

User Manual

Tennessee Stream Quantification Tool Tennessee Debit Tool





**Tennessee Stream Quantification Tool
Tennessee Debit Tool
User Manual**

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Tennessee Wildlife Resources Agency
Natural Resource Conservation Services
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The TN SQT is the collaborative result of agency representatives from the Tennessee Interagency Review Team, the Mitigation Assessment Team, Stream Mechanics, and Ecosystem Planning and Restoration. Individuals key to the development of this project include:

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Preface

This user manual describes the Tennessee Stream Quantification Tool (TN SQT) and the Tennessee Debit Tool and provides instruction on how to enter data into the workbooks. This manual provides a methodology for determining compensatory mitigation credits or debits. However it is not the only information needed. Additional guidance is detailed in the Tennessee Stream Mitigation Guidelines (TDEC, 2019).

Downloads and Revisions

The TN SQT and supporting documents can be downloaded from the Tennessee Department of Environment and Conservation (TDEC) [website](#). Practitioners should check this website before starting each project to ensure that the latest version of the TN SQT and associated user manuals are being used.

The following spreadsheets and documents are available:

- TN Stream Quantification Tool (TN SQT) – Microsoft Excel Workbook described in detail in the User Manual.
- TN Debit Tool – Microsoft Excel Workbook described in detail in the 2019 Stream Mitigation Guidelines and the TN SQT User Manual.
- TN SQT and Debit Tool Examples – Populated versions of the TN SQT and Debit Tool provided as examples.
- List of Metrics – A comprehensive list of the function-based parameters with their measurement methods, reference standards, stratification methods, and references.
- TN SQT User Manual – This manual. Describes the TN SQT and all calculations performed by the workbook.
- Data Collection and Analysis Manual – Describes how to collect data and calculate input for the TN SQT.
- Rapid Data Collection Methods – Outlines the rapid assessment method for the TN SQT and the TN Debit Tool.
- TN Stream Mitigation Guidelines (2019)
- TN Ecoregion Based Regional Curves

This suite of documents will be updated periodically as additional data are gathered and reference standards and measurement methods are refined. The latest version of the TN SQT manuals and tool can be downloaded from the TDEC website.

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Disclaimer

The Tennessee Stream Quantification and Debit Tools, including the spreadsheet and measurement method manuals, are intended for the evaluation of impact sites and compensatory mitigation projects and their departure from reference conditions in terms of functional loss or lift, respectively. The measurement methods are scored based on their current condition as compared to a reference standard. In part or as a whole, the function-based parameters, measurement methods, and their index values are not intended as engineering design criteria and do not serve as the basis of engineering design. The Tennessee Department of Environment and Conservation 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 in order to determine appropriate restoration design variables and specifications.

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Acronyms

ARAP – Aquatic Resource Alteration Permit
BEHI/NBS – Bank Erosion Hazard Index / Near Bank Stress
BHR – Bank Height Ratio
BMP – Best Management Practice
CFR – Code of Federal Register
CPUE – Catch Per Unit Effort
ECS – Existing Condition Score
EPT – Ephemeroptera, Plecoptera, and Trichoptera
ER – Entrenchment Ratio
ETW – Exceptional TN Waters
F – Functioning
FAR – Functioning-At-Risk
FF – Functional Feet
IRT – Interagency Review Team
LWD – Large Woody Debris
LWDI – Large Woody Debris Index
NF – Not Functioning
NPDES – National Pollutant Discharge Elimination System
NRCS – Natural Resource Conservation Services
ONRW – Outstanding National Resource Waters
PWOs – Process Wastewater Outfalls
PCS – Proposed Condition Score
R – Reach
SFPF – Stream Functions Pyramid Framework
SQSH – Semi-Quantitative Single Habitat
TDEC – TN Department of Environment and Conservation
TMDL – Total Maximum Daily Load
TMI – TN Macroinvertebrate Index
TN – Tennessee
TN SQT – TN Stream Quantification Tool
TWRA – TN Wildlife Resources Agency
USACE – U.S. Army Corps of Engineers
USEPA – U.S. Environmental Protection Agency
USFWS – U.S. Fish and Wildlife Service

Glossary of Terms

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

- A confined alluvial valley is confined between adjacent hillslopes. Meander bends often intercept the hillslope. The valley width is typically less than 7 times the channel width.
- An unconfined alluvial valley is a wide, low gradient valley. The valley width is greater than 7 times the channel width.

Best Management Practice (BMP) – A method that is recognized as an efficient, effective, and practical means of preventing or reducing the movement of pollutants into the waters of the state. A BMP may be a physical facility or a management practice achieved through action.¹

Buffer – Strip of dense undisturbed perennial, native vegetation, either original or reestablished, that borders streams and rivers, ponds, lakes, wetlands, and seeps. This vegetated area along aquatic resources provides canopy, bank stabilization, pollution buffering, and wildlife habitat.

Catchment – Portion of the stream watershed that drains to the uppermost end of the reach. The catchment is the total drainage area above the project reach.

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

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

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

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

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

Field Values – A field measurement or calculation input into the TN SQT for a specific measurement method. Units vary based on the metric or measurement method used.

¹ <http://tnpermanentstormwater.org/manual.asp>

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Full Restoration Potential – The project has the potential to restore functions within all categories, including biology, back to a reference condition. 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 conditions and dynamics.

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

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

Functional Category – The levels of the stream functions pyramid: Hydrology, Hydraulics, Geomorphology, Physicochemical, and Biology. Each category is defined by a functional statement.

Functional Feet (FF) – The product of a condition score and stream length.

- Existing FF = Existing Functional Feet. Calculated by measuring the existing stream length and multiplying it by the ECS.
- Proposed FF = Proposed Functional Feet. Calculated by measuring the proposed stream length and multiplying it by the PCS.

Function-Based Parameter – A metric that describes and supports the functional statement of each functional category.

Index Values – Score of functional capacity using a 0.00 to 1.00 scale.

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

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

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.

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Rapid Method – Collection of office and field techniques specific to the TN SQT for collecting quantitative data to inform functional lift and loss calculations. Rapid methods are collected in the *Rapid Data Collection Methods* Manual (TDEC, 2018b). The rapid method will typically take two to four hours to complete per project reach.

Reference Condition – A stream condition that is considered functioning for the parameter being assessed. It does not simply represent the best condition that can be achieved at a given site; rather, a functioning condition score represents an unaltered or minimally impacted system. The TN SQT uses data gathered from ecomorphological reference sites throughout the state. These sites represent least disturbed, stable, functioning streams. It is important to note TDEC also use the term “reference condition” from a use support perspective to mean a parameter-specific set of data from regional reference sites that establish the statistical range of values for that particular substance at least-impacted streams.

Reference Standard – Reference standards evaluate the functional capacity of measurement method field values as functioning, functioning-at-risk, or not functioning using a 0.00 to 1.00 scale.

Stream Functions Pyramid Framework (SFPPF) – 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 SFPPF includes the organization of function-based parameters, measurement methods, and reference standards to assess the functional categories of the Stream Functions Pyramid (Harman et al. 2012).

Stream Restoration – Restoration means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource. (see 33 CFR 332)

Watershed – Drainage area for the lowermost end of the stream reach. The watershed is the total drainage area of the stream reach.

1. Introduction

Commercial, residential and agricultural land development, construction of linear transportation and utility systems, and other activities requiring State and Federal permits have the potential to impact and degrade Tennessee's streams. These impacts often result in loss of aquatic resource values including stream length, hydrology, available habitat, species composition, and other beneficial ecological and physical characteristics. Stream compensatory mitigation projects, where goals to re-establish and improve resource values and stream functions to their natural, best attainable condition, can offset permitted impacts. State and Federal agencies need to ensure proposed mitigation projects adequately offset aquatic losses. Therefore, stream assessment tools are needed to quantitatively verify the mitigation is adequate to offset loss. The Tennessee Stream Quantification Tool (TN SQT) was developed to satisfy this need.

The primary purpose of the TN SQT and associated documents is to evaluate the functional change between an existing and proposed stream condition. The TN Department of Environment and Conservation (TDEC) and the US Army Corps of Engineers (USACE) use these tools when evaluating functional loss and lift associated with stream impacts and stream compensatory mitigation. TDEC and the USACE intend to use the TN SQT as a component of the project review process and to award credits and assess debits through determination of functional lift and loss. The TN SQT may be used as a mechanism to determine the suitability of a project proposal, its potential to generate credits, project goals, objectives and overall project success over time. This document provides instruction on the use of the TN SQT and Debit Tool for Tennessee streams. These instructions outline the procedures for data entry into the SQT Microsoft Excel Workbooks. They also provide guidance on project goals, objectives, restoration potential, selecting function-based parameters and measurement methods.

This manual provides a methodology for determining compensatory mitigation credits and debits associated with authorized stream impacts. However, it is not the only information needed to determine the total amount of credits awarded or debits assessed in a project. This information is detailed in the TN Stream Mitigation Guidelines (TDEC, 2019), or the most recent applicable guidance. Also, the requirements described in this manual do not represent all of the information needed for Mitigation Bank, In-Lieu Fee, and permittee-responsible

TN SQT Manual Guide

1. *User Manual* – Rules and procedures for entering data into the Microsoft Excel Workbooks. (This document)
2. *Data Collection and Analysis Manual* – Provides instruction on how to collect and analyze data needed to run the TN SQT.
3. *Rapid Data Collection Methods* – Provides data collection and analysis instruction for applying the TN SQT rapid assessment method.

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mitigation projects. For more information on additional mitigation requirements, please refer to the USACE and TDEC websites.

This User Manual provides instruction on how to use and understand the TN SQT and Debit Tool. This manual supports and compliments the *Tennessee Stream Quantification Tool Data Collection and Analysis Manual* (Data Collection Manual; TDEC, 2018a) and does not provide guidance on how to collect data for use in the TN SQT. The debit options and functional loss calculations within the TN Debit Tool workbook are described in detail in the 2019 TN Stream Mitigation Guidelines. Please refer to those documents for additional information not found in this manual.

1.1 Purpose and Uses of the TN SQT

The primary purpose of the TN SQT and Debit Tool is to calculate functional loss and lift associated with stream impact and restoration projects. This tool may also be useful when developing Total Maximum Daily Load (TMDL) models or organizing volunteer restoration activities. In addition, the TN SQT **can assist** in mitigation site selection, determining project specific function-based goals and objectives, understanding the potential for functional lift at a site, determining success criteria, and developing a monitoring plan. The potential uses of the TN SQT are described below:

1. Restoration Potential – The tool can assist in determining the level of restoration a project can achieve through evaluation of site constraints, watershed stressors, and selection of reach-based parameters for functional lift.
2. Watershed Stressors – The Watershed Assessment form can be used to determine factors that limit the potential stream functional lift that can be achieved by a restoration project, including for the purpose of compensatory mitigation.
3. Site Selection – The tool can help determine if a site can benefit from a restoration project and if the site has significant limitations that would inhibit a project from being successful. Site selection is critical to determine whether a proposed stream restoration project can achieve enough functional lift to meet project goals and objectives. Rapid field assessment methods coupled with the Watershed Assessment form can be used to assess and select a site at the development phase of a project.
4. Function-Based Goals and Objectives – The tool can be used to describe project goals that match the restoration potential of a site. Quantifiable objectives and performance criteria can be developed that link restoration activities to measurable changes in stream functional categories and function-based parameters assessed by the tool.
5. Functional Lift – The tool can quantify functional lift from a proposed or active stream restoration project. Lift is estimated during the proposal, design or mitigation plan phase and is calculated for each post-construction monitoring event.
6. Functional Loss – Functional loss can be determined with the TN Debit Tool, a separate workbook from the TN SQT. The debit tool workbook uses the same logic as the SQT but

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predicts proposed condition scores based on existing conditions and modeled functional loss based on the effect of typical impact activities.

