

# **Rapid Data Collection Methods**

## **Tennessee Stream Quantification Tool** **Tennessee Debit Tool**





## **Tennessee Stream Quantification Tool Rapid Data Collection Methods**

**TN SQT v1.0**

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***Lead Agency:***

Tennessee Department of Environment and Conservation (TDEC)

***Contractors:***

Stream Mechanics  
Ecosystem Planning and Restoration

***Contributing Agencies:***

U.S. Environmental Protection Agency  
U.S. Army Corps of Engineers  
Tennessee Wildlife Resources Agency  
Natural Resource Conservation Services  
Tennessee Valley Authority  
U.S. Fish and Wildlife Services

## **Rapid Data Collection Methods**

May 20, 2019

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### ***Acknowledgements***

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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:

- Vena Jones, Jimmy Smith, and Jonathon Burr with the TN Department of Environment and Conservation (TDEC);
- Will Harman with Stream Mechanics;
- Cidney Jones with Ecosystem Planning and Restoration;
- Joshua Frost and Tammy Turley with the Nashville District US Army Corps of Engineers; and
- Eric Somerville with USEPA Region 4.

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## Rapid Data Collection Methods

May 20, 2019

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### ***Preface***

This user manual provides guidance on rapid data collection and analysis techniques for the Tennessee Stream Quantification Tool (TN SQT) and the Tennessee Debit Tool. This manual does not provide the methodology for determining compensatory mitigation credits or debits. This information is detailed in the Tennessee Stream Mitigation Guidelines (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 Tennessee Stream Mitigation Guidelines (2019) 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 – 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 – This manual. 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.

## ***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.

## Rapid Data Collection Methods

May 20, 2019

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### Table of Contents

<b>1. Introduction and Purpose .....</b>	<b>1</b>
1.1 Data Collection for the TN SQT and Debit Tool .....	2
<b>2. Preparing for Field Work .....</b>	<b>3</b>
2.1 Reach Segmentation.....	4
2.2 Field Form Reach Information .....	5
2.3 Data Collection Planning.....	6
<b>3. Collecting Data for Field Values .....</b>	<b>8</b>
3.1 Reach Walk.....	9
3.2 Bankfull Verification .....	10
3.3 Stable Riffle Stream Classification .....	12
3.4 Riffle Data (Floodplain Connectivity and Bed Form Diversity) .....	13
3.5 Reach Slope .....	17
3.6 Stream Classification .....	18
3.7 Pool Data (Bed Form Diversity).....	18
3.8 Large Woody Debris .....	20
3.9 Lateral Migration.....	20
3.10 Riparian Vegetation .....	22
<i>Buffer Width .....</i>	<i>23</i>
<i>Riparian Vegetation Plots .....</i>	<i>23</i>
3.11 Sinuosity.....	24
3.12 Channel Evolution.....	25
<b>4. Populating the TN SQT and Debit Tool.....</b>	<b>26</b>
4.1 Reach Information and Reference Standard Stratification .....	26
4.2 Field Data .....	29
4.3 Watershed Land Use Runoff Score.....	31
4.4 Stormwater Infiltration .....	33
<i>Hydrologic Modeling to Determine Stormwater Infiltration Factor .....</i>	<i>36</i>
4.5 Sinuosity.....	38
4.6 Bacteria, Nitrogen, and Phosphorus Measurement Methods.....	39
4.7 Macroinvertebrates .....	39
<b>5. References .....</b>	<b>40</b>
<b>6. TN SQT Rapid Assessment Forms .....</b>	<b>42</b>

### 1. Introduction and Purpose

Rapid assessments can be useful for site selection purposes, concept plans, one-time-only condition assessments, or other applications where detailed data are not required. This document provides instruction on how to collect data needed to run the Tennessee Stream Quantification Tool (TN SQT) and the Debit Tool using a suite of office and field techniques. It allows a user to quickly collect quantitative data for input into the spreadsheets. The TN Debit Tool is an application of the TN SQT designed specifically for calculating functional loss associated with permitted impacts. The TN Stream Mitigation Guidelines (TDEC, 2019) require one-time condition assessments associated with impacts. It is suggested applicants follow the techniques outlined in this manual (i.e. the rapid methodology). Even though the TN SQT can be utilized for large-scale permittee responsible mitigation and banking and in-lieu fee projects, this method of data collection should not be the primary means of determining total functional lift for large-scale, stream compensatory mitigation. Detailed methods for data collection are required to determine functional lift and as part of the mitigation plan. For stream mitigation projects, this document compliments the TN SQT Data Collection and Analysis Manual (detailed data collection manual; TDEC, 2018a). The detailed data collection manual is needed to complete worksheets within the TN SQT including Project Assessment, Watershed Assessment, and the Quantification Tool. The rapid manual document will reference the Data Collection and Analysis Manual for more detail on such topics where appropriate. Both the TN SQT and TN Debit Tool workbooks are described in detail in the TN SQT User Manual (TDEC, 2018b). Please refer to the TN SQT User Manual for any technical questions regarding calculations or spreadsheet functions.

Individuals collecting and analyzing rapid method assessment data should have experience and expertise in ecology, hydrology and geomorphology. Interdisciplinary teams with a combination of these skillsets are beneficial to ensuring consistent and accurate data collection and analysis. Standard surveying equipment like laser levels or a total station are not used in the rapid assessment methodology. Instead, survey tapes, hand levels, and stadia rods are used to take the measurements in the field (a complete equipment list for the field work component is provided in Section 3).

Few measurements are unique to the TN SQT and procedures are often detailed in other instruction manuals or literature. TDEC has attempted to compile these resources and make them available on our [website](#); however, all resources may not be listed there. Where appropriate, this document will reference other data collection manuals and make clear any differences in data collection or calculation methods needed for the TN SQT. Users should become familiar with this entire document before collecting field data.

A TN SQT Rapid Assessment Form (field form) is included in Section 6 of this document and can be used with these instructions to collect field data. This field form is also available as a

## Rapid Data Collection Methods

May 20, 2019

---

Microsoft Excel Workbook where data can be entered in the field or upon returning from the field.<sup>1</sup> Additional field forms are provided in Section 6 and in the Microsoft Excel Workbook for the BEHI/NBS assessment and riparian vegetation plots.

### 1.1 Data Collection for the TN SQT and Debit Tool

The rapid method is divided into two efforts: an office/desktop component and a field component (Table 1). Users will note that not all Function-Based Parameters included in the TN SQT and Debit Tool need to be assessed using the rapid method. This manual will provide instruction to:

1. Prepare the user for fieldwork (Section 2).
2. Collect field data (Section 3).
3. Analyze the field data, perform the desktop component and enter values into the TN SQT or Debit Tool (Section 4).

