudinal profile or the rapid survey method. Field methods are described in Appendix A.

ENTRENCHMENT RATIO (ER)

Floodplain connectivity and width vary naturally by stream and valley type, with some streams more naturally constrained than others. An entrenchment ratio characterizes the vertical containment of the river by evaluating the ratio of the flood prone width to the bankfull width (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).

Entrenchment ratio is calculated by dividing the flood prone width by the bankfull width of a channel, measured at a riffle cross section (Figure 24). The flood prone width is measured perpendicular to the valley fall line and at the same location as the riffle cross section. The flood prone width is the cross-section width at an elevation of two times the bankfull max depth.

Figure 24: Measuring Entrenchment Ratio



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

The ER should be measured at each riffle to calculate the weighted ER (see equation below and Example 7). However, if the valley width is uniform, it is unnecessary to assess every riffle. The ER should be measured at the midpoint of the riffle, halfway between the head of the riffle and the head of the run or pool if there is not a run. A weighted ER is calculated as follows:

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

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

Example 7: Weighted ER 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			

Data Collection Methods:

ER data are collected within the representative sub-reach using cross-sectional survey methods or the rapid survey method. Field methods are described in Appendix A.

2.6.A. Bankfull Identification and Verification

Bankfull stage and bankfull dimensions are needed to calculate field values for several metrics, including floodplain connectivity, large woody debris, lateral migration and bed form diversity. As such, correctly identifying bankfull stage is crucial, and the user, where possible, should verify field-determined bankfull stage elevation and corresponding bankfull channel dimensions to bankfull regional curves or flood frequency analysis using United States Geological Survey (USGS) methods. Bankfull identification should be performed by professionals with a background in geomorphology and the necessary experience to accurately complete accepted methods. Bankfull discharge modeling and flood frequency analysis should be performed by engineers or hydrologists with experience with hydrologic and hydraulic modeling in Minnesota.

The use of bankfull regional curves is the preferred choice for verifying bankfull indicators at ungaged sites. Regional curves can be used to determine if the bankfull dimensions (primarily area) are reasonable. Regional curves are developed from sites that practitioners have deemed as valid reference sites and/or USGS gage stations. The curves plot bankfull area, width, depth, and discharge versus drainage area. The bankfull dimensions, particularly area, from a project site are overlayed with a regional curve that is within the same hydro-physiographic region as the project site. If the project bankfull area falls within the range of scatter used to create the regional curve, then the bankfull feature can be considered verified.

Minnesota DNR provides regional curves for the Western and Eastern parts of the state at the following website: https://www.dnr.state.mn.us/eco/streamhab/geomorphology/watercourse-morphology-data.html. More specific regional curves are currently being developed for the North Shore, Central Minnesota and the Southeast, with further improvements anticipated statewide as additional sites are surveyed and more data are collected.

If a regional curve is not available, a flood frequency analysis can be used to verify the bankfull feature. StreamStats is a simple tool that can be used to help develop a return interval. The USGS StreamStats Web application (USGS, 2020) is a GIS-based tool that delineates the drainage area boundary to a user-specified location based on a dataset consisting of USGS digital elevation models, National Hydrography Dataset streams, and Watershed Boundary Dataset drainage area delineations. StreamStats estimates peak flow rates using the Minnesota regression equations (Lorenz et al. 2009, Ziegeweid et al. 2015) along with other basin characteristics. The minimum return interval reported by StreamStats is the 1.5-year discharge. The national average for bankfull is 1.5 years. Projects that have altered or otherwise complicated hydrology cannot use StreamStats and should include more robust hydrologic analyses, such as hydrologic models to estimate peak flow discharges and return intervals or developing empirical relationships from a nearby gage station.

2.7. Geomorphology Functional Category Metrics

The MNSQT 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. Not all geomorphic parameters will be evaluated for all projects. Refer to Section 2.3 of this manual for guidance on parameter and metric selection.

2.7.A. Large Woody Debris

There are two metrics used to assess large woody debris (LWD), including a LWD piece count and a large woody debris index (LWDI). Either metric can be used to inform this parameter but both metrics should not be used at a single reach. LWD should be assessed for all projects that are in ecoregions that support forested riparian areas.

LWD is defined as dead and fallen wood over 3.28 feet (1m) in length and at least 3.9 inches (10 cm) in diameter at the largest end.[7] 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 counted. Both metrics use data from an LWD assessment reach of 328 feet (100 meters). This reach should be located within the representative sub-reach and should represent the portion of the sub-reach that will yield the highest score.

LWDI

The Large Woody Debris Index (LWDI) is used to evaluate large woody debris within or touching the active channel of a stream. This index was developed by the USDA Forest Service Rocky Mountain Research Station (Davis et al. 2001). Guidance on calculating the LWDI score is included in the *Application of the Large Woody Debris Index: A Field User Manual Version 1*

[7] Note: Standing dead material is not included as LWD. 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.

(Harman et al. 2017). When data are entered digitally into the field form workbook, the LWDI score calculates automatically. The LWDI score is entered as the field value in the MNSQT.

Data Collection Method:

Data collection methods and field forms are provided in the *Application of the Large Woody Debris Index: A Field User Manual Version 1* (Harman et al. 2017).

PIECE COUNT

For this metric, all pieces of LWD within the 328 feet (100 meters) LWD assessment reach are counted. For debris dams, each piece within the dam that qualifies as LWD is counted as a piece. The number of pieces observed is the field value input for the MNSQT. No additional calculation is required.

Data Collection Method:

The field procedure is outlined in Appendix A; data is recorded on the Project Reach form (Appendix B).