7. Compensatory Mitigation – The tool can be applied to on- or off-site compensatory mitigation projects. These include in-lieu fee mitigation, permittee responsible mitigation, and mitigation banks. The tool can help determine if the proposed mitigation activities will provide sufficient functional lift to offset unavoidable adverse impacts to streams. It can also be used to develop monitoring plans and gauge a project's success against established reference standards.
8. Stormwater Best Management Practices (BMPs) in Conjunction with Stream Restoration – The TN SQT was developed with careful consideration to how stream restoration projects using BMPs to treat adjacent runoff could achieve lift.

1.2 Background

In 2006, the Ecosystem Management and Restoration Research Program of the U.S. Army Engineer Research and Development Center noted that specific functions for stream and riparian corridors had yet to be defined in a manner that was generally agreed upon and suitable as a basis for which management and policy decisions could be made (Fischenich, 2006). In an effort to fill this need for USACE programs, an international committee of scientists, engineers, and practitioners defined 15 key stream and riparian zone functions aggregated into 5 categories. These five categories include system dynamics, hydrologic balance, sediment processes and character, biological support, and chemical processes and pathways. This work informed the development of the Stream Functions Pyramid Framework (SFPF; Harman et al., 2012) which provides the scientific basis for the TN SQT. The SFPF enables restoration practitioners and reviewers to develop and identify clear goals, have improved site selection and key-in on a suite of measurements for assessing stream functions in an objective manner. This document assumes the reader has a basic knowledge of stream processes and the SFPF; therefore, it does not provide extensive information and background on this topic.

The TN SQT is based on the original tool developed for North Carolina. It has been regionalized for use in Tennessee. The SQT was developed primarily for stream restoration projects completed as part of a compensatory mitigation requirement. However, the tool can be used for any stream restoration project, regardless of the funding driver. The benefits of using the SQT for evaluating stream restoration include:

1. Establishes a calculator to determine the numerical differences between an existing stream condition and the proposed (restored or enhanced) stream condition. This quantifiable numerical difference is known as functional lift or uplift.

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2. It is part of a stream credit determination method as defined in the TN Stream Mitigation Guidelines (TDEC, 2019) and by the 2008 Federal Mitigation Rule.²
3. Provides a link for restoration activities to changes in stream functions by primarily selecting function-based parameters and measurement methods that can be manipulated by stream restoration practitioners.
4. Links restoration goals to restoration potential. Encourages assessments and monitoring that matches the restoration potential.
5. Incentivizes high-quality stream mitigation by calculating functional lift associated with physicochemical and biological improvements.

Stream Functions Pyramid Framework

Conceptually, the Stream Functions Pyramid Framework (SFPF) provides the scientific basis for the TN SQT (Harman et al., 2012). The stream functions pyramid (Figure 1) consists of five functional categories: Hydrology, Hydraulics, Geomorphology, Physicochemical, and Biology and is built on the premise that lower-level functions support higher-level functions which are all influenced by local geology and climate. Each functional category is defined by a functional statement. For example, the functional statement for Hydrology is “the transport of water from the watershed to the channel.” Hydrology supports all higher-level functions.

The stream functions pyramid *by itself* shows a hierarchy of stream functions but does not provide a specific mechanism for addressing functional capacity, establishing reference standards, or communicating functional lift. Figure 2 expands the pyramid concept into a more detailed framework to quantify functional capacity, establish reference standards, show functional lift, and establish function-based goals and objectives.

² Compensatory Mitigation for Losses of Aquatic Resources, 33 CFR 332 (2012).
<https://www.gpo.gov/fdsys/pkg/CFR-2012-title33-vol3/xml/CFR-2012-title33-vol3-part332.xml>

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

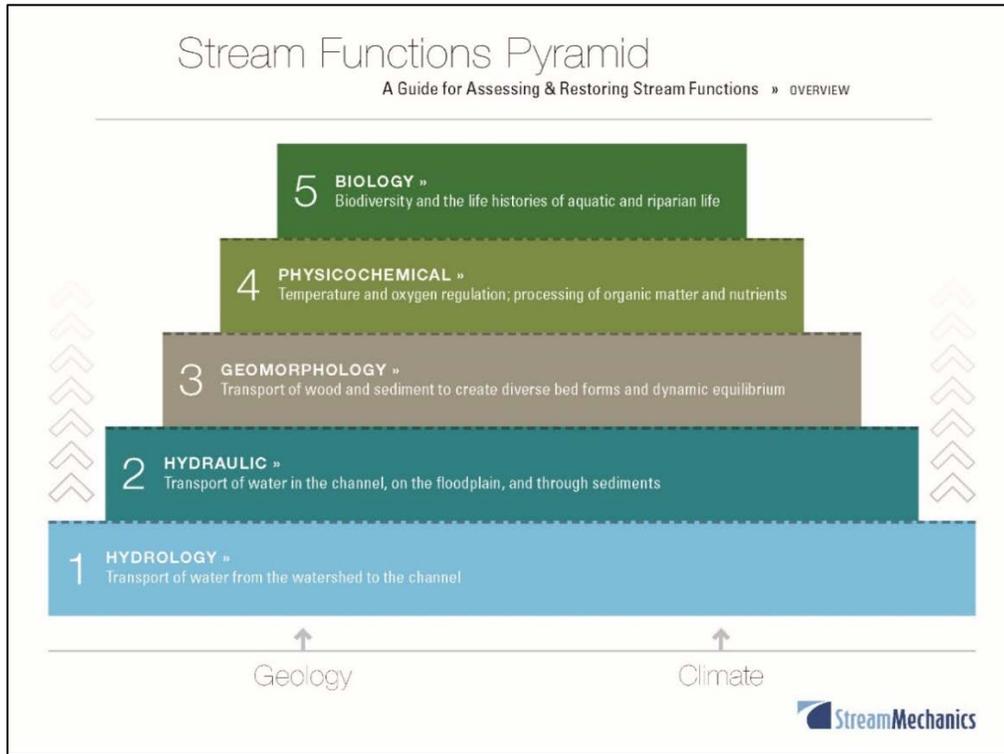
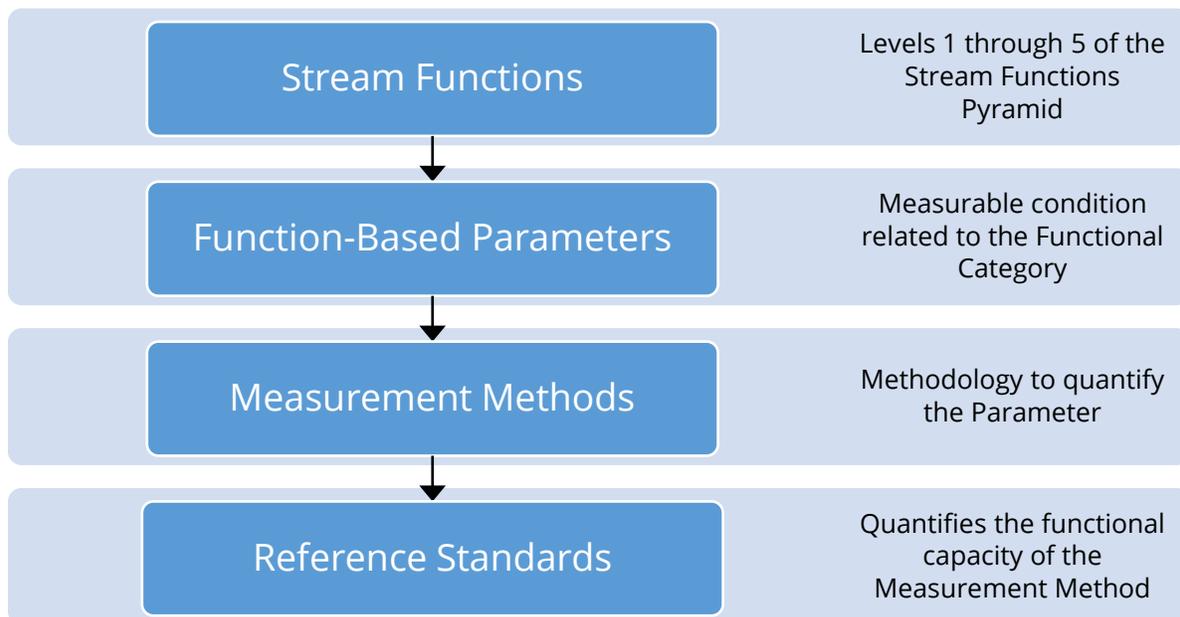


Figure 2. Stream Functions Pyramid Framework



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The Stream Functions block (Figure 2) represents the five levels of the pyramid shown in Figure 1. The remainder of the framework is a “drilling down” approach that provides more detailed forms of analysis to quantify stream functions. The function-based parameters describe and support the functional statements of each functional category. Measurement methods are specific tools, equations, assessment methods, etc. that are used to quantify the function-based parameter. There can be more than one measurement method for a single function-based parameter.

Lastly, reference standards are used to determine functional capacity compared to reference conditions for each measurement method. Definitions for functional capacity descriptions are as follows:

- Functioning – A functioning score indicates the measurement method is describing, quantifiably, one aspect of a function-based parameter that **supports** a healthy aquatic ecosystem.
- Functioning-At-Risk – A functioning-at-risk score means that the measurement method is describing, quantifiably, one aspect of the function-based parameter that **may support** a healthy aquatic ecosystem or may be trending away from reference conditions. In some cases, this may indicate the function-based parameter is adjusting in response to changes in the reach or the catchment. The trend may be towards lower or higher function. A functioning-at-risk score implies that the aspect of the function-based parameter, described by the measurement method, is between functioning and not functioning.
- Not Functioning – A not functioning score means that the measurement method is describing, quantifiably, one aspect of the function-based parameter that **does not support** a healthy aquatic ecosystem. It is not functioning at or near reference condition.

The reference condition does not represent the best condition that can be achieved at a given site; rather, a functioning value from a measurement method represents an unaltered or minimally impacted system.

2. Project Planning

Stream restoration projects, whether volunteer or for compensatory mitigation, are complicated and practitioners often encounter challenges beyond creating a new channel design. The potential for a project to survive and be successful short term, and be resilient long term, may have little to do with the engineering of the stream and more to do with the condition of the surrounding watershed. Practitioners attempting some level of restoration on a stream should recognize that project planning is crucial. Planning for a successful and resilient project starts with selecting the right site, evaluating the project’s restoration potential

and development of clear functional goals and objectives that complement the project proposal.