The rapid method requirements for streams with ephemeral flow are not the same as perennial and intermittent streams. The parameters and measurement methods in Table 1 (on the following page) list the requirements for perennial and intermittent streams. In ephemeral streams, data will only be collected for the following Function-Based Parameters:

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

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<sup>1</sup> Microsoft Excel version of the field form is available from:  
<https://www.tn.gov/content/tn/environment/permit-permits/water-permits1/aquatic-resource-alteration-permit--arap/permit-water-arap-compensatory-mitigation.html>



## Rapid Data Collection Methods

May 20, 2019

**Table 1.** Parameters and Measurement Methods included in the Rapid Method

Function-Based Parameter	Measurement Method	Effort Category
Catchment Hydrology	Watershed Land Use Runoff Score	Desktop
Reach Runoff	Stormwater Infiltration	Desktop
Floodplain Connectivity	Bank Height Ratio	Field
	Entrenchment Ratio	Field
Large Woody Debris	# Pieces	Field
Lateral Migration	Dominant BEHI/NBS	Field
	Percent Streambank Erosion (%)	Field
	Percent Armoring (%)	Field
Riparian Vegetation	Average Diameter at Breast Height (in)	Field
	Buffer Width (feet)	Field
	Tree Density (# / acre)	Field
	Native Herbaceous Cover (%)	Field
	Native Shrub Cover (%)	Field
Bed Form Diversity	Pool Spacing Ratio	Field
	Pool Depth Ratio	Field
	Percent Riffle (%)	Field
	Aggradation Ratio	Field
Plan Form	Sinuosity	Desktop or Field
Bacteria	E. coli (Cfu/100 mL)	Desktop
Nitrogen	Nitrate-Nitrite (mg/L)	Desktop
Phosphorus	Total Phosphorus (mg/L)	Desktop
Macroinvertebrates	Tennessee Macroinvertebrate Index	Desktop

## 2. Preparing for Field Work

To get started with the data collection process for the TN SQT and Debit Tool, users should first familiarize themselves with the region, river basin, soils, available topography data, local geology and climate for the project area. These data are informative when interpreting field data and some of these data will inform values for the Reach Information and Stratification Section of the field form. The following resources will assist in gathering information:

- [USGS Stream Stats](#) – Users can delineate the basin of interest and retrieve basin, flow and soil characteristics for the project reach.
- [TDEC Map Viewers](#) – Users can retrieve information concerning permitting activity, hydrologic determinations, water quality assessments, and more for watersheds across the state.
- [Web Soil Survey](#) – Users can delineate an area of interest and download soil data and information for that area.

## Rapid Data Collection Methods

May 20, 2019

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- [TN Geology](#) – Users can retrieve information on the geologic units and structural features in the state of Tennessee.

### 2.1 Reach Segmentation

Mitigation and impact projects can be a combination of many streams whose characteristics can change significantly from upstream sections to downstream sections. Therefore, it is important to capture the dynamic nature of these features by segmenting reaches based, in part, on physical form. Delineating stream reaches within a project area occurs in two steps. The first step is to identify whether there are multiple reaches along the project stream based on differences in physical stream characteristics. The second step is to identify appropriate sub-reach lengths to meet measurement method assessment requirements. The process to define a stream reach is described in detail below. The process to delineate a reach is described first, followed by specific guidance on selecting sub-reaches by parameter.

#### Step 1: Physical Segmentation

Each stream reach within a project area is evaluated separately in TN SQT and Debit Tool. A large project may have multiple streams within the project boundary. These streams may be subdivided into multiple reaches (each requiring its own field form), as stream condition or character can vary widely from the upstream to the downstream extent. Reach segmentation identifies whether there are multiple reaches along the stream based on differences in physical characteristics.

For segmentation based on physical stream characteristics, a reach is first defined as a stream segment with similar discharge or flow type (perennial, intermittent, or ephemeral), valley morphology, Rosgen stream type (Rosgen, 1996), stability condition, streambank and riparian vegetation type, and bed material composition. Stream length is not used to delineate a stream reach. For example, a channelized reach through cropland in an alluvial valley may be long but an un-incised reach upstream of a headcut may be short. Additional examples are provided below to assist in making consistent reach identifications:

- Tributaries are separate reaches from the mainstem.
- A significant increase in drainage area or change in flow type should lead to a reach break. Typically, when a large tributary enters the main stem, the main stem would consist of one reach upstream and one reach downstream of the confluence. Small tributaries to a main stem may not indicate the need for a reach break of the main channel.
- Changes to existing anthropogenic constraints such as the presence of a road embankment, which narrows the valley, or a culvert crossing.
- Changes to impact activity or mitigation approach. This typically occurs where proposed activities or practices change, e.g., restoration versus enhancement or a reach to be replaced with a culvert versus a channel relocation.

## Rapid Data Collection Methods

May 20, 2019

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The user will need to make an initial estimate of reach breaks before going into the field. However, observed site conditions may change the desktop segmentation. It is good practice to bring extra field forms in case site conditions require unanticipated reach breaks. Since the TN SQT and Debit Tool evaluate each reach separately, separate field forms are required for separate reaches and the remainder of this manual will outline the procedure to be followed **at a single reach**.

### Step 2: Parameter-Based Segmentation (Stream Reach Assessment Segments)

Some parameters, such as riparian vegetation and reach runoff, will be evaluated along the entire length of the stream reach, but other parameters will only be evaluated within a representative sub-reach, or stream reach assessment segment. Selecting an assessment segment is necessary to avoid having to quantitatively assess very long reaches with similar physical conditions. The stream length evaluated will vary by functional category and parameter. For short reaches, the assessment segment may encompass the entire reach.

1. Hydrology Functional Category:
  - a. The catchment hydrology parameter is assessed at the catchment or sub-catchment scale rather than the reach scale.
  - b. Reach runoff is evaluated for the entire length of each stream reach.
2. Hydraulic and Geomorphology Functional Categories:
  - a. Riparian vegetation is evaluated for the entire length of each stream reach.
  - b. Floodplain connectivity, lateral stability, and bed form diversity are assessed for a length **at least** 20 times the bankfull width encompassing at least two meander wavelengths (Harrelson et al., 1994). If the entire stream reach is shorter than 20 times the bankfull width, then the entire reach should be assessed.
  - c. Large woody debris (LWD) is assessed for a length that is 100 meters (m) (~328') (Davis et al., 2001). If the stream reach is less than 100m, the LWD assessment must extend proportionally into the upstream and downstream reach to achieve the 100m requirement. If the 100m is less than the length of 20 times the bankfull width, the 100m section should be within the same stream reach assessment segment as the bed form diversity assessment.
  - d. Sinuosity is evaluated for the entire length of each stream reach.
3. Physicochemical and Biology Functional Categories: The rapid methodology does not include physical sampling of physicochemical and biology parameters, see Section 4.