2.7.B. LATERAL MIGRATION

Lateral migration is a parameter that assesses the degree of streambank erosion relative to natural rates of erosion and is recommended for all projects. There are three metrics for this parameter: dominant bank erosion hazard index /near bank stress (BEHI/NBS), percent streambank erosion, and percent armoring. When using the BEHI/NBS assessment, the percent of bank erosion is also assessed. The dominant BEHI/NBS characterizes the magnitude of bank erosion and the percent of erosion characterizes the extent of bank erosion within a reach. Percent armoring is used when armoring techniques are present or proposed.

DOMINANT BANK EROSION HAZARD INDEX/NEAR BANK STRESS (BEHI/NBS)

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 (BANCS) model and produce cumulative estimates of stream bank erosion rates for surveyed reaches (Rosgen 2014). In the MNSQT, the BEHI/NBS assessment is used to determine the dominant BEHI/NBS category within the representative sub-reach. Evaluation of BEHI/NBS should be completed for **every** outside meander bend. The outside of the meander bend is assessed whether or not it is eroding. In addition to all meander bends, any other bank that is actively contributing sediment is also assessed. 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 dominant BEHI/NBS survey.

Banks that are armored should not be assessed with the dominant BEHI/NBS metric. If armoring is present or proposed, this metric does not apply. And, if more than 75% of the reach is armored, it is recommended that the other metrics in the lateral migration parameter not be measured. At this magnitude, the armoring is so pervasive that lateral migration processes would likely have no functional value.

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. For each bank, the BEHI/NBS category percent is calculated by summing the length of each bank and then dividing that length by the total assessed length. The total percent for each BEHI/NBS category is calculated by summing the percentage for each category (see Example 8). If there is a tie between more than one BEHI/NBS category, the category representing the highest level of bank erosion should be selected.

To enter the field value in the MNSQT, a drop-down list of BEHI/NBS categories is provided in the Quantification Tool worksheet.

Example 8: 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 because that score is highest and describes 48% of the assessed banks.

Data Collection Method:

Field methods are included in Appendix A and datasheets are included in Appendix B. Detailed field procedures are not provided for the BEHI/NBS method but can be found in the following references: Appendix D of the *Function-Based Rapid Field Stream Assessment Methodology* (Starr et al. 2015) and *River Stability Field Guide, Second Edition* (Rosgen 2014).

PERCENT STREAMBANK EROSION

The percent streambank erosion is measured as the length of streambank that is actively eroding divided by the total length of bank (left and right) in the project reach. All banks with a BEHI/NBS score indicating an actively eroding bank (Table 11) should be summed together to calculate this metric.

Table 11: BEHI/NBS Stability Ratings that Represent Actively Eroding and Non-eroding Banks

Non-eroding Banks	*Actively Eroding Banks*
VL/VL, VL/L, VL/M, VL/H, VL/VH, VL/Ex, L/VL, L/L, L/M, L/H, L/VH, L/Ex, M/VL, M/L	M/M, M/H, M/VH, M/Ex, H/L, H/M, H/H, H/Ex, VH/VL, VH/VH, Ex/VL, Ex/L Ex/M, Ex/H, Ex/VH, Ex/Ex
VL = Very Low, L=Low, M = Moderate, H = High, VH = Very High, Ex = Extreme	

This metric is calculated by dividing the total length of eroding bank by the total length of streambank within the sub-reach, refer to Example 9. The total length of streambank is the sum of the left and right bank lengths within the sub-reach (approximately twice the channel length).

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

Data Collection Method:

Data from the BEHI/NBS assessment method and reach length determination are used to calculate percent erosion. Methods are included in Appendix A, and datasheets are included in Appendix B. Additional resources to use in the field include: Appendix D of the *Function-Based Rapid Field Stream Assessment Methodology* (Starr et al. 2015) and *River Stability Field Guide, Second Edition* (Rosgen 2014).

Example 9: Calculation of Percent Erosion

This example uses the same BEHI/NBS results as Example 8. In the table below, actively eroding banks are identified in bold per Table 11. 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**

PERCENT ARMORING

Bank armoring is any rigid human-made stabilization practice that permanently prevents lateral migration processes. Examples of armoring include rip rap, gabion baskets, concrete, boulder toe, and other engineered materials that covers the entire bank height. Bank stabilization practices that include toe protection to reduce excessive erosion are not considered armoring if the stone or wood does not extend from the streambed to an elevation that is beyond one-third the bank height and the remainder of the bank height is vegetated.

This metric should only be used if bank armoring is present or proposed in the project reach. If banks are not armored in the project reach, a field value should not be entered. To calculate the armoring field value, measure the total length of armored banks (left and right) within the project reach and divide 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 MNSQT.

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

Data Collection Method:

Collect along entire project reach length using the field method described in Appendix A.

2.7.c. Bed Material Characterization

Bed material is a parameter recommended for projects in gravel bed streams with sandy banks where fining of the bed material is occurring due to bank erosion or where activities are proposed that could lead to fine sediment deposition over gravel bed material. 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. Bed material is characterized using a Wolman Pebble Count procedure and the Size-Class Pebble Count Analyzer (v1; Potyondy and Bunte 2007).[8]

The field value for this metric is informed by a comparison between the project reach and a reference reach. Bevenger and King (1995) provide a description of how to select and potentially combine reference reaches for bed material characterization. Note, reference reach stratification may include Rosgen stream classification, catchment area, gradient, and lithology. When possible, the reference reach should be located upstream of the project reach and upstream of the source of sediment imbalance. For example, a stable C stream type with a forested catchment upstream of an unstable C4 or Gc/F4 stream type would represent a good reference reach. If a reference reach cannot be located, this metric cannot be calculated. The location of the reference and project reaches should be mapped and provided.