Project planning requires practitioners to carefully evaluate all conditions within the project watershed that may help or hinder the restoration efforts. When planning a project, it is recommended that the TN SQT is used to gauge factors that influence the potential functional lift of a site that are beyond the channel itself. This includes identifying site constraints and watershed stressors. Once these elements have been evaluated, practitioners can then select reach-scale function-based parameters that can be lifted given the site condition. This will assist in determining the overall restoration potential of a project site. Once the restoration potential has been determined, practitioners can develop function-based goals and objectives for the project that indicate whether partial or full restoration may be achieved.

2.1 Restoration Potential

Restoration potential is defined as the highest level of restoration that can be achieved based on results of the watershed assessment, identification of site 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 TN SQT can be used to evaluate the restoration potential for each stream in a project. Practitioners should evaluate the potential of each stream by weighing site constraints and watershed stressors to develop a proposal for full or partial restoration. Once the potential of the site has been determined, practitioners can develop complementary function-based goals and objectives.

Site Constraints

Many factors influence the amount of functional lift a project can reasonably achieve, including site constraints. These constraints have a direct effect on the restoration potential of a site. Applicants need to explore all types of site constraints that may affect project success. It is important to note that site constraints as it pertains to restoration potential, are anthropogenic and not natural conditions. Examples of anthropogenic constraints include adjacent sewer and utility lines, existing easements, master plans for community development, and other infrastructure, including current and planned transportation projects.

Lack of conservation easements is a form of site constraint. Wide conservation easements can provide protection for systems against current and future impacts or changes in the watershed. The restoration potential for a project can be greatly reduced if land use restrictions are not implemented. Although greenways and public parks are protected and may seem to partner well with restoration activities, park management missions, active use parcels, and simple landscaping and maintenance activities can limit functional lift.

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Natural conditions create biodiversity, providing suitable habitats for some species. Anthropogenic stressors limit the biology that would naturally occur in a watershed (Harman et al., 2012). Therefore, natural conditions are not included in the constraints analysis or the determination of restoration potential because they would not limit a project's ability to achieve functional lift. It is possible that natural conditions, such as bedrock, natural waterfalls, hillslope processes, or other natural barriers to fish migration could prevent fish passage, but this would be natural for that watershed. These natural conditions should be explained separately from the restoration potential analysis to keep the cause and effect relationships between watershed drivers and stream function clear.

Final site selection is critical to the success of stream restoration projects and requires a thoughtful assessment of whether the site will be able to achieve both programmatic and project goals given land use restrictions, utility easements, financial constraints, and a myriad of other factors. Even though the assessment of restoration potential can aid in the site selection process, the site selection process can depend on many factors and is not limited to this assessment alone. Once a site has been selected, understanding the potential for full or partial restoration through each functional level allows a practitioner to tailor restoration design goals and objectives, as well as monitoring efforts, to focus on appropriate and achievable functional lift.

Watershed Stressors

Stressors that exist either outside the project boundaries or within the lateral drainage area of a stream may limit functional lift, and therefore, restoration potential. The Watershed Assessment worksheet helps document and convey the condition of the contributing watershed along with identifying potential stressors or constraints that would limit the restoration potential. These watershed scale stressors may not be modified through restoration activities and could potentially limit the amount of restoration a practitioner can successfully achieve at a site. All of this information is critical to determine if a stream project is feasible, if the goals and objectives are reasonable and appropriate, and if the restoration potential is adequate to justify the proposal.

The Watershed Assessment worksheet assists in identifying watershed scale limitations of most functional categories in the SQT. Hydrologic forces play a significant role in designing and implementing a restoration project. Understanding the hydrologic watershed scale stressors from impervious surfaces, roads, and other land uses can enhance practitioner understanding of site limitations. Frequently, geomorphological function is controlled at the site scale; however, catchment scale conditions can contribute to morphological challenges beyond the practitioner's control. The Watershed Assessment can also assist in identifying limitations with water quality and biology categories which can limit restoration potential.

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Improving the physicochemical functions of a stream can be more challenging than addressing issues with hydraulic and geomorphic functions. Control of the entire project watershed (catchment and lateral drainage area) is often a key to restoring physicochemical functions towards a reference condition. If within the watershed there are a significant number of impaired streams and/or many process wastewater discharges directly affecting the project stream, this will limit the potential physicochemical functional lift. Other factors such as highly urbanized and urbanizing areas within the watershed or significant amounts of roads and impervious surfaces all have an effect on the restoration potential. Proposals may include stormwater or agricultural best management practices (BMPs), restoration of riparian buffers, or other adjacent land use changes to help offset watershed stressors. Reducing physicochemical watershed stressors can also be accomplished by eliminating livestock access to streams, providing buffers along edges of cropland, or fixing problematic infrastructure.

Significant biologic recovery may occur when catchment hydrology and water quality conditions that support a healthy aquatic ecosystem are optimal. Practitioners should evaluate the existing aquatic functions throughout the watershed at every potential restoration site to gauge current ecological health and restoration potential. Watershed stressors from barriers to aquatic organism passage and lack of recruitment potential from the catchment can all play a role in limiting the restoration potential of a project through the biology functional category.

Limitations in both the physicochemical and biology parameter are the most common watershed stressors where projects can still yield partial restoration. For example, elevated specific conductance values in a stream impacted by mining operations could limit potential for biological lift, even if the other categories in the Watershed Assessment indicate a good condition. If proposal goals were to restore biomass of a rare species in the stream and eliminate water quality issues, it may be unachievable at this site. The specific conductance impairment would also prevent physicochemical functional lift, yet would not prevent the restoration from achieving goals related to stability and limiting sediment input to a receiving water body.

Full or Partial Restoration Potential

The potential for a stream to achieve full or partial restoration should be evaluated through each functional category of the SQT. A stream with full restoration potential would restore functions within all categories, including biology, back to a reference condition. 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 conditions and dynamics. Projects with limited restoration potential that implement reach-scale and catchment scale restoration may, over time, shift a project from partial to full restoration.

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Partial restoration is the most common restoration potential level for stream restoration projects. This is evident where one or more functional categories may be restored to conditions typical of or approaching reference condition, but some catchment stressors or reach-scale constraints are preventing the site from reaching full potential. These types of projects, with stability-focused goals and objectives, can improve floodplain connectivity, lateral migration, bed form diversity, and riparian vegetation (function-based parameters describing hydraulic and geomorphology functions) to or closer to a reference condition, but may not lift physicochemical or biological functions to the same extent. Biological or physicochemical improvement can still be obtained; however, the improved condition would not likely achieve a reference condition. If the contributing catchment is somewhat impaired and/or anthropogenic constraints place overall limits on restoration activities, then the restoration potential would be considered a partial restoration.

Restoration potential alone cannot determine the amount of lift a project will achieve within the time constraints the TN SQT (or any method of calculating functional lift) requires. All projects will need detailed monitoring and evaluation of each parameter proposed for lift to gauge the level of success a restoration has achieved. It is important to note that a project may have good potential for partial restoration, but throughout the monitoring years, never reach reference conditions or be a functioning system through all parameters and levels of the stream functions pyramid. This does not mean a project failed or should have been abandoned due to limitations. Improving and revitalizing urban and rural systems that have site constraints can play a valuable role individually and cumulatively in improving overall water resource health. It should also be noted that even a site with a healthy catchment and full restoration potential may not be returned to a functioning system until long after the monitoring period has ended.

2.2 Function-Based Design Goals and Objectives

Function-based design goals and objectives can be developed once the restoration potential has been determined. Design goals are general intentions and often cannot be validated. This is different than programmatic goals. Programmatic goals are bigger-picture goals that are often independent of the project site and may be related to funding sources. For example, a programmatic goal might be to create mitigation credits for transportation agency impacts. Design goals are statements about *why* restoration is needed at the specific project site. Objectives compliment design goals by explaining *how* the project will be completed. Objectives are tangible and can be validated, typically by performance standards.

The SFPF can aid designers in effectively communicating goals and objectives through the use of the stream function pyramid levels. Examples of design goals using the pyramid levels include: restore native brook trout habitat (pyramid level 3 goal), restore native brook trout biomass (pyramid level 5), restore the stream biology to a functioning condition (pyramid level 5), reduce sediment supply from eroding streambanks (pyramid level 3), and reduce nutrient

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inputs (pyramid level 4). All of these goals communicate why the project is being undertaken. Example objectives include: increasing floodplain connectivity, establishing a riparian buffer, and increasing bed form diversity. These objectives can't stand alone, but with the goals, they can describe what the practitioner will do to address the functional impairment. The objectives can be quantitative as well. For example: floodplain connectivity will be improved by reducing the bank height ratio from 2.0 to 1.0. Now, functional lift is being communicated and the performance standard is established for monitoring.

The design goals and objectives are communicated in a narrative form and entered into the Project Assessment worksheet of the TN SQT. The design goals are then compared to the restoration potential to ensure that the goals do not exceed this potential. For example, it is not possible to have a design goal of restoring native brook trout biomass (pyramid level 5) to reference levels if the restoration potential is limited through geomorphology, meaning that the catchment stressors and reach constraints will not support brook trout, e.g., because the catchment is developed and water temperature entering the project reach is too high for brook trout. However, the goal could be revised to restore the physical habitat for native brook trout, e.g. provide riffle-pool sequences, cover from a riparian buffer, and appropriate channel substrate. This is a pyramid level 3 goal that matches the restoration potential. If native brook trout populations in the project reach are to be monitored, increasing native brook trout biomass could be possible even with a partial restoration potential but restoring native brook trout populations to reference conditions would not be expected or necessarily possible.

3. TN SQT and Debit Tool Worksheets

The Tennessee Stream Quantification Tool (TN SQT) is a stream-based Microsoft Excel Workbook with 19 worksheets that can contain data for up to five reaches. There are no macros in the spreadsheet and all formulas are visible, but some worksheets are locked to prevent editing and protect the formulas that provide scores and calculate functional lift and loss. The worksheets include:

- Project Assessment
- Watershed Assessment
- Parameter Selection Guide
- Quantification Tool R1, R2, R3, R4, and R5 (locked)
- Monitoring Data R1, R2, R3, R4, and R5 (locked)
- Data Summary R1, R2, R3, R4, and R5 (locked)
- Reference Standards (locked)

The Tennessee Debit Tool is a Microsoft Excel Workbook with five worksheets. There are no macros in the spreadsheet and all formulas are visible but some worksheets are locked to prevent editing. The worksheets include:

- Project Assessment

- Measurement Selection Guide
- Debit Calculator (locked)
- Existing Conditions (locked)
- Photos by Reach

3.1 Project Assessment Worksheet

The Project Assessment worksheet is used to communicate the goals of the project. This worksheet is, therefore, much different for stream restoration projects using the TN SQT than impact activities using the TN Debit Tool.

Components of the TN SQT Project Assessment Worksheet

Programmatic Goals – The programmatic goals relate to the purpose of the project. These are bigger-picture goals that are often independent of the project site such as a compensatory mitigation project, volunteer restoration, or a TMDL.

Function-Based Goals and Objectives – Describe the goals and objectives of the stream project related to aquatic resource functions. These goals should match the restoration potential.

Restoration Potential – Explain the restoration potential as it relates to stressors and constraints within the watershed. Discuss how the restoration potential can meet the function-based goals of the stream. The connection between the restoration potential and goals should be explained.