## 2.2 Field Form Reach Information

Some of the information on the field form (provided in Section 6) should be completed prior to the field work component. Sections I and III of the field form require the following inputs prior to conducting field work:

- Project name
- Reach ID

## Rapid Data Collection Methods

May 20, 2019

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- Reach location (latitude and longitude in decimal degrees of the upstream and downstream extent of the stream reach)
- Ecoregion
- Drainage area (measured in square miles)
- Stream reach length (measured in feet; verified in the field)
- Valley type (verified in the field)
- Regional Curve Used
- Regional Curve Width, Bankfull Mean Depth, and Bankfull Area

If the entire reach will be assessed, the latitude and longitude of the beginning and end of the reach can be entered prior to the field work. If the stream reach assessment segment is shorter than the reach length, the investigator should also note the upstream and downstream latitude and longitude **in the field** to denote the beginning and end of the assessment segment within the reach. Projects assessing conditions for impacts (Debit Tool) may not assess an entire stream reach based on the parameters and measurement methods used to establish an existing condition score.

Bankfull regional curve dimensions are required to be reported on the field forms. The state of Tennessee has worked with consultants to develop ecoregion-based regional curves across the state. The curve dataset is comprised of a diverse range of drainage areas and covers large geographic areas of Tennessee. The TDEC ecoregion regional curves can be accessed on the TDEC mitigation [webpage](#). This information is a point of reference to build on for a specific restoration project. Ideally, practitioners would develop site-specific regional curves representative of the watershed in addition to using the ecoregion based regional curves. Site-specific regional curves should be compared to the TDEC regional curve for the ecoregion.

Using the appropriate regional curve and the delineated catchment area, calculate bankfull dimensions for each stream reach. The data will be used to validate the bankfull indicators observed in the field. The regional curve dimensions should be entered on the field forms. The field form also provides space for the user to identify which bankfull regional curve was used (e.g. Ecoregion 71 Interior Plateau). Bankfull verification is discussed in more detail in Section 3.2.

### 2.3 Data Collection Planning

Before the field component, it is also recommended to:

- Describe the valley morphology (e.g. confined versus unconfined)
- Measure buffer widths from recent aerial imagery
- Determine the number and possible locations of riparian vegetation plots
- Print field forms and maps

## Rapid Data Collection Methods

May 20, 2019

The user should review recent aerial imagery and elevation data to measure or estimate valley widths, riparian buffer widths, and study the riparian buffer heterogeneity. Desktop estimates of valley widths and buffer widths should be confirmed in the field and can assist in determining locations to take measurements. On maps that will be taken into the field, mark locations where valley width changes and where valley measurements will need to be taken.

The user should determine whether they will need to measure sinuosity in the field or if it is possible to measure it from a desktop review. Given the prevalence and quality of aerial imagery, sinuosity can often be measured from the office. If recent aerial imagery is not available, or the stream channel is not visible in the imagery, then sinuosity must be measured in the field. Refer to Sections 3.11 and 4.5 for instructions on measuring sinuosity.

Riparian vegetation can be highly variable along streams and creeks. It is recommended that users assess the riparian vegetation at representative locations within major assessment area types for each reach within a project. Major assessment area types can consist of, but are not limited to, levels of mechanical site preparation, dominant strata variation, proposed credit generating treatment method, and soil drainage class types. In addition, users should familiarize themselves with the Carolina Vegetation Survey (CVS) level 3 data collection method (Lee et al., 2008) before going into the field.

The number of riparian vegetation plots for each stream reach in a project should be determined before field work. The area of all the sample plots must be equal to or greater than 2% of the total proposed riparian buffer area. Each 0.025 acre plot (10m by 10m) module represents 1/10 hectare of riparian area. The number of riparian vegetation plots may be adjusted based on site conditions to adequately represent the major assessment area types for each reach within a project. If additional plots are deemed to be necessary, this will be requested during the review process.

### Riparian Vegetation Plots Example

Project Total Length = 4,500 LF

Reach Length = 1,500 LF

Average buffer width LEFT = 50 ft

Average buffer width RIGHT = 50 ft

Approximate Riparian Buffer Area =

150,000 SF = 3.44 acres

Since the total length of stream in the project is 4,500 LF the plot area must be at least 2% of the riparian buffer area. Plots are 0.025 acres

Number of Plots for this reach =

$$\frac{3.44 \text{ acres} * 0.02}{0.025 \text{ acres}} = 2.7 \Rightarrow 3 \text{ plots}$$

## Rapid Data Collection Methods

May 20, 2019

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### 3. Collecting Data for Field Values

The rapid data collection methods will typically take two to four hours per stream reach. At a minimum, the following equipment will be needed to perform the field portion of a rapid assessment:

- Site maps
- Field forms
  - Rapid Assessment Form (field form)
  - Additional field forms for specific measurement methods or data collection include: BEHI/NBS, Riparian Vegetation Rapid Plots, and Hydrologic Determination Field Data Sheet
- Waders
- Stadia rod
- Hand level
- Line level
- Metric ruler
- 100-foot tape
- DBH tape
- 300-foot tapes for the stream reach assessment segment length (the number will vary based on bankfull width)
- Additional 300-foot tapes to measure riparian buffer widths, flood prone widths, and riparian vegetation plots (will vary based on valley topography)
- Chaining pins to secure tapes
- Clinometer for measuring bank angles (Part of the BEHI assessment)
- \*GPS unit (helpful with lateral migration and sinuosity field measurements)
- \*Range finder (helpful with sinuosity and flood prone width field measurements)
- Camera for photographing bankfull features, cross-sections, eroding banks, etc.

*\*Denotes item is optional.*

These field forms noted above are available in Section 6 and are also available for download as a Microsoft Excel Workbook. The rapid assessment form (field form) is the primary field form for the TN SQT and TN Debit Tool. Other forms are considered supplementary to this field form. The workbook version of the field form contains calculation cells that will automatically populate values based on the collected field data.

#### Flow Type

Perennial streams normally maintain baseflow throughout the year and are connected to groundwater. Intermittent streams are those whose connection to groundwater sustains baseflow only seasonally (generally in the late winter and early spring). Ephemeral streams only flow for short duration in direct response to a rain event and are not connected to the water table. All of these stream types may be considered Waters of the United States and

## Rapid Data Collection Methods

May 20, 2019

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should have jurisdictional evaluations submitted to the U.S. Army Corps of Engineers. TDEC's regulations reflect a similar distinction in flow regime but uses differing terms and determination procedures. The term "Wet Weather Conveyance" is defined in state statute and is generally analogous (but not identical) to that for an ephemeral stream. Watercourses with more persistent flow regimes are all simply defined as "Streams".