Steps for calculating this metric:

1. Download the Size-Class Pebble Count Analyzer and read the Introduction tab.
2. Read and complete the Sample Size worksheet. Note, keeping the sample size the same between the reference and project reach is recommended. At least 100 samples should be collected for both reaches. Keep the default values for Type I and Type II errors, which are 0.05 and 0.2 respectively. Set the study proportion to 0.25.
3. Complete a Representative Pebble Count at the project and reference reaches.
4. Enter the results for the reference and project reaches in the Data Input tab in the Size-Class Pebble Count Analyzer. Run the analyzer.
5. Review the contingency tables to determine if the project reach is statistically different from the reference condition for the 4mm and 8mm size classes. Depending on the size of gravel

[8] www.fs.fed.us/biology/nsaec/assets/size-classpebblecountanalyzer2007.xls

in your project area and the reference reach, change the size class if appropriate for your site.

6. The p-value from the contingency tables for the selected size class (typically either 4 mm or 8 mm) should be entered as the field value for the existing condition assessment. A non-statistically significant value, such as 0.5, can be entered as the proposed condition assuming that the project will reduce the supply of fine sediment to the project reach.

Data Collection Method:

Bed material data should be collected using pebble count procedures described in Bevenger and King (1995).

2.7.d. Bed Form Diversity

Bed forms include the various channel features that maintain heterogeneity in the channel form, including riffles, runs, pools, and glides (Rosgen 2014). Together, these bed features create important habitats for aquatic life. The location, stability, and depth of these bed features are responsive to sediment transport processes acting against the channel boundary conditions. Therefore, if the bed forms are representative of a reference condition, it can be assumed that the sediment transport processes are in equilibrium within the system. There are four metrics for this parameter: pool spacing ratio, pool depth ratio, percent riffle, and aggradation ratio.

Pool Definitions

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 different for pool spacing than it is for pool depth and percent riffle metrics.** Guidance on pool identification for each metric is provided under each metric's description.

Geomorphic pools are associated with planform features that create large pools that remain intact over many years and flow conditions. These pools are associated with the outside of a meander bend (streams in alluvial valleys) and downstream of a large cascade or step (streams in colluvial and v-shaped valleys). These pools are used exclusively with the pool spacing ratio metric.

Significant pools are geomorphic pools (see above) AND pools associated with wood, boulders, convergence, and backwater that meet the following criteria:

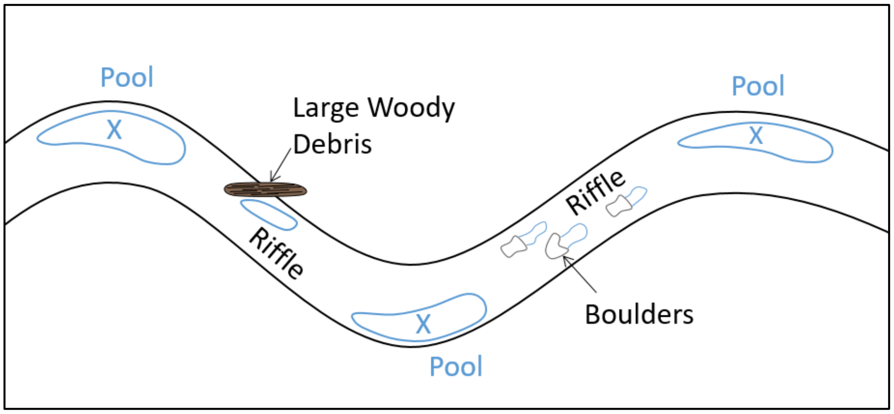
- Have a width that is at least one-half the channel bottom width,
- Are concave in profile, and
- Have a water surface slope that is flatter than the riffle.

Identifying Geomorphic Pools in Alluvial-Valley Streams:

Geomorphic pools in alluvial valleys are located along the outside of the meander bend. Figure 25 provides an illustration of what is and is not considered a geomorphic pool (pools counted as geomorphic are marked with an 'X'). The figure illustrates a meandering stream, where the lateral scour 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. There are small pools associated with the large woody debris and boulder clusters in this figure that do not constitute as geomorphic pools.

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.

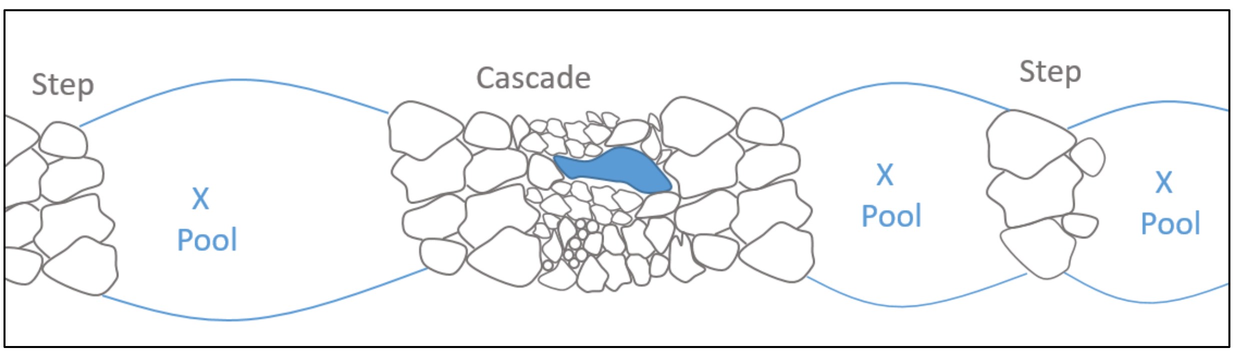
Figure 25: Pool Spacing in Alluvial Valley Streams



Identifying Geomorphic Pools in Colluvial and V-Shaped Valleys:

Pools in colluvial or v-shaped valleys should only be counted as geomorphic if they are downstream of a step, riffle, or cascade. Small pools within a riffle or cascade are not counted. An example of pool spacing in a colluvial or v-shaped valley is shown in Figure 26. For these bed forms, pools are only counted at the downstream end of the riffle or cascade; small pools within the cascade feature are not included.