Stream and Reach Break Criteria – The TN SQT is a stream-based workbook that can be used for up to five reaches of one stream within a project site. Space is provided to briefly describe the stream and the criteria used to break the stream into separate reaches based on physical characteristics.

Stream Summary Information – This table does not require user input. The Stream Summary Information table is populated automatically from the five Quantification Tool worksheets within the TN SQT workbook. The Reach ID, existing and proposed stream lengths, the change in functional condition, and the functional lift (i.e. credits) are populated as data are entered in the Quantification Tool worksheets.

Stream Evolution Description – Describe the stage of channel evolution for each reach using either the Stream Evolution Model (Cluer and Thorne, 2013) and/or Rosgen Channel Succession Scenario (Rosgen, 2006).

Aerial Photograph of Project Reach – Provide an aerial photograph of the project reach. The photo could include labels indicating where work is proposed, the project easement, and any important features within the project site or watershed.

The bottom of the Project Assessment worksheet provides acknowledgements, contact information and version information.

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Components of the TN Debit Tool Project Assessment Worksheet

The Project Assessment worksheet within the Debit Tool requires the user to provide general and detailed information concerning the proposed project.

Project Name – Provide the name of the project. This could be a developing subdivision, a road project, or commercial and retail space.

Applicant – Identify the name of the person or entity legally responsible for the project.

Permit Number(s) – If applying for an Aquatic Resource Alteration Permit, 401 Water Quality Certification, or 404 Permit and the permit number is known, provide them in the space given. Otherwise, the regulatory agency will fill this out when a permit number is issued.

Project Description – Provide a description of the project including purpose, any associated previous activity, or permits.

Date - Provide the date the application or project was submitted.

Total Debits – This box automatically populates from the Debit Calculator worksheet once all impacts have been tallied.

Stream ID by Reach – Identify each impact by stream and reach. For example, STR-1 R-2 would be the second reach of the first stream impacted in the project. If there is only one reach along the impacted stream, no reach identifier is needed. This information will automatically populate the fields in the Debit Calculator worksheet.

Impact Description – Describe the proposed impact to the stream. For example, 300 linear foot, 6' x 4' culvert, 600 linear feet of full bank hard armoring, or 250 linear feet of stream fill. This information will automatically populate the fields in the Debit Calculator worksheet.

Latitude and Longitude - The uppermost point of the impact location for each discrete impact site.

3.2 Watershed Assessment Worksheet

This worksheet is present in the TN SQT but not the Debit Tool. The purpose of the Watershed Assessment is to assist in determining the restoration potential of the stream.

The Watershed Assessment includes descriptions of watershed processes and stressors that are outside of the stream and may limit functional lift (shown in Table 1). Most of the categories describe potential stressors or constraints upstream of the project since the catchment has the most influence on the stream water quality and biological health. However, there are several categories, like location of impoundments and fish barriers that are upstream and downstream of the project. Further detail on completing the Watershed Assessment is provided in the *Data Collection and Analysis Manual*. For each category in Table 1, the user determines whether the

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stream watershed or catchment is Poor, Fair, or Good and enters a “P”, “F”, or “G” in the rating column of the worksheet.

Table 1. Watershed Assessment Categories

Categories (Functional Category Affected)		Descriptions
1	Impervious Cover in Watershed (Hydrology)	Percent of catchment upstream of the restoration site that is impervious surface.
2	Percent Land Use Change in Watershed (Hydrology)	Rapidly urbanizing versus rural and primarily forested.
3	Road Density in Watershed (Hydrology)	Proximity of existing and planned roads to the restoration site.
4	Percent Forested (Catchment) (Hydrology)	Percent of catchment that is forested upstream of the restoration site.
5	Catchment Impoundments (Hydrology)	Presence and size of impoundments upstream of the restoration site likely to limit flow in the reach. These include small dams, farm ponds, and large impoundments
6	Catchment Forested Riparian Corridor (Geomorphology)	Presence of riparian corridors on streams contributing to the restoration site.
7	Fine Sediment Deposition (Geomorphology)	Extent of fine sediment present in the project reach. This category is used to assess excessive fine sediment supply embedding the channel at the site.
8	Streams within the Catchment Area Currently Assessed as Impaired (Physicochemical)	Extent of streams contributing to the restoration site known to be impaired.
9	Agricultural Land Use (Physicochemical)	Livestock access to stream and/or intensive cropland in the catchment likely to impact restoration site conditions.
10	Process Wastewater Outfalls in Watershed (Physicochemical)	Proximity of Process Wastewater Outfalls (PWOs) and NPDES permits to the restoration site.
11	Aquatic Organism Barriers (Biology)	Proximity of impoundments impacting fish passage to the restoration site, both upstream and downstream.
12	Organism Recruitment (Biology)	Potential for and availability of the desired taxa to be recruited to the restoration site.
13	Other	This space is left for the user to describe another stressor identified for the stream reach that limits restoration potential.

Once watershed conditions are assessed for each category, the user selects the overall watershed condition using the drop-down menu. The overall score is a combination of averaging conditions and best professional judgement. There is not an automatic scoring

methodology. The overall watershed condition is left as a subjective determination so that the user and reviewer can assess and interpret the information gathered about the watershed. There is space provided underneath the overall watershed condition to discuss and explain the selection. It is possible that the watershed condition score is heavily influenced by one or more categories that severely limits stream restoration.

3.3 Parameter Selection Guide Worksheet

This worksheet is present in the TN SQT and a **Measurement Selection Guide** is present in the Debit Tool. The Parameter Selection Guide in the TN SQT can help the user determine which parameters are most appropriate for different types of stream restoration projects. A project would rarely, if ever, enter field values for all parameters included in the TN SQT. **However, if a parameter is evaluated in the Existing Condition Assessment, it must be evaluated in the Proposed Condition Assessment and all monitoring events.** The TN SQT is a calculator and will score a functional category if only one parameter within that category is assessed. Its application as a condition assessment should therefore be limited and results evaluated based on what parameters have been included in the assessment. The Debit Tool contains existing condition assessments that assume a default score for all unassessed parameters and measurement methods included in the rapid methods. Rapid methods are detailed in the *Rapid Data Collection Methods Manual*.

The Parameter Selection Guide provides recommendations on when parameters in the TN SQT are applicable to a project. However, these required parameters are not policy and users performing stream restoration for compensatory mitigation should consult the TN Stream Mitigation Guidelines (TDEC, 2019) and the IRT, TDEC, and/or the USACE to modify the required parameter list based on specific site conditions and project goals.

The following parameters should be included for perennial and intermittent streams throughout Tennessee and are included in the rapid methods:

- Catchment Hydrology
- Reach Runoff
- Floodplain Connectivity
- Large Woody Debris (not required in naturally herbaceous or scrub-shrub floodplain reference conditions)
- Lateral Migration
- Riparian Vegetation
- Bed Form Diversity (not required for bedrock dominated channels)
- Plan Form

Floodplain connectivity, lateral migration, bed form diversity, and riparian vegetation are considered “The Big Four” parameters and may be the primary drivers of channel equilibrium

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after a restoration project is complete. In order to provide a minimum condition achieved by restoration, it is recommended that **ALL** perennial and intermittent streams bring floodplain connectivity, lateral migration, and riparian vegetation to a functioning condition at the end of the project. Bed form diversity should be raised to a functioning condition on all non-bedrock dominated channels. The Quantification Tool worksheet will display a warning message reading “WARNING: Sufficient data are not provided” if data are not entered for at least the big four parameters.

TN SQT data collection requirements for streams with ephemeral flow are not the same as perennial and intermittent streams. The following parameters should be included for ephemeral streams throughout Tennessee:

- Catchment Hydrology
- Reach Runoff
- Large Woody Debris
- Lateral Migration
- Riparian Vegetation

Data entry will be restricted to the parameters listed above when an ephemeral flow regime is selected in the spreadsheet. The user may propose to evaluate additional function-based parameters, as appropriate. The user should coordinate with the regulatory agencies and receive approval to evaluate additional parameters prior to initiating data collection.

The TN SQT can be applied to stream restoration projects installed in combination with BMPs. If your project is proposing BMPs, add any of the following applicable parameters to the list above based on what the BMP will treat:

- Organic Enrichment
- Nitrogen
- Phosphorus

Note that the measurement method for the organic enrichment parameter is a biological response surrogate for nutrient monitoring (nutrient tolerant macroinvertebrate measurement method) and may not require additional monitoring of nitrogen and/or phosphorus. At least one of these parameters (organic enrichment, nitrogen, or phosphorus) should be required for streams with goals and objectives related to physicochemical functions.

The following additional parameters should be required for streams with goals and objectives related to biology functions but are encouraged for use at all sites:

- Macroinvertebrates
- Fish for streams large enough to have a reference standard capable of supporting a level of species diversity adequate for the measurement methods

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Not all regions in Tennessee have reference standards for fish. If a project lies outside of these areas, monitoring is still encouraged to document change but scoring will not be available in the TN SQT. If the user monitors the stream reach and a reference reach, site-specific reference standards could be developed and incorporated into the TN SQT.

The rest of the parameters and their measurement methods can be selected based on their applicability to the stream reach:

- Bed Material Characterization is recommended for streams with gravel or cobble beds and sandy banks, where there is potential to coarsen the bed.
- Bacteria is recommended where livestock have access to the stream.

Bacteria, Nitrogen, Phosphorus, and Macroinvertebrates are included in the rapid methods. Applicants should consult with TDEC DWR Natural Resources Unit regarding available data and assumptions in applying available data to the project area.

Parameter Selection Example

Consider a typical project with a potential to restore geomorphology to a perennial channel in a pasture setting. The catchment is small and consists mostly of rural and agricultural land uses. The overall watershed assessment is fair and stressors would not prevent at least some biological lift (but not back to reference condition). The project goals are habitat improvement for native fish and reducing sediment supply from eroding banks. The work will include: 1) fencing to keep cattle out of the channel; 2) grading to provide floodplain connectivity and greater bed form diversity; 3) adding woody debris to the channel to provide channel complexity and fish habitat; and 4) planting woody riparian vegetation along the streambank and across the floodplain. The parameter list would likely consist of:

- Catchment Hydrology
- Reach Runoff
- Floodplain Connectivity
- Lateral Migration
- Riparian Vegetation
- Bed Form Diversity
- Large Woody Debris
- Plan Form
- Bacteria
- Organic Enrichment
- Macroinvertebrates
- Fish

The project has the potential to improve geomorphology (e.g. partial restoration potential), therefore, the “Big 4” should be raised to functioning (riparian vegetation should be on the trajectory to functioning) condition. Users may benefit from monitoring biology and physicochemical categories due to potential improvement in these functional categories. If the project does functionally lift these categories, appropriate credit can be awarded. However, if the user did not establish the existing condition score prior to work, no credit would be awarded. The user is not expected, nor required, to return water quality metrics, macroinvertebrates, or fish biomass back to a reference condition.

Measurement Method Selection

Measurement methods are specific tools, equations, and assessment methods used to quantify the function-based parameter. Some function-based parameters in the TN SQT have more than one measurement method. Some parameters have measurement methods that complement each other, while some measurement methods are redundant. The Parameter Selection Guide can help the user determine which measurement methods are most appropriate for the selected parameters. Like parameters, **if a measurement method is evaluated in the Existing Condition Assessment, it must also be evaluated in the Proposed Condition Assessment and all monitoring events.** Changing the measurement methods and parameters will change the relative weighting of scores within the TN SQT.