TDEC requires a hydrologic determination to determine the jurisdictional status of aquatic features. Wet Weather Conveyance determinations are made by following a [Standard Operating Procedures](#) (hydrologic determinations), informed by Rules in Chapter 0400-40-03 of the Division of Water Resources rules.<sup>2</sup> The hydrologic determination field data sheet, SOP, guidance, and a schedule of trainings to become a qualified professional to make hydrologic determinations are also available at [www.tnhdt.org](http://www.tnhdt.org). Hydrologic determinations of Wet Weather Conveyances and Streams should be submitted to the appropriate TDEC field office for evaluation. These field forms are not provided in this manual.

### 3.1 Reach Walk

It is recommended to walk the **entire reach** at the beginning of field work. Data is recorded during the reach walk in Section II of the field form. The reach walk should extend along the entire stream reach and include both sides of the stream channel.

1. Determine the location of the stream reach assessment segment. The assessment segment for floodplain connectivity, bed form diversity, and lateral migration parameters is roughly 20 times the bankfull width or two meander wavelengths. The assessment segment should capture the bed form diversity that is typical of the stream reach and contains the stretch of channel with the greatest amount of large woody debris (LWD). The assessment segment for LWD is the 100 m segment within the reach that contains the greatest amount of LWD.
2. Determine the location of the required number of 0.025 acre riparian vegetation plots. The number of riparian vegetation plots was determined in preparation for field work. Select the locations along the entire reach within the left and right riparian areas that will provide a representative sampling of the riparian buffer vegetative community. Areas of average tree density and size should be considered when selecting a location.
3. Record the length of any armored sections of bank. Measure and record the length of each bank that is armored. Examples of armoring include rip rap, gabion baskets, concrete, and other engineered materials that prevent streams from naturally meandering. Stone toe protection is not counted if the remainder of the bank height is natural vegetation, e.g., bioengineering methods. If stone toe protection exceeds more than half of the bankfull bank height, it is classified as armoring. Rock bluffs, bedrock

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<sup>2</sup> <https://publications.tnsosfiles.com/rules/0400/0400-40/0400-40.htm>

## Rapid Data Collection Methods

May 20, 2019

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outcrops and other natural geological formations are **not** counted. The field value for percent armoring is the total length of armored bank divided by the total length of bank in the stream reach. Space is provided for this calculation on the field form. The workbook version of the field form will sum the armored bank length and divide that sum by two times the reach length provided in Section I. Note that two times the reach length is an approximate total bank length for a reach and this calculation should be revised if the actual length of banks within the stream reach are measured.

4. Measure the distance between water surface elevation and bankfull indicators throughout the reach. Detail on this data collection method is provided in the following section.

### 3.2 Bankfull Verification

Multiple parameters in the TN SQT use bankfull dimensions in their measurement methods. These include floodplain connectivity, large woody debris, lateral migration, and bed form diversity. Prior to making field measurements for these parameters, the user should verify the bankfull stage and associated dimensions.

Bankfull verification should be completed for any mitigation project implementing natural channel design due to the importance of identifying and characterizing the stable form of the stream. Bankfull verification should also be completed for impact activities that include large scale fill and replacement.

#### *Tips for Identifying the Bankfull Feature:*

1. Look for depositional features such as point bars. Bankfull is often the highest elevation or top of point bar.
2. Check the bank for a break between depositional processes and channel formation processes such as a slope break.
3. For incised channels with a developing floodplain, bankfull is typically the back of a sloping bench. The front of the bench is typically the inner berm.
4. Scour lines should only be used to reinforce indicators from depositional features.

Bankfull verification is not necessary when using the Debit Tool to assess the existing conditions, the regional curve dimensions can be used for measurement method calculations. Regional curves are discussed in Section 2.2.

Users should verify bankfull using at least three pieces of evidence:

1. The difference between the stage of observed bankfull indicators and water surface throughout the reach.
2. Riffle dimensions.
3. Regional curves. The role that each of these play in bankfull verification is described below.



## Rapid Data Collection Methods

May 20, 2019

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### Difference Between Bankfull Stage and Water Surface

Measuring the distance between bankfull indicators and water surface elevation throughout the reach increases the accuracy of bankfull determinations compared to a bankfull indicator that is determined at a single location. Identify bankfull features throughout the reach during the reach walk. Methods for identifying bankfull features can be found in Harman (2000)<sup>3</sup>, Harrelson et al. (1994), and Rosgen (2014). As bankfull indicators are noted, measure the difference between water surface elevation and bankfull indicators using a stadia rod and a hand level (or line level) and describe the feature (e.g. back of a point bar, top of bank, or break in slope). These data can be recorded in Section II of the field form and will be used as a part of bankfull verification.

The data collected in Section II.B of the field form are used to form a consensus on the difference between the bankfull (BKF) elevation and water surface (WS) elevation. This should be recorded in Section III.A of the field form. This difference should only vary by a couple of tenths of a foot throughout the reach.

### Riffle Dimensions

Recall that the methods outlined in this manual do not require standard surveying equipment like laser levels or a total station. However, riffle dimensions are necessary to verify bankfull and to create dimensionless ratios for other measurements that quantify the departure of the stream from a stable condition. Therefore, a rapid survey of the bankfull channel at a single riffle cross-section within, or near, the reach is performed. The selection of a suitable riffle is critical, and a stable riffle is preferred.

Select a suitable riffle within the reach that has stable width and depth, no signs of bank erosion or headcutting, a bank height ratio near 1.0, and a bankfull width depth ratio that is on the lower end of the range for the reach. In a highly degraded reach, a stable riffle cross-section may be used from an adjacent upstream or downstream reach. Ideally, the riffle section will be very close to the project reach. If a stable riffle meeting these criteria cannot be found within or adjacent to the reach, then the user will survey a riffle within the reach that contains the strongest bankfull indicator identified during the reach walk.

Survey the stable riffle cross-section as follows:

1. Stretch a tape from the left bankfull indicator to the right bankfull indicator. Use the primary bankfull indicator (left or right) to level the tape.