Figure 26: Pool Spacing in Colluvial and V-Shaped Valleys



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 alone are used to calculate pool spacing. These include pools associated with meander bends and downstream of cascades/steps. Further explanation of pool types is provided in the previous section.

The pool spacing ratio is the distance between sequential geomorphic pools divided by the bankfull riffle width determined from the representative riffle cross section.

$$Pool\ Spacing\ Ratio = \frac{Distance\ between\ sequential\ pools}{Riffle\ Bankfull\ Width}$$

The pool spacing ratio is calculated for each pair of sequential pools in the representative sub-reach. The field value entered in the MNSQT should be a median value based on at least three pool spacing measurements.

Data Collection Method:

Field methods are described in Appendix A. Pool-to-pool spacing is the distance between the deepest point of two pools, and these data can be collected using either longitudinal profile or the rapid survey method. Bankfull riffle width data is collected using the Representative Riffle Survey method.

POOL DEPTH RATIO

The pool depth ratio is a measure of pool quality with deeper pools scored higher than shallow pools. All **significant pools** (geomorphic and pools associated with wood, boulders, convergence, and backwater) are assessed. These pools have a width that is at least one-half the channel bottom width, and a concave profile. Further explanation of pool types is provided in the Pool Definitions section above.

$$Pool\ Depth\ Ratio = \frac{D_{max\ pool}}{D_{mean\ riffle}}$$

The pool depth ratio is calculated by dividing the maximum bankfull pool depth by the mean bankfull riffle depth. The pool depth ratio is calculated for each pool in the representative sub-reach. The minimum, maximum, and average values are then calculated. However, only the average value is input into the MNSQT.

Data Collection Method:

Field methods are described in Appendix A. Pool depth represents the elevational difference between the deepest points of each pool and the bankfull elevation. These data can be collected using either longitudinal profile and cross-sectional survey methods or the rapid survey method. Mean bankfull riffle depth is calculated using the Representative Riffle Survey method.

PERCENT RIFFLE

Riffles are the river's natural grade control feature (Knighto, 1998) and are commonly referred to as fast-water channel units (Hawkins et al. 1993; Montgomery and Buffington 1998). The riffles are shallower than pools and are located between pools. In conventional literature, a riffle is partially defined by bed material size and is limited to gravel bed streams. Sand bed streams are classified by bedforms of ripples, dunes, and antidunes (Knighton 1984). In the SQT, and most other assessment methods that include sand and gravel beds, the section between lateral-scour pools is called a riffle, regardless of bed material size. In this application, the riffle is defined as the crossover between meander bends. It is a straight section of the channel where the thalweg crosses from one side of the channel to the other.

The percent riffle is the proportion of the representative sub-reach containing riffle bed form features. Riffle length is measured from the head (beginning) of the riffle downstream to the head of a **significant pool.** (Further explanation of pool types is provided in the Pool Definitions section above). Run features are included within the riffle length. Glide features should be classified as pools. A run is a transitional feature from the riffle to the pool and the glide transitions from the pool to the riffle (Rosgen 2014). Percent riffle is calculated by dividing the total length of riffles within the representative sub-reach by the total sub-reach length.

Data Collection Method:

Field methods are described in Appendix A. Percent riffle data can be collected using either longitudinal profile survey methods or the rapid survey method.

AGGRADATION RATIO

Channel instability can result from excessive deposition that causes channel widening, lateral instability, and bed aggradation. Visual indicators of aggradation include mid-channel bars and bank erosion within riffle sections. The aggradation ratio is the bankfull width at the widest riffle within the representative sub-reach divided by the mean bankfull riffle depth at that riffle. This ratio is then divided by a reference width-to-depth ratio (W/D).

$$Aggradation\ Ratio = \left. \frac{W_{max\ riffle}}{D_{mean\ riffle}} \middle/ Reference\ W/D \right.$$

Because 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 practitioner. The reference W/D can come from the representative riffle cross section at, or adjacent to the project reach or through the design process. Justification for the selected W/D should be provided.

Data Collection Method:

Data can be collected using either cross-sectional survey methods or the rapid survey method. Both methods are outlined in Appendix A. It is recommended to measure this metric at multiple riffle cross sections with aggradation features to ensure that the widest value for the sub-reach is obtained and to document the extent of aggradation throughout the project reach.

2.7.E. RIPARIAN VEGETATION

For purposes of the MNSQT, riparian vegetation is a parameter in the geomorphic category of the stream functions pyramid emphasizing its role in supporting the dynamic equilibrium of the stream channel. Dynamic equilibrium is part of the geomorphology functional statement. Riparian vegetation is supported by the hydrology and hydraulic functions. For example, non-incised streams have more overbank flooding and shallower depths to the water table, which affect riparian vegetation composition. Moving up the pyramid, riparian vegetation supports physicochemical functions like denitrification and supports various life stages of aquatic organisms.