Hydrology Functional Category

1. Catchment Hydrology Parameter. This parameter currently has only one measurement method, Watershed Land Use Runoff Score, and it should be assessed for all streams.
2. Reach Runoff Parameter. The reach runoff parameter consists of one measurement method: stormwater infiltration. This measurement method should be assessed for all streams.

Hydraulics Functional Category

3. Floodplain Connectivity Parameter. This parameter contains two measurement methods: entrenchment ratio (ER) and bank height ratio (BHR). The entrenchment ratio quantifies the lateral extent of floodplain inundation while the bank height ratio quantifies the frequency that the floodplain is inundated. Both measurement methods should be used for all perennial and intermittent streams.

Geomorphology Functional Category

4. Large Woody Debris Parameter. This parameter contains two measurement methods: a large woody debris index (LWDI) and a LWD piece count. This parameter should be assessed for all streams except those in naturally herbaceous or scrub-shrub floodplain reference conditions. It is recommended to use the LWDI but the piece count can be used instead of the index for rapid assessments.
5. Lateral Migration Parameter. There are four measurement methods for this parameter: erosion rate, dominant BEHI/NBS, percent streambank erosion, and percent streambank armoring. Erosion rate and dominant BEHI/NBS are redundant and only one is selected. Percent streambank erosion is used to supplement the data from either the erosion rate or dominant BEHI/NBS and is not used by itself to describe lateral migration. Percent armoring can be used in addition to the other measurement methods for any reach where bank armoring is present. Percent armoring is used for all proposed impact activities.

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6. Riparian Vegetation Parameter. There are five measurement methods for riparian vegetation and each measurement method assesses the left and right bank separately resulting in 10 field values. The measurement methods are average diameter at breast height, buffer width, tree density, native herbaceous cover, and native shrub cover. All five measurement methods should be used for all stream reaches.
7. Bed Material Characterization Parameter. There is one measurement method for this parameter: Size Class Pebble Count Analyzer spreadsheet tool.³ This measurement method should be assessed for perennial and intermittent streams with gravel or cobble beds and sandy banks where fining is occurring.
8. Bed Form Diversity Parameter. There are four measurement methods for this parameter: pool spacing ratio, pool depth ratio, percent riffle, and aggradation ratio. The first three measurement methods should be used for all perennial and intermittent non-bedrock dominated streams. The aggradation ratio is optional for those stream reaches where symptoms of aggradation are present, such as mid-channel or transverse bars.
9. Plan Form Parameter. There is one measurement method for this parameter, sinuosity, and it should be assessed for all perennial and intermittent streams.

Physicochemical Functional Category

10. Bacteria Parameter. There is one measurement method for this parameter: *E. coli*. This measurement method should be assessed for perennial and intermittent streams with livestock access and any proposed project with functional lift to water quality. *E. Coli* is included in the rapid methods.
11. Organic Enrichment, Nitrogen, and Phosphorus Parameters. There are three measurement methods, one for each parameter: percent nutrient tolerant macroinvertebrates, nitrate-nitrite, and total phosphorus. The percent nutrient tolerant macroinvertebrates measurement method for organic enrichment is a biological response surrogate for nutrient monitoring and may not require additional monitoring of nitrogen and/or phosphorus. At least one of these measurement methods (percent nutrient tolerant macroinvertebrates, nitrate-nitrite, or total phosphorus) should be required for streams with goals and objectives related to physicochemical functioning. Nitrogen and phosphorus measurement methods are included in the rapid methods.

Biology Functional Category

12. Macroinvertebrates Parameter. There are four measurement methods for this parameter: Tennessee Macroinvertebrate Index (TMI), percent clingers, percent EPT-*Cheumatopsyche*, and percent Oligochaeta and Chironomidae. A practitioner would enter values for either (1) the TMI or (2) the other three biometrics. However, sample collection methods will yield a TMI score that is reflective of a suite of seven biometrics.

³ <http://www.stream.fs.fed.us/publications/software.html>

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TDEC has determined that the suite of three biometrics (clingers; EPT- *Cheumatopsyche*, and Oligochaeta and Chironomidae) will most likely respond the quickest to a restoration activity. Therefore, users may attempt lift in biology and decide, after monitoring, whether the full TMI or the subset will yield the most lift. Please note that the index scores for the three biometric measurement methods are capped at 0.50. The TMI measurement method is included in the rapid methods.

13. Fish Parameter. There are two measurement methods for this parameter: native fish score index and fish catch per unit effort (CPUE) score. Both measurement methods are recommended to be assessed for this parameter. These measurement methods must be applied in consultation with the IRT to determine the stream size and scoring criteria appropriate for the project watershed.

3.4 Quantification Tool Worksheets (TN SQT) and Existing Conditions Worksheet (Debit Tool)

The reach-specific Quantification Tool worksheets are the main sheets in the TN SQT Microsoft Excel Workbook. It is the calculator where users enter data describing the existing and proposed conditions of the stream reach and the functional lift is quantified. The Existing Conditions Worksheet in the Debit Tool is where users can calculate an existing condition score for each impacted reach. In the Debit Tool, the existing condition score can be calculated for up to ten reaches on the Existing Conditions worksheet. If the project includes more than ten reaches, the user can make a copy of the Existing Conditions worksheet. NOTE: In the TN SQT the user cannot make copies of the Quantification Tool worksheets.

The user CAN create copies of the Existing Conditions worksheet in the Debit Tool if more assessments are needed.

The user CANNOT create copies of the Quantification Tool, Monitoring Data, and Data Summary worksheets in the TN SQT as index value calculations that link to Reach Information and Reference Standard Stratification will not connect to the new sheets and scoring will be incorrect.

Each reach-specific Quantification Tool worksheet in the TN SQT requires data entry in three areas: Reach Information and Reference Standard Stratification, Existing Condition Field Values, and Proposed Condition Field Values. Each condition assessment in the Debit Tool requires data entry in two areas: Reach Information and Reference Standard Stratification and Existing Condition Field Values. The cells that allow input are shaded grey and all other cells are locked. For ephemeral stream reaches, some cells will become hatched to indicate which measurement methods are not applicable to ephemeral channels within the TN SQT and Debit Tool.

Reach Information and Reference Standard Stratification

The TN SQT Reach Information and Reference Standard Stratification is a critical component of the TN SQT and gives general background details on the physical characteristics and location of a site. Much of this information is also used to determine the reference standards appropriate for that stream. This “stratification” ensures, for example, that the sinuosity of streams in alluvial valleys are not scored using the same references as streams in colluvial valleys. The Reach Information and Reference Standard Stratification section in the Debit Tool requires the same input as the TN SQT section except for the existing and proposed stream lengths. In the Debit Tool, the existing and proposed stream lengths are input in the Debit Calculator worksheet (Section 3.7).

If there are no reference standards for a selected measurement method, the spreadsheet may return an index value of FALSE. An index value of FALSE may also occur if data are missing from the Reach Information and Reference Standard Stratification section.

Most of the inputs shown in Figure 3 are linked to the selection of reference standards when a field value is entered for a measurement method. The reference standards and stratification for each measurement method are summarized in the List of Metrics document. If there are no reference standards for a selected measurement method, the spreadsheet may return an index value of FALSE. An index value of FALSE may also occur if there are data missing from the Reach Information and Reference Standard Stratification section. If the TN SQT or Debit Tool is returning FALSE, the user should check this section for data entry errors and then check the stratification for the measurement method in the List of Metrics to see if there are reference standards applicable to the stream. Incorrect information in the Reach Information and Reference Standard Stratification section may result in applying reference standards that are not suitable for the reach.

Figure 3. TN SQT Reach Information and Reference Standard Stratification Input Fields

Project Name:	Deep River Mitigation Bank
Reach ID:	UT4 Reach 2
Upstream Latitude:	35.89596°
Upstream Longitude:	-89.65309°
Downstream Latitude:	35.88964°
Downstream Longitude:	-89.66013°
Existing Stream Type:	G
Proposed Stream Type:	
Ecoregion:	66e
Drainage Area (sqmi):	5.6
Proposed Bed Material:	Gravel
Existing Stream Length (feet):	1000
Proposed Stream Length (feet):	
Proposed Stream Slope (%):	
Proposed Flow Type:	Perennial/Intermittent
Data Collection Season:	
Macro Collection Method:	
Valley Type:	Unconfined Alluvial

Project Name – Enter the project name.

Reach ID – Enter a unique name or identification number for the stream reach. For example: Reach 1. Note, a single stream can have multiple reaches.

Upstream and Downstream Latitude and Longitude – Enter the coordinates in TN State Plane decimal degrees of the upstream and downstream extents of the reach.

Existing Stream Type – Select the existing Rosgen Stream Type from the drop-down menu. This input is not used in the scoring; it is only for communication purposes.

Proposed Stream Type – Select the proposed Rosgen Stream Type from the drop-down menu. The proposed stream type is used as a communication tool and to select the correct reference standard table for entrenchment ratio and sinuosity. This input is referred to as the “Reference Stream Type” in the Debit Tool rather than proposed stream type.

Ecoregion – Select the EPA Level IV Ecoregion⁴ from the drop-down menu. This selection is used to determine the correct reference standard table for the large woody debris index, large woody debris piece count, percent riffle, percent nutrient tolerant macros, nitrate-nitrite, total phosphorus, TMI, percent clingers, percent EPT- *Cheumatopsyche*, and percent Oligochaeta and Chironomidae.

⁴ ftp://newftp.epa.gov/EPADDataCommons/ORD/Ecoregions/tn/tn_eco_lg.pdf

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Drainage Area – Enter the catchment drainage area in square miles. The reach catchment is the portion of the watershed that drains to the uppermost end of the stream reach. This value is used to determine the correct reference standard table for percent nutrient tolerant macros, nitrate-nitrite, total phosphorus, percent clingers, percent EPT- *Cheumatopsyche*, and percent Oligochaeta and Chironomidae.

Proposed Bed Material – Select the proposed bed material from the drop-down menu based on the proposed d50 for the stream reach. This selection is used to determine the correct reference standard table to use for bed material characterization and plan form.

Existing Stream Length – Enter the existing stream length in feet. The proposed and existing stream lengths are used to calculate functional feet. In the Debit Tool, this value is entered in the Debit Calculator worksheet rather than in the Reach Information and Reference Standard Stratification section.

Proposed Stream Length – Enter the proposed stream length in feet. The proposed and existing stream lengths are used to calculate functional feet. In the Debit Tool, this value is entered in the Debit Calculator worksheet rather than in the Reach Information and Reference Standard Stratification section.

Stream Slope (%) – Enter the proposed stream slope as a percent. This value is used to determine the correct reference standard table to use for pool spacing ratio.

Flow Type – Select perennial/intermittent or ephemeral from the drop-down menu. The selection of ephemeral will trigger conditional formatting throughout the Condition Assessments to indicate which measurement methods within the TN SQT and Debit Tool which measurement methods are not applicable to ephemeral channels.