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<sup>3</sup> [https://content.ces.ncsu.edu/finding-bankfull-stage-in-north-carolina-streams/#\\_section\\_heading\\_9234](https://content.ces.ncsu.edu/finding-bankfull-stage-in-north-carolina-streams/#_section_heading_9234)

## Rapid Data Collection Methods

May 20, 2019

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2. Level the tape by attaching a line level or by measuring the distance from the water surface to the tape at the left and right edge of water surface; the location where the water meets the streambank. The distance should be the same on both sides and should be within the range recorded in Section II.B of the field form during the reach walk.
3. Record the bankfull width.
4. Working from left to right, record the station from the tape and the depth from the tape to the channel bottom using a stadia rod. Include major breaks in slope, the thalweg, points halfway between edge-of-channel and bankfull, and other points along the channel bottom. Record these data in Section III of the field form.
5. Calculate the bankfull mean depth and cross-sectional area. These calculations are automatically performed in the workbook version of the field form using the station and depth values. A rough estimate of the mean depth can be calculated in the field by adding all the depth measurements (except for zeros at bankfull) and dividing by the number of observations. The area is the bankfull width times the mean depth.

### Regional Curves

Compare the measured bankfull cross-sectional area from the stable riffle to the regional curve. The field data for the site should fall within the range of scatter of the regional curve in order for bankfull to be verified. Typically, the cross-sectional area curve is used to make this determination since bankfull width and mean depth vary by stream type.

### Steps to Verify Bankfull Indicators – Three Pieces of Evidence

The user has (1) identified potential bankfull indicators throughout the reach and recorded the stage as a consistent distance above water surface; (2) surveyed a riffle cross-section within or near the reach that is consistent with the observed bankfull stage; and (3) compared the measured results with the regional curves. If the field data are outside the range of scatter used to develop the regional curve, the user will need to determine if the wrong indicator was selected or if the regional curve represents a different hydro-physiographic region than the field site. If the wrong indicator was selected, then the user can review the bankfull indicators identified in the reach walk to determine if the bankfull indicator at the selected riffle needs to be revised and bankfull dimensions recalculated.

If the reach is degraded such that bankfull indicators are scarce, the dimensions calculated from regional curves are used to quantify the departure of the stream from a stable condition.

### **3.3 Stable Riffle Stream Classification**

The TN SQT and Debit Tool require that the existing stream type be determined according to the Rosgen classification system (Rosgen, 1996). Section 3.6 of this manual and Section VI of the field form provide direction and space to determine the stream type representative of the

## Rapid Data Collection Methods

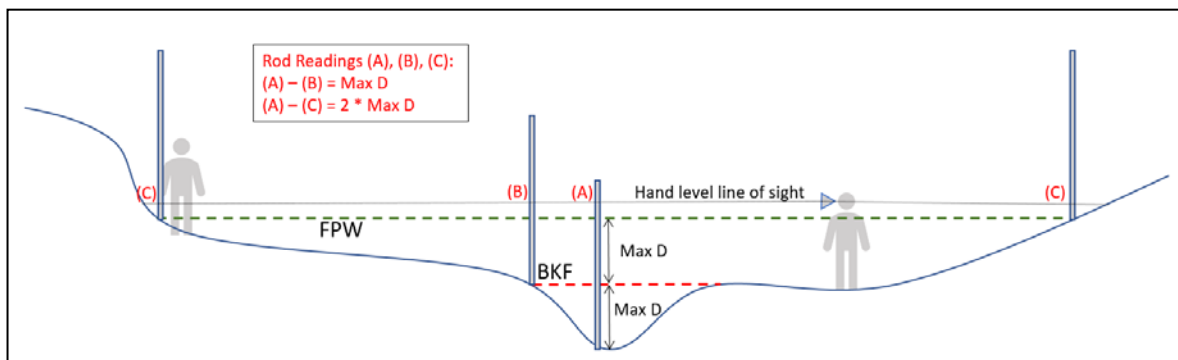
May 20, 2019

reach based on data collected at each riffle in the assessment segment. Space is also provided in Section III of the field form to determine the stream type at the stable riffle.

The procedures below are a continuation of the stable riffle cross-section survey procedure.

6. Measure the flood prone width. The flood prone width is the width of the valley at a height that is twice the bankfull max depth (Figure 1).

**Figure 1.** Surveying Entrenchment Ratio



7. Use the information in Section III of the field form to calculate the entrenchment ratio (ER; flood prone width divided by the bankfull width) and the width depth ratio (WDR; bankfull width divided by the bankfull mean depth).
8. Determine the stream type of the stable riffle based on the valley type, ER, and the WDR.

Note that sinuosity, bed material, and channel slope also contribute to stream classification. These values will be calculated later and can be used to revise the stream type of the stable riffle, but an initial classification of E, C, B, F, or A/G is possible using just ER and WDR.

### 3.4 Riffle Data (Floodplain Connectivity and Bed Form Diversity)

Sections IV through IX of the field form are performed for the assessment segment of the stream reach. The assessment segment for floodplain connectivity, bed form diversity, and lateral migration parameters is at least 20 times the bankfull width or two meander wavelengths (Harrelson et al., 1994). The assessment segment should capture the bed form diversity that is typical of the stream reach and contains the stretch of channel with the most pieces of large woody debris within the reach.

1. Stretch a tape or multiple tapes along the edge of the channel or top of streambank. Begin and end the assessment segment at the head of a riffle feature. Enter the assessment segment length in Section IV.A of the field form.

Measure the following at every riffle within the assessment segment and record values in Section IV.B of the field form:

## Rapid Data Collection Methods

May 20, 2019

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2. Record the station along the tape where the riffle begins.
3. Record the station along the tape where the riffle ends. If there is a run, the end station should be at the end of the run feature.
4. Identify the middle of the riffle feature or a location that is most representative of the overall bank height ratio.
5. Identify the lower of the two streambanks and measure the difference in stadia rod readings from the thalweg to the top of the low streambank. Record this value as the low bank height in Section IV.B of the field form.

The low bank height is the lower of the left and right streambanks, indicating the minimum water depth necessary to inundate the floodplain. For systems with no floodplain connectivity, or no floodplain bench, the lower of the right and left banks that define the channel should be recorded.

6. Measure the difference in stadia rod readings from the thalweg to the bankfull indicator, and record this value as the bankfull max depth in Section IV.B of the field form. Alternatively, if no bankfull indicators are present, measure the difference in stadia rod readings from the thalweg to the water surface then add the value recorded for the difference between bankfull stage and water surface (Section III.A on the field form).
7. Bankfull width – Measure at the midpoint of every riffle by stretching a tape from the left bankfull indicator to the right bankfull indicator. Use the primary bankfull indicator or the difference between water surface elevation and bankfull that has been recorded on the field form to level the tape.
8. Flood prone width – For reaches with changes in valley width or a bank height ratio greater than 2.0, flood prone width should also be measured at the midpoint of each riffle. The flood prone width is the width of the valley at a height that is twice the bankfull max depth. Locate and flag the points along the cross-section in the floodplain where the difference in stadia rod readings between the thalweg and that point is twice the maximum bankfull depth (refer to Figure 1). Use tapes and/or a range finder to measure the distance between the flags. Rosgen (2014) shows examples of ER calculations.<sup>4</sup>
9. Bankfull mean depth – Mean depth is the cross-sectional area divided by the width and therefore a calculation rather than a measurement. The mean depth can be estimated as the difference between the edge of channel and the bankfull stage.