There are four metrics for riparian vegetation:

1. Effective vegetated riparian area (%)
2. Canopy cover (%)

3. Herbaceous strata vegetation cover (%)

4. Woody stem basal area (square meters/hectare)

Woody stem basal area is not required if woody vegetation is not a natural component of the riparian buffer.

Effective Vegetated Riparian Area

This metric is the percentage of the effective riparian area that is vegetated. The effective riparian area is the area adjacent to and contiguous with the stream channel that supports the geomorphological dynamic equilibrium of the stream. This area varies by channel size (specifically the bankfull width) and valley type. The percentage of the effective riparian area that is vegetated is the field value entered into the MNSQT.

For proposed stream restoration projects, the designed bankfull width and channel alignment should be used per the method below to identify the critical riparian area for land acquisition and/or protection.

Desktop Determination Method:

The effective vegetated riparian area metric is determined based on the valley type and bankfull width as described below for the defined stream reach.

1. Obtain aerial imagery and topographic information (preferably at least 2-foot contour intervals) of the stream reach and associated valley.

2. Determine valley type (alluvial, confined alluvial, or colluvial).

3. Determine bankfull width (feet) using regional curves and field indicators.

4. Multiply bankfull width by the typical Meander Width Ratio (MWR) based on the valley type (Table 12). Add additional width (to account for outer meander bends) per the equation that follows.

$$Effective\ Riparian\ Area\ \ Width = \ W_{Bankfull} * MWR + 2 * W_{additional}$$

Table 12: MWR by Valley Type adapted from Harman et al. (2012) and Rosgen (2014)

Valley Type	MWR	Additional Width (ft) $W_{additional}$
Alluvial Valley	7	25
Confined Alluvial	3	15
Colluvial	2	10

5. Apply the effective riparian area width to the stream reach by centering it on the stream channel and, if necessary, adjusting it to lie within the stream valley (use procedure in Appendix A).

6. Determine the area (square meters) of the polygon formed by the application of the effective riparian width to the upper and lower reach limits. This is the *effective riparian area* for the stream reach.

7. Within the effective riparian area, use aerial imagery to identify and delineate areas that are *not vegetated*. Areas within the active channel including exposed point bars are not factored into this determination and should be considered vegetated. The following should be considered *not vegetated* for this metric:
   - Contiguous areas of less than 50% relative areal vegetative cover (all strata combined)
   - Areas with artificial vegetation that is periodically harvested, removed, or otherwise managed such as crops, sod, tree farms, etc.
   - Areas with human-induced structures or features (roads, buildings, utility lines, driveways, etc.) even if vegetation is growing within their footprint

<u>Field Determination Method:</u>

1. Walk through effective riparian area along both banks and confirm or adjust aerial imagery-based riparian vegetation mapping based on field observations. It may be necessary to locate areas that are not vegetated using Global Positioning Satellite (GPS) units and/or other survey and measurement methods for stream reaches with small effective riparian areas that cannot be readily discerned on aerial imagery.
2. Determine the total area (square meters) within the effective riparian area that is not vegetated and subtract it from the effective riparian area determination in step 6. This is the total vegetated riparian area.
3. Divide the vegetated riparian area by the effective riparian area and multiply by 100 to calculate the percentage of the effective riparian area that is vegetated. This is the metric field value.

Canopy Cover

This metric characterizes the canopy cover provided by the leaves and branches of trees and shrubs in the effective riparian area. Canopy cover is determined by separately assessing the relative areal cover of the shrub and tree vegetation strata and then adding those values together. The shrub strata is defined as woody vegetation greater than or equal to 1.37 meters in height (breast height) and less than 7.62 cm in diameter at breast height (dbh). The tree strata are woody vegetation greater than 1.37 meters high and 7.62 cm or greater dbh. This metric uses the data from the riparian sampling plots collected according to the instructions provided in Appendix A.

In certain ecological sections of the state, trees and shrubs are not a significant natural component of the riparian area of some stream reaches. In those instances, high canopy cover can be detrimental to natural stream functioning by suppressing or otherwise altering the underlying herbaceous vegetation layer. Methodology for determining if trees and shrubs are a natural component of the riparian area is described in Appendix A.

Herbaceous Strata Vegetation Cover

This metric characterizes vegetation cover in the herbaceous strata. The herbaceous strata is defined as all herbaceous vegetation as well as all woody vegetation less than 1.37 meters in height (breast height). A higher relative areal cover in the herbaceous strata provides more leaf and stem surfaces to intercept precipitation and trap sediment. Areas that are devoid of herbaceous cover expose the riparian area to potential erosive forces. This metric uses the data from the riparian sampling plots collected according to the instructions provided in Appendix A.

Woody Stem Basal Area

This metric is an estimate of the average amount of the effective riparian area occupied by woody stems. Woody stems intercept and slow flood and overland flows to protect against associated erosive forces. A higher basal area of woody stems will provide more attenuation of flows and protect the stream channel. For purposes of the MNSQT, woody stem basal area is determined by measuring all woody stems greater than 1.37 meters in height (breast height). The resulting sampling values are expressed as an area (m^2) per hectare and averaged across all sampling plots for the reach. This metric uses the data from the riparian sampling plots collected according to the instructions provided in Appendix A.

In certain ecological sections of the state, trees and shrubs are not a significant natural component of the effective riparian area of some stream reaches. In those instances, this metric should not be used. Methodology for determining if trees and shrubs are a natural component of the riparian area is described in Appendix A.

2.8. Physicochemical Functional Category Metrics

The MNSQT contains three function-based parameters to assess the physicochemical functional category: temperature, dissolved oxygen, and total suspended solids.