Data Collection Season – Select the season in which macroinvertebrate data were or will be collected. This value is used to determine the correct reference standard table to use for percent nutrient tolerant macros, percent clingers, percent EPT- *Cheumatopsyche*, and percent Oligochaeta and Chironomidae.

Macroinvertebrate Collection Method – Select the method that was used to collect macroinvertebrate data (e.g. SQSH-Kick or SQSH-Bank). This value is used to determine the correct reference standard table to use for percent clingers, percent EPT- *Cheumatopsyche*, and percent Oligochaeta and Chironomidae.

Valley Type – Select the valley type from the drop-down menu. This value is used to determine the correct reference standard table to use for sinuosity.

Important Notes:

- In the TN SQT, if a value is entered for a measurement method in the Existing Condition Assessment, a value must also be entered for the same measurement method in the Proposed Condition Assessment.
- In the TN SQT, for measurement methods that are not assessed (i.e., a field value is not entered), the measurement method is removed from the scoring. It is NOT counted as a zero.
- In the Debit Tool, any measurement method included in the rapid data collection methods assumes an index score of 0.80 unless a field value is entered. For measurement methods that do not assume a score of 0.80 and are not assessed (i.e., a field value is not entered), the measurement method is removed from the scoring. It is NOT counted as a zero.

Existing and Proposed Condition Assessment Data Entry

Once the Reach Information and Reference Standard Stratification section have been completed, the user can input data into the field value column of the Condition Assessment tables. In the TN SQT, there are separate tables for the Existing Condition Assessment and Proposed Condition Assessment. In the Debit Tool, there is only an Existing Condition Assessment for each reach. The user will input field values for the measurement methods as shown in Figure 4 on the following page. The Proposed Condition Assessment field values in the TN SQT should consist of reasonable values that the stream could achieve within the monitoring period. In other words, the proposed values are a prediction, which will be validated during the monitoring phase.

A practitioner would rarely, if ever, enter field values for all measurement methods included in the TN SQT. The Parameter Selection Guide worksheet and Section 3.3 of this manual provide guidance on which parameters and measurement methods to assess. Practitioners should work with regulators to determine a list of parameters and measurement methods suitable for each stream that will determine whether project goals and objectives are being met. Likewise, the practitioners and regulators can work together to determine if any reference standards need to be adjusted based on local data.

In order to accommodate the different options for calculating functional loss described in the TN Stream Mitigation Guidelines (TDEC, 2019), the Debit Tool assumes the parameters and measurement methods included in the rapid data collection methods are applicable to all impact sites. The Existing Condition Assessment tables in the Debit Tool automatically assume a default index score of 0.80 for these measurement methods. The user can enter field values for any of these measurement methods to overwrite the assumed score. If a parameter or measurement method is applicable that is not automatically assumed, data must be collected so a field value can be entered and it will score as described in the following section.

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Figure 4. Example of Field Value Data Entry in the Condition Assessment

EXISTING CONDITION ASSESSMENT				
Functional Category	Function-Based Parameters	Measurement Method	Field Value	
Hydrology	Catchment Hydrology	Watershed Land Use Runoff Score		
	Reach Runoff	Stormwater Infiltration		
Hydraulics	Floodplain Connectivity	Bank Height Ratio	1.3	
		Entrenchment Ratio	2	
Geomorphology	Large Woody Debris	Large Woody Debris Index		
		# Pieces	5	
	Lateral Migration	Erosion Rate (ft/yr)		
		Dominant BEHI/NBS	M/M	
		Percent Streambank Erosion (%)	20	
	Riparian Vegetation		Percent Armoring (%)	20
			Left - Average Diameter at Breast Height (DBH; in)	8.2
			Right - Average DBH (in)	8.5
			Left - Buffer Width (feet)	20
			Right - Buffer Width (feet)	100
			Left - Tree Density (#/acre)	20
			Right - Tree Density (#/acre)	80
Left - Native Herbaceous Cover (%)			10	
Right - Native Herbaceous Cover (%)			40	
Left - Native Shrub Cover (%)			0	
Right - Native Shrub Cover (%)	50			
Bed Material Characterization	Size Class Pebble Count Analyzer (p-value)			
Bed Form Diversity		Pool Spacing Ratio	5.4	
		Pool Depth Ratio	1.9	
		Percent Riffle (%)	60	
Plan Form		Aggradation Ratio	1.1	
		Sinuosity	1.2	
Physicochemical	Bacteria	E. Coli (Cfu/100 mL)		
	Organic Enrichment	Percent Nutrient Tolerant Macroinvertebrates (%)		
	Nitrogen	Nitrate-Nitrite (mg/L)		
	Phosphorus	Total Phosphorus (mg/L)		
Biology	Macroinvertebrates	Tennessee Macroinvertebrate Index		
		Percent Clingers (%)		
		Percent EPT - Cheumatopsyche (%)		
Fish		Percent Oligochaeta and Chironomidae (%)		
		Native Fish Score Index		
		Catch per Unit Effort Score		

Scoring Functional Lift

The SQT uses a simple scaling and scoring system to determine a condition score for each reach. The user enters a field value for each measurement method and scoring occurs automatically, starting with calculating an index value for the measurement method based on the established reference standards. The TN SQT averages measurement method scores to calculate a parameter score. Therefore, a functioning measurement method score averaged with a not functioning score could yield a functioning-at-risk parameter score. A single measurement method, out of several measurement methods, may not define the functional

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capacity of the parameter or stream process. Multiple measurement methods are often used to describe a function-based parameter. For example, pool spacing, pool depth, and percent riffle are three measurement methods for the bed form diversity function-based parameter. Understanding how each measurement method result contributes to the overall bed form condition is more important than a single measurement method result. Functioning bed form diversity would have an appropriate number of pools (pool spacing), good variability in depth, and an appropriate split of riffles and pools.

Lastly, functional category scores are the average of the parameter scores. The functional category scores are multiplied by 0.20 and summed to calculate the existing condition score or the proposed condition score. Each of these components is explained below.

Index Values. The reference standards available for each measurement method are visible in the Reference Standards worksheet and summarized in the List of Metrics workbook. When a field value is entered for a measurement method in a Condition Assessment table, an index value between 0.00 and 1.00 is assigned to the field value (An example is shown in Figure 5). Reference standards are discussed in more detail in Section 3.6.

Figure 5. Index Values Automatically Populate when Field Values are Entered

Measurement Method	Field Value	Index Value	Parameter
Watershed Land Use Runoff Score	0.67	0.71	0.71
Stormwater Infiltration	0.6	0.60	0.60
Bank Height Ratio	1.6	0.20	0.25
Entrenchment Ratio	1.2	0.30	

When a field value is entered in a Condition Assessment table, the neighboring index value cell checks the data in the Reach Information and Reference Standard Stratification section and either returns an index value based on the appropriate reference standard (Figure 5) or returns FALSE (Figure 6). Some of the reference standards have a limited range of application. For example, the entrenchment ratio for floodplain connectivity does not have reference standards for F, G or Gc stream types. If the proposed, or reference, stream is a G stream type, then the field value will return FALSE. An index value of FALSE may also occur if the Reach Information and Reference Standard Stratification section is missing data, as is the case in Figure 6 where stream type was not entered into the TN SQT.

Figure 6. Index Value Errors

Measurement Method	Field Value	Index Value
Bank Height Ratio	1.6	0.20
Entrenchment Ratio	1.2	FALSE

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Roll Up Scoring. Measurement method index values are averaged to calculate parameter scores; parameter scores are averaged to calculate category scores. The category scores are then multiplied by 0.20 and summed to calculate overall condition scores (Figure 7). In the TN SQT, for measurement methods that are not assessed (i.e., a field value is not entered), the measurement method is removed from the scoring and no index value is provided. It is NOT counted as a zero in calculating the parameter score. In the Debit Tool, an index value is calculated when a field value is entered. If a field value is not entered, the index value defaults to 0.80.

The category scores are multiplied by 0.20 and summed to calculate overall condition scores. This roll-up scoring procedure will incentivize monitoring of physicochemical and biology functional categories since the maximum overall condition score achievable without monitoring these levels is 0.60.

While the overall condition is described as not functioning or functioning-at-risk depending on the scoring outlined above, a functioning overall condition can only be achieved if all functional categories are functioning, as shown in Figure 7 where the overall condition score is 0.72 but the physicochemical and biology functional categories are functioning-at-risk; therefore, the overall condition is described as functioning-at-risk.

Since the tool is a calculator, caution must be taken in interpreting the results. For example, while the tool may report that a stream is functioning at a physicochemical level, this may be because only bacteria was monitored. There may still be indicators in the watershed assessment to suggest that other parameters may be a concern in the stream. The Parameter Selection Guide can help ensure that all appropriate parameters are assessed.

Figure 7. Roll Up Scoring Example

Functional Category	Function-Based Parameters	Parameter	Category	Category	ECS	ECS
Hydrology	Catchment Hydrology	0.95	0.87	Functioning	0.72	Functioning At Risk
	Reach Runoff	0.79				
Hydraulics	Floodplain Connectivity	0.75	0.75	Functioning		
Geomorphology	Large Woody Debris	1.00	0.77	Functioning		
	Lateral Migration	0.87				
	Riparian Vegetation	1.00				
	Bed Material Characterization					
	Bed Form Diversity	1.00				
Physicochemical	Plan Form	0.00	0.68	Functioning At Risk		
	Bacteria	0.94				
	Organic Enrichment	1.00				
	Nitrogen	0.10				
Biology	Phosphorus		0.55	Functioning At Risk		
	Macroinvertebrates	0.43				
	Fish	0.68				

Functional Change. The TN SQT Quantification Tool worksheet summarizes the scoring at the top of the sheet, next to, and under the Reach Information and Reference Standard Stratification section. There are three summary tables: Functional Lift Summary, Functional Category Report Card, and Function Based Parameters Summary. The Functional Lift Summary (Figure 8) provides the overall scores from the Existing Condition Assessment and Proposed Condition Assessment sections.

In the Debit Tool, the functional change is calculated in the Debit Calculator worksheet (see Section 3.7).

Figure 8. TN SQT Functional Change Summary Example

FUNCTIONAL LIFT SUMMARY	
Existing Condition Score (ECS)	0.46
Proposed Condition Score (PCS)	0.72
Change in Functional Condition (PCS - ECS)	0.26
Existing Stream Length (feet)	1000
Proposed Stream Length (feet)	1200
Additional Stream Length (feet)	200
Existing Stream Functional Feet (FF)	460
Proposed Stream Functional Feet (FF)	864
Functional Lift (Proposed FF - Existing FF)	404

The change in functional condition is the difference between the PCS and the ECS (PCS-ECS). The rest of the table calculates and communicates Functional Feet (FF). A FF is produced by multiplying a condition score by the stream length. Since the condition score must be 1.00 or less, the functional feet score is always less than or equal to the actual stream length.

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

The Proposed FF – Existing FF is the amount of functional lift generated by the restoration activities.

$$\text{Functional Lift} = \text{Proposed Stream FF} - \text{Existing Stream FF}$$

In the Debit Tool, functional loss is calculated using the same equation for change in functional feet in the Debit Calculator worksheet. Since the proposed condition is worse than the existing condition, this equation will yield a negative value.

$$\text{Functional Loss} = \text{Proposed Stream FF} - \text{Existing Stream FF}$$

In the TN SQT, the Functional Category Report Card (Figure 9 on the following page) pulls the existing condition score (ECS) and proposed condition score (PCS) for each of the five functional categories from the Condition Assessment sections of the worksheet for a side-by-side comparison.