These data are used to calculate the BHR, ER, aggradation ratio, and percent riffle measurement method field values. BHR and ER assess the floodplain connectivity parameter in

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<sup>4</sup> ER examples are also available from [https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent\\_object\\_id=1259](https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=1259)

## Rapid Data Collection Methods

May 20, 2019

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the hydraulic functional category while aggradation ratio and percent riffle assess the bed form diversity parameter in the geomorphology functional category. The rest of the riffle data table (field form Section IV.B) uses the data collected above to calculate field values for the TN SQT. Each measurement method is described in more detail below.

### Riffle Length

The riffle length is calculated as the difference between the end station and the beginning station of each riffle (or riffle and run). This value will be used to calculate percent riffle, weighted BHR, and weighted ER. The lengths of all riffles are summed in Section IV.C of the field form.

### Bank Height Ratio (BHR)

BHR is a direct measurement of channel incision. The BHR is calculated by dividing the low bank height by the bankfull maximum riffle depth ( $D_{max}$ ). To improve consistency, the TN SQT requires BHR to be measured at every riffle within the assessment segment. The BHR should be measured at the midpoint of the riffle, halfway between the head of the riffle and the head of the pool, or a location that is most representative.

Using this dataset, a weighted BHR is calculated using the equation below.

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

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

Section IV.B of the field form provides space to calculate the BHR and multiply the BHR by the riffle length (numerator of the equation above). Section IV.C of the field form sums the riffle lengths for the assessment segment (denominator of the equation above) while Section IV.D of the field form calculates the final weighted BHR. These values are automatically calculated in the workbook version of the field form and can be used to check field calculations. The weighted BHR is the field value entered into the TN SQT existing condition assessment.

### Entrenchment Ratio (ER)

The entrenchment ratio (ER) is a measure of floodplain connectivity and describes the ability of a stream to spread water across a floodplain to dissipate energy. ER is the flood prone width divided by the bankfull width of a channel. The ER does not have to be measured at every riffle, as long as the valley width is fairly consistent. For valleys that have a variable width or for channels that have bank height ratios above 2.0, it is recommended that the ER be measured at all riffles and to calculate the weighted ER.

## Rapid Data Collection Methods

May 20, 2019

Using this data set, a weighted ER is calculated as follows:

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

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

Space is provided in Section IV.B of the field form to record the flood prone width, bankfull width and calculate entrenchment ratio at each riffle. Section IV.B of the field form also provides space to multiply the ER by the riffle length at each riffle (numerator of the equation above). Section IV.C of the field form sums the riffle lengths for the assessment segment (denominator of the equation above) while Section IV.E of the field form calculates the final weighted ER.

These values are automatically calculated in the workbook version of the field form and can be used to check field calculations. The final entrenchment ratio, either one representative value for the reach or the weighted entrenchment ratio, is the field value entered into the TN SQT existing condition assessment.

### Maximum WDR and Aggradation Ratio

Channel instability can result from excessive deposition that causes channel widening, lateral instability, and bed aggradation. Visual indicators of aggradation include mid-channel bars and bank erosion within riffle sections. The aggradation ratio is the width depth ratio (WDR) at the widest riffle within the assessment segment divided by the expected WDR for the stream type (Table 2). The WDR is calculated by dividing the bankfull width at each riffle by the mean depth at the same riffle. In order to improve consistency, document the extent of aggradation, and classify the existing stream type for the reach, the TN SQT rapid method requires WDR to be estimated at every riffle within the assessment segment.

Space is provided in Section VI.B of the field form to record the bankfull mean depth, bankfull width and to calculate the WDR at each riffle. The field value for the aggradation ratio measurement method that gets entered into the existing condition assessment of the TN SQT is the maximum WDR ratio observed within the assessment segment (Section IV.F of the field form) divided by a reference WDR based on stream type. This step is not included in the field form.

**Table 2.** Reference Bankfull WDR Values by Stream Type

Stream Type	Reference WDR
B	16
C	13
E	9

## Rapid Data Collection Methods

May 20, 2019

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Note that for streams where a stable riffle was identified and surveyed within or adjacent to the stream reach, the measured WDR may be applicable to use as the denominator for this measurement method. A stable riffle will have stable width and depth, no signs of bank erosion or headcutting, bank height ratio is near 1.0, and bankfull width depth ratio that is on the lower end of the range for the reach.

### Percent Riffle

The percent riffle is the total length of riffles and runs within the assessment segment divided by the total assessment segment length. Riffle length is calculated from the recorded start and end stations, indicating the head (beginning) of the riffle and the head of the pool respectively. Run features are included within the riffle length.

Start and end stations are recorded in Section IV.B of the field form (these data were also collected for the weighted BHR and ER calculations). Line IV.C of the field form provides space to sum the riffle lengths for the assessment segment while Section IV.G provides space to divide the total riffle length by the length of the assessment segment. The length of the assessment segment was recorded in Section IV.A of the field form. The total riffle length and percent riffle are automatically calculated in the workbook version of the field form and can be used to check field calculations.

### **3.5 Reach Slope**

The slope of a stream reach is indicative of the energy within a channel and necessary for discharge calculations. Although energy and discharge calculations are not a part of the rapid method, reach slope is a component of the Rosgen stream classification system. Ideally, the average reach slope would be calculated for the entire stream reach as the difference between the water surface elevation at the head of the first riffle and at the head of the last riffle in the reach, divided by the centerline channel distance between these two points. For this assessment, the distance will be limited by the line of sight and magnification of the hand level being used. Estimate the slope of the channel by:

1. Taking a stadia rod reading of water surface at the head of similar features (i.e. riffle to riffle, or pool to pool, etc.);
2. Calculating the difference in stadia rod readings;
3. Measuring the centerline channel distance between the two shots; and
4. Dividing the difference in stadia rod readings by the centerline channel distance between these two points.

Space is provided in Section V of the field form to record the station along the tape and stadia rod readings at the beginning and end of the slope measurements. The distance between the readings, change in elevation, and slope are automatically calculated in the workbook version of the field form and can be used to check field calculations.