2.8.A. Temperature

This parameter evaluates summer average temperature measured in degrees Celsius, which plays a key role in aquatic life cycles. High water temperatures and/or rapid increases of temperature above ambient temperatures can be very detrimental to fish.

Data Collection Method:

The summer average temperature metric is the average of continuously recorded temperatures measured during the summer months of June, July, and August. Temperature measurements are collected in-situ during summer and measured using in-water temperature sensors installed as described in Appendix A of the User Manual following *Procedure for Temperature Logger Deployment at Stream Monitoring Sites* (MPCA 2015). Appendix A also describes equipment selection, deployment methodologies, and data QAQC and includes a temperature logger form.

Temperature sampling for use in the MNSQT requires a temperature logger be deployed during the summer months of June 1 through August 31 and set to record continuously (minimum of every 30 minutes). Loggers should be located in comparable habitats for pre- and post-project data collection and follow the “Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams” guidelines published the USEPA (2014). All measures are used to calculate a summer average.

The summer average should be entered as a field value in the SQT.

2.8.B. Dissolved Oxygen

This parameter evaluates dissolved oxygen (DO), which plays a key role in supporting aquatic life. There is one metric included in the MNSQT for this parameter, the dissolved oxygen concentration, measured in milligrams per liter (mg/L). DO standards differ depending on the use class of the water as described in the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b)Report and 303(d) List* (MPCA 2019).

Data Collection Method:

Measuring dissolved oxygen concentration should be conducted according to the *Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component* document (MPCA 2018b). The standard for DO is expressed in terms of daily minimums and concentrations generally following a diurnal cycle. Consequently, measurements in open-water months (April through November) should be made before 9:00 a.m. Sampling events may coincide with biological sampling where sampling periods overlap. It is recommended instantaneous DO measures be collected prior to 9:00 a.m. weekly over the summer months during lower flow periods using calibrated field instruments. A minimum of 10 samples is recommended to generate an average value.

The average DO concentration should be entered as a field value in the SQT.

2.8.c. Total Suspended Solids

Total suspended solids (TSS) consist of soil particles, algae, and other materials that are suspended in water and cause a lack of clarity. Excessive TSS can harm aquatic life, degrade aesthetic and recreational qualities, and make water more expensive to treat for drinking. Total suspended solids (TSS) standards differ depending on the use class of the water as described in the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b)Report and 303(d) List* (MPCA 2019). There is one metric included in the MNSQT for this parameter, the TSS concentration, measured in milligrams per liter (mg/L).

Data Collection Method:

Measuring total suspended solids should be conducted according to methods described in the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b)Report and 303(d) List* (MPCA 2019) and *Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component* document (MPCA 2018b). We recommend a grab sample be collected weekly over a range of flows over the spring and summer seasons. A minimum of 10 samples is recommended to generate an average value. TSS samples should be analyzed by a certified lab.

In 2012, Minnesota's turbidity water quality standard was replaced by TSS, which is a direct concentration-based measure of sediment levels in surface waters. Historically the state used turbidity as a surrogate for sediment levels in streams and rivers. The protocol for turbidity sampling is described in *Turbidity TMDL Protocol Guidance and Submittal Requirements* (MPCA 2007). Transparency and TSS values reliably predict turbidity and have been used as surrogates at sites where there are an inadequate number of turbidity observations (MPCA 2019a). As such, another option to deploy a sonde with an optical turbidity probe and follow the guidance from the State on determining TSS from that data (*Turbidity TMDL Protocol Guidance* *and Submittal Requirements* MPCA 2007). Due to the rigor of this method, we recommend the less intensive grab samples with lab analysis; however, we offer this option for consideration.

The average of the weekly measures over the total sampling period or TSS value calculated from the sonde deployment is the field value entered into the SQT.

2.9. Biology Functional Category Metrics

The function-based parameters included in the MNSQT for the biology functional category are macroinvertebrates and fish. The presence of a healthy, diverse, and reproducing aquatic community is a good indication that the aquatic life beneficial use is being supported by a lake, stream, or wetland. The aquatic community integrates the cumulative impacts of pollutants, habitat alteration, and hydrologic modification on a water body over time. Monitoring the aquatic community, or biological monitoring, is therefore a relatively direct way to assess aquatic life use-support. Interpreting aquatic community data is accomplished using an index of biological integrity or IBI. The IBI incorporates multiple attributes of the aquatic community, called "metrics," to evaluate a complex biological system (MPCA 2019). MPCA has developed fish (MPCA 2014b) and macroinvertebrate (MPCA 2014a) IBIs to assess the aquatic life use of rivers and streams statewide in Minnesota.

2.9.A. Macroinvertebrates

Macroinvertebrates are an integral part of the food web and are commonly used as indicators of stream ecosystem condition. The MPCA recognizes nine different macroinvertebrate IBI classes based on stream type and the expected natural macroinvertebrate community associated with each. Stream types are defined using drainage area, geographic region, thermal regime, and gradient. Table 7 presents the different classes and their criteria while Figure 15 shows the geographic distribution of each class.

Data Collection Method:

Macroinvertebrate sampling should be conducted following the guidance in *Macroinvertebrate Data Collection Protocols for Lotic Waters in Minnesota* (MPCA 2017b).

2.9.B. Fish

Fish are an integral part of functioning river ecosystems. Similar to macroinvertebrates, the MPCA has developed a comprehensive, statewide IBI to assess the biological integrity of riverine fish communities in Minnesota. IBI classes were first defined using watershed lines that reflect post-glacial barriers to movement, resulting in 'north' and 'south' streams (Figure 16). These two classes were further refined into nine total classes based on stream/watershed size, thermal regime, and gradient (Table 8). Figure 17 shows the general geographic distribution of each class. It is important to note that the map is for display purposes only; classification of individual sampling locations should utilize site-specific attributes as outlined in Table 8.