Figure 9. TN SQT Functional Category Report Card Example

FUNCTIONAL CATEGORY REPORT CARD			
Functional Category	ECS	PCS	Functional Lift
Hydrology	0.48	0.63	0.15
Hydraulics	0.10	0.85	0.75
Geomorphology	0.18	0.79	0.61
Physicochemical	0.46	0.58	0.12
Biology	0.21	0.32	0.11

In the TN SQT, the Function Based Parameters Summary also provides a side-by-side comparison, but for individual parameter scores (Figure 10 on the following page). Values are pulled from the Condition Assessment sections of the worksheet. This table can be used to better understand how the functional category scores were determined. This table also makes it possible to quickly spot if a parameter was not assessed for both the Existing and Proposed Condition Assessments. Recall that if a value is entered for a measurement method in the Existing Condition Assessment, a value must also be entered for the same measurement method in the Proposed Condition Assessment. Finally, the table can be reviewed to determine if any required parameters were totally omitted from the assessment.

Figure 10. TN SQT Function Based Parameters Summary Example

FUNCTION BASED PARAMETERS SUMMARY			
Functional Category	Function-Based Parameters	Existing Parameter	Proposed Parameter
Hydrology	Catchment Hydrology	0.63	0.95
	Reach Runoff	0.47	0.44
Hydraulics	Floodplain Connectivity	0.15	0.75
Geomorphology	Large Woody Debris	0.14	1.00
	Lateral Migration	0.22	0.87
	Riparian Vegetation	0.20	1.00
	Bed Material		
	Bed Form Diversity	0.67	1.00
Physicochemical	Sinuosity	0.00	0.00
	Bacteria	0.75	0.94
	Organic Enrichment	0.32	0.63
	Nitrogen	0.31	0.57
Biology	Phosphorus		
	Macroinvertebrates	0.17	0.21
	Fish	0.33	0.68

3.5 Monitoring the Reach (Monitoring Data and Data Summary Worksheets)

These worksheets are present in the TN SQT but not the Debit Tool. Monitoring reports are an effective means to demonstrate project success year after year in a consistent manner. The TN SQT is designed to aid in that effort. Monitoring data worksheets, data summary tables, trackers for functional feet scores over time, and comparisons by reach of proposed conditions vs. as-built conditions vs. monitored years are all provided for users. This information can aid in determining if a stream project is reaching stated goals and objectives or identifying areas of potential issues. These sheets should be provided with monitoring reports as proof of stream condition and confirmation of functional lift. However, stream compensatory mitigation projects will often have additional success criteria or other reporting requirements to submit as part of a monitoring report. Information on additional monitoring requirements can be found in the 2019 TN Stream Mitigation Guidelines, and on the TDEC and USACE websites. Monitoring data worksheets are typically only used for projects that are considered for compensatory mitigation.

Monitoring Data Worksheet

The Monitoring Data worksheets contain multiple Condition Assessment tables. The first table is identified as the As-Built Condition followed by ten Condition Assessment tables for use throughout the monitoring years. It is important to complete the as-built table to compare to the proposed condition score.

The user can enter the monitoring year at the top of each Condition Assessment table and the date of the monitoring event. In order to plot data on the Data Summary worksheet, the monitoring year is the number of years after project completion. For all projects, the as-built condition is considered monitoring year 0. For a project that was completed in 2015, a monitoring event in 2017 should be identified as monitoring year 2. Each condition assessment table is identical to the condition assessment tables in the Quantification Tool worksheet. All tables are linked to the Reach Information and Reference Standard Stratification section on the corresponding Quantification Tool worksheet and scoring is identical to the process described in Section 3.4.

Please note that if a value is entered for a measurement method in the Existing and Proposed Condition Assessments, a field value must also be entered for the same measurement method for every monitoring event completed in the Monitoring Data worksheet. Changing the measurement methods and parameters will change the relative weighting of scores within the TN SQT.

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Data Summary Worksheet

This worksheet provides tables and plots summarizing stream reach data from the existing, proposed, and as-built condition, along with yearly monitoring assessments. Information is pulled from the Quantification Tool and Monitoring Data worksheets by corresponding reach. The Function-Based Parameters Summary example shown in Table 2 tracks the assessed parameters over time. It is recommended that **ALL** perennial and intermittent, non-bedrock stream projects monitor and bring floodplain connectivity, lateral migration, riparian vegetation, and bed form diversity parameter scores to a functioning condition at the end of the project. The condition of these parameters is shown graphically in the Big Four Parameters – Condition Score Tracking plot.

The Functional Category Report Card (Table 3) tracks the progress of the functional categories over the monitoring period. The Functional Category – Condition Score Tracking plot shows the condition score for each functional category throughout the monitoring period along with the overall condition score (Figure 11).

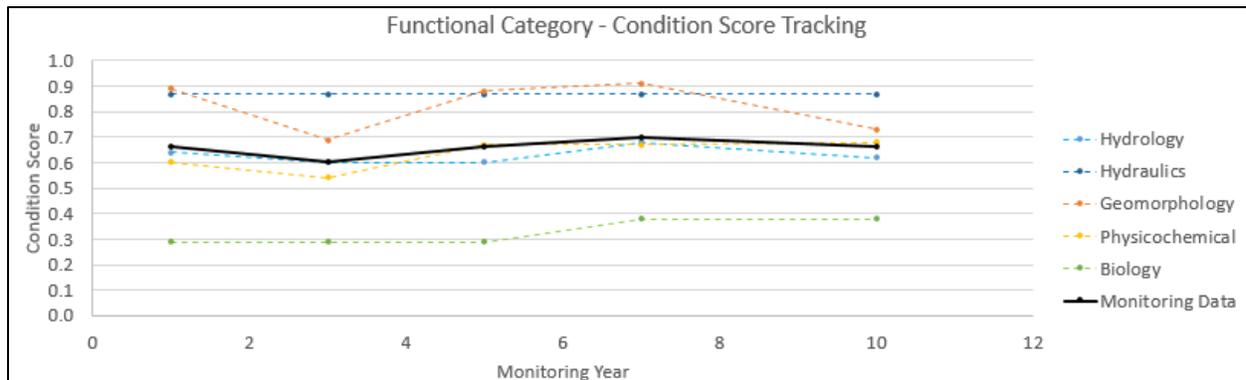
Table 2. TN SQT Function Based Parameters Summary

FUNCTION BASED PARAMETERS SUMMARY							
Functional Category	Function-Based Parameters	Existing Parameter	Proposed Parameter	As-Built	Monitoring Year		
					1	3	5
Hydrology	Catchment Hydrology						
	Reach Runoff	0.50	0.50	0.50	0.50	0.50	0.50
Hydraulics	Floodplain Connectivity	0.20	0.85	0.85	0.85	0.85	0.85
Geomorphology	Large Woody Debris						
	Lateral Migration	0.08	0.85	0.75	0.75	0.77	0.85
	Riparian Vegetation	0.00	0.61	0.46	0.50	0.55	0.63
	Bed Material Characterization						
	Bed Form Diversity	0.20	0.80	0.80	0.80	0.80	0.80
	Plan Form						
Physicochemical	Bacteria	0.37	0.48	0.37	0.37	0.43	0.46
	Organic Enrichment						
	Nitrogen						
	Phosphorus						
Biology	Macroinvertebrates	0.11	0.25	0.00	0.02	0.11	0.25
	Fish						

Table 3. TN SQT Functional Category Report Card

FUNCTIONAL CATEGORY REPORT CARD								
Functional Category	ECS	PCS	As-Built	Monitoring Year				
				1	3	5	7	10
Hydrology	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Hydraulics	0.20	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Geomorphology	0.09	0.82	0.77	0.71	0.62	0.61	0.82	0.82
Physicochemical	0.37	0.48	0.37	0.37	0.43	0.48	0.64	0.69
Biology	0.11	0.25	0.00	0.02	0.11	0.25	0.30	0.36
Overall Score	0.16	0.43	0.42	0.41	0.39	0.39	0.43	0.43
Functional Feet	16	65	63	62	59	59	65	65

Figure 11. TN SQT Functional Category Condition Score Tracking



Finally, the overall condition score and functional feet for the reach over the monitoring period are plotted graphically. The Overall Condition Score tracking shows the existing condition, proposed condition, and as-built condition as horizontal lines on the plot.

3.6 Reference Standards Worksheet

The purpose of the Reference Standards worksheet is to provide equations that convert field values for each measurement method into index values. This worksheet is present in both the TN SQT and the Debit Tool. Reference standards are based on regional data, national data, and in some instances, a combination of data and best professional judgement. Many reference standards for the state of TN are based on data gathered from ecomorphological reference sites. These sites represent least disturbed, stable, functioning streams. The field value ranges used to determine functional capacity are compared to reference conditions. The field values

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for each measurement method are then normalized on a 0.00 to 1.00 scale where 0.00 represents not functioning and 1.00 is an optimally functioning metric. It is important to remember that the reference condition concept does not simply represent the best condition that can be achieved at a given site; rather, a functioning condition score represents a least disturbed, stable, functioning stream compared to an unaltered system. The TN SQT uses this concept and the definition of reference condition for biological integrity developed by Stoddard, et al (2006). Collectively, these reference conditions indicate stream ecological integrity and functional health.

The field value is measured while the index value is a score between 0.00 and 1.00. The reference standards determine the functional capacity of a measurement method as functioning (F), functioning-at-risk (FAR), or not functioning (NF) compared to a reference condition. Definitions for functional capacity and index value scoring for all measurement methods are as follows:

- Functioning – Scores ranging from 0.70 to 1.00 are indicative of a reference condition. A functioning score indicates the measurement method is describing, quantifiably, one aspect of a function-based parameter that **supports** a healthy aquatic ecosystem.
- Functioning-At-Risk – Score ranges from 0.30 to 0.69. A functioning-at-risk score means the measurement method is describing, quantifiably, one aspect of the function-based parameter that **may support** a healthy aquatic ecosystem or may be trending away from reference conditions. In some cases, this may indicate the function-based parameter is adjusting in response to changes in the reach or the catchment. The trend may be towards lower or higher function. A functioning-at-risk score implies that the aspect of the function-based parameter, described by the measurement method, is between functioning and not functioning.
- Not Functioning – Score ranges from 0.00 to 0.29. A not functioning score means the measurement method is describing, quantifiably, one aspect of the function-based parameter that **does not support** a healthy aquatic ecosystem. It is not functioning at or near reference condition.

Best-fit equations were applied to the known breaks between F, FAR and NF based on published research or best professional judgement of the contributors. Note that reference standard curves are only shown in the TN SQT and not in the Debit Tool. The Reference Standards worksheet in the Debit Tool is hidden and only contains the coefficients from the best-fit equations.

The Reference Standards worksheets are locked to protect the index value calculations. The user cannot make changes to the reference standards. However, the user can see all of the reference standards, may contribute to the database for the reference standards, and can suggest changes based on that data. This could include local reference reach data or better modeling, depending on the parameter and measurement method.