## Rapid Data Collection Methods

May 20, 2019

### 3.6 Stream Classification

The TN SQT requires that the existing stream type be determined according to the Rosgen classification system. This stream classification system and the fluvial landscapes in which the different stream types typically occur are described in detail in *Applied River Morphology* (Rosgen, 1996).<sup>5</sup>

Stream classification is based on entrenchment ratio, width depth ratio, sinuosity, slope, and channel material. Space provided in Section VI of the field form to record the existing stream type and the values used to determine the stream type. Space was also provided in Section III of the field form to determine the stream type at the stable riffle. Sections III, IV, and V of the field form can be useful in determining the stream type that represents the project reach. However, the stream type of a degraded reach may not be the same as the stream type of a stable riffle within the reach. Sinuosity and bed material are additional variables that are used to determine stream type classification. Sinuosity may have been calculated in the desktop component but there is space provided in Section XI of the field form to calculate this in the field, see Section 3.11 of this manual. The user can estimate bed material by performing a reach-wide pebble count (Rosgen, 2014) or, perform a rapid assessment by estimating the  $d_{50}$  of the material throughout the reach. The pebble sizes that classify different materials are provided in Table 3.

**Table 3.** Sediment Size Ranges for Stream Classification

Channel Material	Size Range (mm)
Silt or Clay	< 0.062
Sand	0.062 – 2.00
Gravel	2.01 – 64
Cobble	64.01 – 256
Boulder	256.01 – 2048
Bedrock	

### 3.7 Pool Data (Bed Form Diversity)

This section uses the same tape(s) stretched along the centerline of the assessment segment as the riffle data section. Data to calculate the pool spacing ratio and pool depth ratio measurement methods are collected in Section VII of the field form. Both of these measurement methods assess the bed form diversity parameter in the geomorphology functional category of the TN SQT.

<sup>5</sup> Rosgen Stream Type information is also available through the EPA:  
[https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent\\_object\\_id=1189](https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=1189)



## Rapid Data Collection Methods

May 20, 2019

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Working upstream to downstream, record the following at every pool within the assessment segment:

1. Whether the pool is a geomorphic pool;
2. Maximum pool depth (measured from bankfull); and

If no obvious bankfull indicators are present, measure the difference in stadia rod readings from the thalweg to the water surface then add the value recorded for the difference between bankfull stage and water surface recorded in Section III.A on the field form.

3. Station of max pool depth.

Each measurement method is described in more detail below.

### Pool Identification

Pool-to-pool spacing can be indicative of channel stability and geomorphic function. For this metric, pools should only be included if they are geomorphic pools; micro-pools within riffles are not counted using this metric. Geomorphic pools are associated with planform features that create large pools and patterns that remain intact over many years and flow conditions. Examples of geomorphic pools include pools associated with the outside of a meander bend and downstream of a large cascade/step, or a scour pool downstream of a single piece of large woody debris. Micro-pools within riffles are small, typically less than half the width of the channel, and may not remain long after a large flow event.

For the pool depth ratio, all significant pools (geomorphic and micro-pools associated with wood, boulders, convergence, and backwater) are assessed. If a pool is not associated with a planform feature (e.g. meander bend or cascade/step), it should still meet the following criteria:

1. The pool must be deeper than the riffle;
2. Have a concave bed surface;
3. Have a water surface slope that is flatter than the riffle; and
4. Have a width that is at least one-third the width of the channel.

### Pool Spacing Ratio

The pool spacing ratio is the distance between the deepest point of sequential geomorphic pools divided by the stable riffle bankfull width.

Calculate the pool-to-pool spacing between geomorphic pools in Section VII.A of the field form. Divide each spacing measurement by the bankfull riffle width from Section III of the field form. In order to characterize the departure of a stream from a stable condition, the bankfull riffle width used as the denominator for this ratio should be from a stable riffle or from the regional curve. A stable riffle will have stable width and depth, no signs of bank erosion or headcutting, bank height ratio is near 1.0, and bankfull width depth ratio that is on the lower end of the

## Rapid Data Collection Methods

May 20, 2019

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range for the reach. The pool spacing and median pool spacing ratio are automatically calculated in the workbook version of the field form and can be used to check field calculations.

Since the reference standard curve is bell-shaped for meandering channels, low and high field values (both non-functioning) could average to a functioning score. Therefore, the field value entered in the TN SQT is the median value based on at least three pool spacing measurements.

### Pool Depth Ratio

The pool depth ratio is calculated by dividing the maximum bankfull pool depth by the mean bankfull riffle depth. In order to characterize the departure of a stream from a stable condition,

the mean bankfull riffle depth used as the denominator for this ratio should be from a stable riffle or from the regional curve. A stable riffle will have stable width and depth, no signs of bank erosion or headcutting, bank height ratio is near 1.0, and bankfull width depth ratio that is on the lower end of the range for the reach.

The pool depth ratio is calculated for each pool in the assessment segment by dividing each bankfull pool depth measurement by the mean bankfull riffle depth from Section III of the field form. This is automated in the workbook version of the field form to check field calculations. The field value for the pool depth measurement method is the average of the pool depth ratios for pools within the assessment segment. Section VII.B provides space to average the pool depth ratios calculated in Section VII.A. The pool depth ratios are automatically calculated in the workbook version of the field form and can be used to check field calculations.

### **3.8 Large Woody Debris**

For the rapid method, all pieces of LWD within a 100-meter long assessment segment (328 feet) are counted. In this methodology, large woody debris is defined as dead wood over 1 meter in length and at least 10 centimeters in diameter at the largest end. The wood must be within the stream channel or touching the top of the streambank. In a debris dam, the number of pieces of large wood within than dam should be counted. The 100 meter LWD assessment segment should be within the same reach limits as the other geomorphology assessments and should represent the length that will yield the highest score. Record the number of pieces in Section VIII of the field form.

### **3.9 Lateral Migration**

Section IX of the field form provides space to assess the dominant BEHI/NBS and percent streambank erosion measurement methods for the lateral migration parameter. This section uses the same tape(s) stretched along the centerline of the assessment segment as the riffle data section. Dominant BEHI/NBS characterizes the magnitude of bank erosion while percent streambank erosion characterizes the extent of bank erosion within a reach.

## Rapid Data Collection Methods

May 20, 2019

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### Dominant BEHI/NBS

Detailed field procedures to measure BEHI/NBS are not provided below, but can be found in the following references:

- Appendix D of *Function-Based Rapid Field Stream Assessment Methodology* ([Starr et al., 2015](#))
- River Stability Field Guide, Second Edition (Rosgen, 2014)

The dominant BEHI/NBS measurement method assesses all meander bends, whether they are eroding or not, and other banks within the assessment segment that are eroding. Depositional zones and riffle sections that are not eroding and have a low potential to erode are not included. However, if a riffle is eroding, it is assessed.