Data Collection Method:

Fish sampling should be conducted following the guidance in Fish Data Collection Protocols for *Lotic Waters in Minnesota* (MPCA 2017a) and *Water Chemistry Assessment Protocol for Stream Monitoring Sites* (MPCA 2014d).

Chapter 3. Calculating Functional Lift

This chapter outlines the process and concepts that should be considered during restoration project planning using the MNSQT, including projects providing mitigation under CWA 404 or RHA Section 10 (i.e., mitigation banks, in-lieu fee projects, or on-site/off-site permittee responsible mitigation projects). The sections of the MNSQT workbook that should be completed for restoration and mitigation projects are summarized in Table 13. See Section 1.2.e. for information on how the MNSQT calculates functional lift.

Table 13: MNSQT Worksheets Used for Restoration Projects

Worksheets	Relevant Sections
Project Assessment (Section 1.2.a)	• Reach Description • Aerial Photograph of Project Reach • Restoration Approach
Catchment Assessment (Section 1.2.b)	• Complete entire form • Determine restoration potential
Major Flow Variability Metrics	No data entry in this worksheet
Measurement Selection Guide	No data entry in this worksheet
Quantification Tool (Section 1.2.e)	• Site Information and Reference Selection • Existing Condition field values* • Proposed Condition field values*
Monitoring Data (Section 1.2.f)	• As-Built Condition field values* • Field values for up to 10 monitoring events*
Data Summary	No data entry in this worksheet
Reference Curves	No data entry in this worksheet
***Guidance on parameter selection is provided in Section 2.3. and detailed instructions for collecting and analyzing field values for all metrics are provided in Chapter 2 and Appendix A.**	

3.1. Site Selection

The MNSQT can be used to assist with selecting or ranking the priority of a potential stream restoration or mitigation site. While there are many other elements to include in a thorough site-selection process (ELI 2016; Starr and Harman 2016), this section only illustrates the role of the MNSQT.

In the MNSQT, functional lift is estimated from the difference in pre- and post-project condition scores, scaled to project length, and expressed as an overall change in functional feet. Therefore, if the user is deciding between multiple sites, the MNSQT can be used to rank sites based on the amount of functional lift available. 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 2 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 determine how much lift is reasonable for each parameter. While evaluating different sites, it is generally recommended to focus on whether a proposed site can achieve the following post-project condition scores:

1. An index score of 0.70 or higher for floodplain connectivity, bed form diversity, and lateral migration; and
2. An index score of 0.60 or higher for riparian vegetation (recognizing that riparian vegetation may take multiple years to reach full potential).

If the purpose of the project is to provide mitigation under CWA 404 or RHA Section 10, the user should also refer to the St. Paul District Stream Mitigation Procedures (USACE Date pending) or consult with the Corps for further guidance on site selection.

3.2. Restoration or Mitigation Project Planning

3.2.A. Restoration Potential

Users will need to complete the Catchment Assessment Form and determine the restoration potential of the project reach. Once the restoration potential has been determined, the results are provided in the Site Information and Reference Selection section of the Quantification Tool worksheet. The Catchment Assessment worksheet is described in Sections 1.2 and 2.2 of this manual. The information below provides guidance on how to determine restoration potential using the results from the Catchment Assessment.

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 standard. A project with full restoration potential would restore the functional capacity within all categories to a reference standard. Partial restoration would improve some but not all functions to reference standard. For example, partial restoration might mean restoring stability and aquatic habitat to a reference standard by implementing activities that manipulate processes in the Hydrology, Hydraulics and Geomorphology categories but not restoring temperature or fish communities to a reference standard due to watershed stressors (Beechie et al. 2010; Harman et al. 2012).

Full Restoration Potential – The project has the potential to restore functions within all categories, including Biology, to a reference standard (see Table 1, page 14). 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 standard 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 standard, 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 standard. For partial restoration projects, improvements in all functional categories may be observed, but these improvements may not reflect a reference standard.

There are likely situations where even partial restoration is not possible due to the severity of catchment stressors and project 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 to such a degree that partial-restoration is not feasible. Some stressors and constraints limit restoration potential to such a degree that the site may not be suitable for restoration activities.

<u>Procedure for Determining Restoration Potential</u>:

1. Determine the project reach limits and delineate the catchment area to the downstream end of the project reach (see reach delineation in Chapter 2).
2. Complete the Catchment Assessment worksheet (see Section 2.2 of this manual). Review the scores for each category to determine if an identified stressor can be overcome or if it will prevent the project reach from achieving even partial restoration. A stressor that prohibits partial restoration may constitute a “deal breaker” that could affect site selection until catchment-scale stressors can be improved.
    a. Upon completing the Catchment Assessment worksheet, the user should determine if restoration activities can overcome any or all of the catchment perturbations. Refer to the individual category ratings in the Catchment Assessment Form. Can the fair or poor ratings for each individual category be overcome by the scale of the project or by doing additional work in the catchment? If individual category ratings can change from fair or poor to good, then full restoration may be possible.
    b. Compare the reach size to the catchment size (length and/or area). Can the scale and type of restoration overcome the catchment stressors? At the reach scale, practitioners should consider several factors, including the scale of the restoration project in relation to the watershed. 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.
    c. Consider whether catchment-scale efforts, in combination with a restoration project, are feasible and could overcome catchment perturbations/stressors. 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 this tool.
3. 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 (e.g., roads, utility easements, levees/berms, etc.) and prevent streambed elevation changes during design. Note that natural conditions are not constraints. For example, although hillslopes constrain the lateral extent of meandering, they are a natural condition of the catchment and so therefore not a constraint as defined here. Similarly, 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 diversity. They are not considered constraints in this methodology and would therefore not limit the restoration potential.