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The worksheets organize measurement method reference standards into columns based on the functional category. One measurement method can have multiple sets of reference standards depending on the stratification. For example, the entrenchment ratio (one of two measurement methods determining the functional capacity of floodplain connectivity) has different reference standards based on the proposed stream type (shown in Table 4). The full list of reference standards and their stratification is provided in in the List of Metrics workbook.

Table 4. Entrenchment Ratio Reference Standards

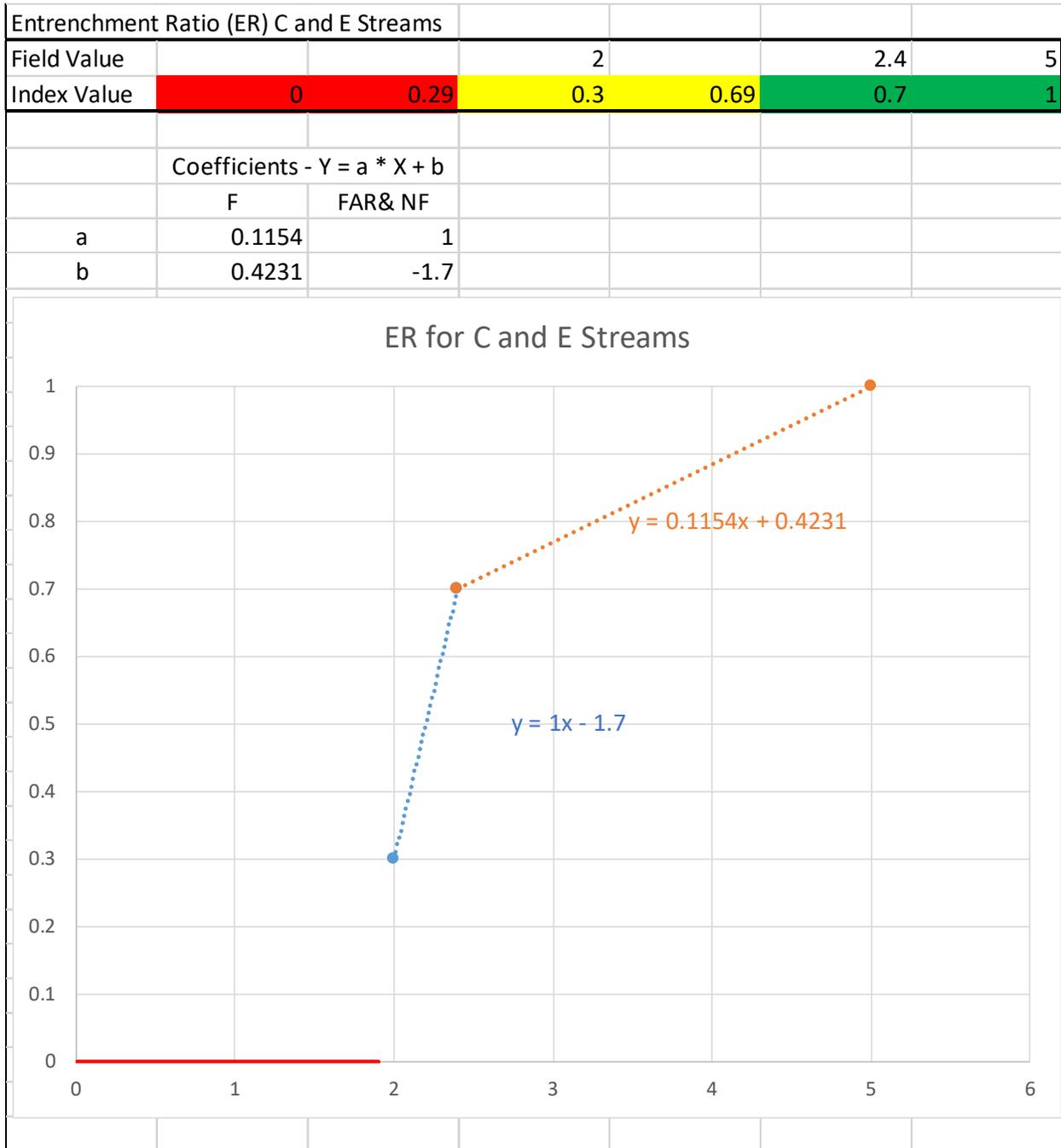
Measurement Method (Units)	Reference Standard Stratification		NF Score		FAR Score		F Score	
	Type	Description	Min	Max	Min	Max	Min	Max
Entrenchment Ratio (ft/ft)	Proposed Stream Type	C or E	< 2.0	-	2.0	2.3	2.4	≥ 5.0
	Proposed Stream Type	A, B or Bc	< 1.2	-	1.2	1.3	1.4	≥ 2.2

For a C-type channel, an entrenchment ratio of 2.4 or greater is considered functioning while an entrenchment ratio of less than 2.0 is considered not functioning. An entrenchment ratio of 5.0 or greater will give the maximum index value possible in the TN SQT. Figure 12 shows the reference standards used to define functional capacity for C and E streams. Threshold values that define the functional capacity ranges (0.00, 0.30, 0.70, and 1.00) are used to define equations that relate field values (x) to index values (y).

The Quantification Tool worksheet in the TN SQT and the Existing Condition worksheet in the Debit tool link to the coefficients on the Reference Standards worksheets to calculate index values (y) from the field values (x). The red line shown at the bottom of Figure 12 indicates where a cliff occurs in the reference standard curve. For C and E proposed stream types, it is not possible to receive an index value between 0.00 and 0.30; therefore, any entrenchment ratio less than 2.0 will yield an index value of 0.00.

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Figure 12. Entrenchment Ratio Reference standards for C and E Stream Types



3.7 Debit Calculator Worksheet

This worksheet is only present in the Debit Tool workbook and not in the TN SQT. The Debit Calculator worksheet is the calculator 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 Conditions worksheet within the Debit Tool. A more complete description of the activity modeling, impact factor development, and debit options is provided in the TN Stream Mitigation Guidelines (TDEC, 2019). 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

Permit Number: 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 13) 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 13. Debit Tool Table Example

Stream ID by Reach	Impact Description	Option	Existing Stream Length	Existing Condition Score	Proposed Length	Impact Severity Tier	Proposed Condition Score	Change in Functional Feet
STR1 R1	750 linear foot pipe	1	1000	0.8	750	Tier 5	0.10	-725.0
STR1 R2	500 linear foot pipe	1	800	0.8	500	Tier 5	0.10	-590.0
0	0		275	0.8	300	Tier 5	0.10	-190.0
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
Total Functional Loss (Debits in FF):								-1505.0

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Stream ID by Reach: Applicants enter each impact site by reach. This information will be automatically populated from the Project Assessment worksheet.

Impact Description: Describe the impact proposed. For example, installation of a 14' x 10', three-sided box, encapsulating 250 linear feet of stream. 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.

Options: There are three options for determining the existing site conditions. These options are described below and summarized in Table 5 on page 39.

- Option 1 requires the permit applicant to establish the **existing condition** of the proposed impact reach by quantitatively assessing **all** required parameters in an existing condition assessment within the Existing Condition spreadsheet of the Debit Tool using the Rapid Data Collection Methods (TDEC, 2018b). Once the rapid assessment is complete and the data are processed, the user will enter the data into the Existing Conditions worksheet of the Debit Tool (Section 3.4). The Existing Conditions worksheet will calculate the overall existing condition score for the reach.
- Option 2 is for permit applicants that do not want to assess **all** of the required parameters shown on the Existing Conditions worksheet of the TN Debit Tool. The applicant will **estimate the existing condition** by selecting the parameters and measurement methods to assess. The applicant will then follow the assessment methodology described in the Rapid Assessment Manual. The applicant then enters the field values into the TN Debit Tool in the same way as Option 1. For all required parameters where measurement methods are not measured, the values for those measurement methods will be a default score of 0.80. Because the metrics are not being assessed, the tool assumes these metrics are functioning. This approach acknowledges it is possible some measurement methods can and often score high where other values may be functioning at a lower capacity. Once the rapid assessment is complete and the data are processed, the user will enter the data into the Existing Conditions worksheet. The Existing Conditions worksheet will calculate the overall existing condition score for the reach. Please note if the stream is an Exceptional TN Waters (ETW) or Outstanding National Resource Waters (ONRW), applicants will not be able to select Option 2. The ECS for these features is entered as 1.00 on the Debit Calculator worksheet.
- Option 3 allows permit applicants to use a standard existing condition score for the stream reach. In most cases, the Division will apply a **standard existing condition** score of 0.80 for perennial and intermittent streams. The 0.80 value assumes that the existing stream is a functioning stream. The exception to this is for ONRWs, or waters designated as ETW due to exceptional ecology. In these highest quality waters, the Division will apply a standard condition score of 1.00.

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The Aquatic Resource Alteration Permit (ARAP) rules require that the determination of existing conditions shall ensure at least minimal protection for all streams notwithstanding prior degradation. **Therefore, any degraded stream will not be assessed as having an existing condition score of any less than 0.40.** This lower limit recognizes that even degraded streams have values outside of the of the functional quantification evaluation that must be offset if lost. Resource values are the benefits provided by a water resource that help maintain the classified uses established under Tennessee's water quality standards regulations. The TN Debit Tool and the TN Stream Quantification Tool measure functions of streams such as the physical, chemical and biological processes that are primarily associated with ecosystem functions. However, a stream's current condition may provide little to no ecosystem function while still providing other resource values that help maintain additional classified uses such as irrigation, recreation, wildlife, and livestock watering. In this regard, a permanent loss of stream length or significant loss of resource values must be balanced by compensatory mitigation to ensure no overall net loss of resource values for Tennesseans.

Please note that for 404 permits, the USACE may establish a lower limit existing condition score for ephemeral channels.

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 – 6 where 0 represents no appreciable permanent loss of stream functions and therefore would not require compensatory mitigation, while a 6 would result in significant loss of stream functions.

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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 3.4. The absolute value of the change in functional feet total 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 TN Stream Mitigation Guidelines (TDEC, 2019), or the most recent applicable guidance. Multiple stream impacts can be reported on a single spreadsheet. The spreadsheet will automatically total the debit sum. The Summary of Existing Conditions table on the Debt Calculator tab will total the overall existing condition scores of all stream reaches from the Existing Conditions tab when applicants elect to establish an ECS or estimate an ECS based on the site conditions. Therefore, applicants can easily transfer overall ECS scores from the summary table to the Debit Tool Table.

Table 5. Debit Tool Options

TN Debit Tool Option	Existing Condition Score (ECS) *	Proposed Condition Score (PCS)	Recommended Use
1	Applicants complete an existing condition assessment of all the required parameters and metrics.	Use Debit Calculator	Permit applicants who have the staff and expertise to perform the assessments. Typically used for larger impacts.
2	Applicants estimate the existing condition score by assessing some, but not all, of the required metrics included in the assessment.	Use Debit Calculator	Permit applicants who only want to assess a subset of the required parameters.
3	Applicants use a standard existing condition score (1.00 for ETWs or ONRWs and 0.80 for other waters as a default value)	Use Debit Calculator	Permit applicants who do not want to perform an assessment.

* ECS cannot be below 0.40 for any of the options.

4. References

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