4. Use the Quantification Tool worksheet to determine the baseline, existing condition of the reach. The Quantification Tool worksheet will quantify functional capacity by parameter and functional category.

5. Determine the current and future potential Stream Evolution Model (SEM) or Rosgen Channel Succession Stage (Table 14). Is the stream trending towards greater or lesser functionality? What is the realistic final Stage or Stream Type as compared to the previously undisturbed Stage or Stream Type? Note: this information is also used to determine the Reference Stream Type in the MNSQT and is described in Chapter 2.

   The future SEM stage (Cluer and Thorne 2013) or Rosgen Stream Type (Rosgen 1996) can be determined by considering the reach-scale constraints and Catchment Assessment results in combination with the baseline existing condition data. The SEM and Rosgen Channel Succession Stages are not described in this manual, and users should consult the source material in applying these methods. The SEM provides more detail for systems that historically started as stream/wetland complexes or multi-thread systems than the Rosgen method and provides functional descriptions for each stage. Table 14 provides a crosswalk to assist the user in determining the SEM from the existing stream type for the project reach. The Rosgen approach includes channel evolution changes in a wider range of valley types than the SEM and responses to a wider range of disturbances.

Table 14: Crosswalk Linking Stream Evolution Model Stages to Rosgen Stream Type Succession

Stream Evolution Model Stages (Cluer and Thorne 2013)	Corresponding Rosgen Stream Types
Stage 0 - Anastomosing	DA
Stage 1 – Sinuous Single Thread	C, E
Stage 2 - Channelized	C, E → Gc
Stage 3 - Degradation	Gc
Stage 3a – Arrested Degradation	Gc → F → Bc
Stage 4 – Degradation and Widening	Gc → F
Stage 5 – Aggradation and Widening	F → C
Stage 6 – Quasi Equilibrium	C, E
Stage 7 – Laterally Active	C, E, F
Stage 8 - Anastomosing	DA

Based on Steps 1-5, describe the restoration potential as Full or Partial. Explain the reasons for your selection. Identify which parameters/functions could be restored to a functioning condition (reference standard) and which may not. The restoration potential of the project reach is recorded on the Catchment Assessment worksheet and described on the Project Assessment worksheet. Results are also entered in the Site Information and Reference Selection section of the Quantification Tool worksheet.

3.2.B. Function-Based Design Goals and Objectives

After the restoration potential has been determined, users should develop function-based goals and objectives. This information is also entered into the MNSQT Workbook on the Project Assessment worksheet. Guidance on developing function-based goals and objectives is provided below.

Design goals are statements about *why* the project is needed at the specific project site and outline a general intention for the restoration project. These goals communicate the reasons behind the project's development. Design objectives explain *how* the project will be completed. Objectives are specific, tangible and can be validated with monitoring and performance standards. Objectives, in combination with the stated goals, describe what the practitioner will do to address the functional impairment. Typically, objectives will explain how key function-based parameters like floodplain connectivity, bed form diversity, lateral migration, and riparian vegetation will be changed to meet the goals. Design goals and objectives can be used to inform parameter selection within the MNSQT (see Examples 10 and 11).

The design goals should be cross referenced with the restoration potential of the project site to ensure that the goals do not exceed the restoration potential. For example, restoring wild trout biomass is not feasible if the restoration potential is limited due to the level of catchment development and higher water temperatures entering the project reach. In this example, the design goal could be revised to restore physical habitat for trout, a partial restoration goal that matches the restoration potential. If wild trout populations in the project reach are to be monitored, increasing wild trout biomass could be possible even with partial restoration potential; however, restoring wild trout biomass to reference standard would not be expected or possible. If catchment-level improvements are implemented to address stormwater runoff and temperature issues, full restoration could be achieved. This outcome would require reach-scale *and* catchment-scale restoration efforts.

Example 10: Project with Partial Restoration Potential

Partial Restoration Potential: The catchment draining to the project is mostly farmland. The overall catchment health is fair and biological improvements are limited by flow alteration.

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

Objectives: Fence out cattle and replant riparian vegetation to stabilize banks, reconstruct portions of channel to improve bed form diversity (habitat).

Possible Parameter List:

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

Monitoring is included for metrics within the Biology category because the project is expected to show some improvement. However, the project is not expected to restore macroinvertebrates and fish parameters to a reference standard

Example 11: Project with Full Restoration Potential

Full Restoration Potential: The project is located on a headwater stream where the catchment draining to the project is recovering from historical cattle grazing and farming. The overall existing catchment health is fair but expected to improve due to the changes in land use. The stream has been channelized and is incised due to agricultural land use practices.

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

Objectives: Replant riparian vegetation to stabilize banks, reconstruct the entire channel to improve floodplain connectivity and bed form diversity (habitat).

Possible Parameter List:

- Reach Runoff
- Floodplain Connectivity
- Large Woody Debris
- Lateral Migration
- Bed Form Diversity
- Riparian Vegetation
- Temperature
- Dissolved Oxygen
- Total Suspended Solids
- Macroinvertebrates
- Fish

Due to the changes in upstream land use practices, it is expected to restore temperature, dissolved oxygen, total suspended solids, macroinvertebrates, and fish parameters to a reference standard.

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