For banks throughout the assessment segment:

1. Identify all meander bends,
2. Identify all other banks that are actively eroding,
3. Determine the BEHI/NBS rating for each bank identified as actively eroding or that is located in a meander bend. Record the rating in Section IX.A of the field form.
  - a. The BEHI/NBS field form provided in Section 6 can be used to record field data used to determine the BEHI/NBS ratings.
4. Measure and record the length of each bank assessed in Section IX.A of the field form. Bank lengths can be paced in the field or measured back in the office if a GPS unit is used to map assessed banks.

Using the data recorded in Section IX.A of the field form, the dominant BEHI/NBS rating can be determined and recorded in Section IX.B of the field form. The dominant BEHI/NBS is the single category that describes the longest bank length of the categories represented. For example, if an assessment segment evaluated five banks with scores and lengths shown in Table 4 the dominant BEHI/NBS rating would be High/High (H/H).

**Table 4.** Example BEHI/NBS Data

BEHI/NBS Score	Bank Length (Feet)
Low/Low	50
High/High	12
Mod/High	22
High/High	31
Low/Mod	9
High/High	31

## Rapid Data Collection Methods

May 20, 2019

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Enter the dominant BEHI/NBS value in Section IX.B of the field form. If there is a tie between BEHI/NBS categories, the category representing the highest level of bank erosion should be selected.

### Percent Streambank Erosion

The percent streambank erosion is measured as the length of streambank that is actively eroding divided by the total length of bank (left and right) in the project reach. The total length of stream bank is the sum of the left and right bank lengths, approximately twice the centerline stream length.

The BEHI/NBS rating is used to identify reaches of bank that are actively eroding. Banks with a BEHI rating of Extreme, Very High or High are considered an eroding bank regardless of their NBS rating. Additionally, banks with the following BEHI/NBS scores are considered to be actively eroding:

- M/Ex, M/VH, M/H, M/M, M/L,
- L/H

Using the data collected in Section IX.A of the field form to determine the length of eroding bank and enter it in Section IX.C of the field form. Enter the total bank length for the assessment segment in Section IX.D of the field form. The percent bank erosion is calculated by dividing these two numbers; space to record this value is provided in Section IX.E of the field form. The workbook version of the field form will sum the divide total eroding bank length by two times the reach length provided in Section I. Note that two times the reach length is an approximate total bank length for a reach and this calculation should be revised if the actual length of banks within the stream reach are measured.

### **3.10 Riparian Vegetation**

Riparian vegetation can be highly variable along streams and creeks. This method requires that riparian vegetation is assessed throughout the reach rather than within the assessment segment. Users should assess the riparian vegetation at representative locations within major assessment area types for each reach within a project (e.g. levels of mechanical site preparation, dominant strata variation, proposed credit generating treatment method, soil drainage class types). Major assessment area types refer to areas where there is significant variation between structural or vegetation components throughout the mitigation reach (e.g. forested areas versus herbaceous area, or upland communities versus wetland communities). Major assessment area types would not refer to small inclusions within a dominant plant community type. Five measurement methods are included in the rapid assessment: buffer width, average diameter at breast height (DBH), tree density, native herbaceous stratum total cover, and native shrub stratum total cover. There is space on the field form to record buffer width measurements. There is a separate Riparian Vegetation Rapid Plots field form provided in Section 6 to record plot data.

## Rapid Data Collection Methods

May 20, 2019

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### ***Buffer Width***

Riparian buffers contain riparian trees and shrub species. Large zones of herbaceous vegetation and grasses are not counted as functioning buffer areas unless these zones are limited and contribute to the species diversity and structure of the riparian area. The riparian buffer width is measured horizontally from the top of the stream bank to the proposed conservation easement boundary, project limits, edge of riparian tree/shrub community, or the edge of valley. Buffer width is measured perpendicular to the fall-line of the valley on the left and right sides of the channel. This measurement does not include the channel width. An average buffer width should be reported for the right and left side of the channel separately.

Space is provided to record individual buffer width measurements and calculate an average buffer width for the left and right sides of the channel in Section X.A of the field form if the riparian corridor varies drastically over the reach assessed. The average buffer width will automatically calculate from data entered into this section in the workbook version of the field form.

### ***Riparian Vegetation Plots***

Potential plot locations and the number of plots determined during the desktop component of the rapid methodology can be identified on field maps using aerial imagery and/or during the reach walk. Areas of average tree density and size should be considered when selecting a sampling location.

Tree density, DBH, native herbaceous cover, and native shrub cover data will be collected within 0.025 acre plots throughout the riparian buffer on both banks. Data will be collected in accordance with the Carolina Vegetation Survey EEP Level 3 protocol. Data forms and protocols can be found on the Carolina Vegetation Survey website<sup>6</sup> and a rapid method field form was developed and is provided in Section 6 of this manual.

Within each plot:

1. Measure the DBH class for all single trunked species (trees and saplings) and record a tally in the corresponding column on the Riparian Vegetation Rapid Plots field form. The average tree density and average DBH from all sampling locations are calculated for the left and right banks separately and entered as field values into the TN SQT.
2. Estimate the total native herbaceous cover across the entire herbaceous strata as one unit. All species cover within the strata will be combined for a total absolute native species cover for each sampled stratum. Individual species cover will not be collected in the rapid protocol.

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<sup>6</sup> <http://cvs.bio.unc.edu/methods.htm>

## Rapid Data Collection Methods

May 20, 2019

- Estimate the total native shrub cover across the entire shrub strata as one unit. All species cover within the strata will be combined for a total absolute native species cover for each sampled stratum. Individual species cover will not be collected in the rapid protocol.

Herbaceous and shrub strata are defined by height class and not true form, see Table 5 adapted from the CVS protocol (Lee et al. 2008).

**Table 5.** Strata Definitions

Strata	Height Range (ft)	Description
Herbaceous	< 3.28	All groundcover, including herbaceous species and woody species within this height class, tree saplings and moss/lichen cover are not included.
Shrub	3.28– 16.40	Woody multi-stemmed species (shrubs) only, tree saplings are not included.
Tree	Enter actual tree height range in feet for all single trunked tree species in the plot.	All single trunked tree species within the plot.

The average native herbaceous cover and native shrub cover from all sampling locations are calculated for the left and right banks separately and entered as field values into the TN SQT.

### 3.11 Sinuosity

Sinuosity is also covered in the desktop component, Section 4.5. Sinuosity calculations are described in more detail on page 2-32 of Rosgen (2014).<sup>7</sup>

Sinuosity can be measured in the field using **either** of the following methods depending on available equipment:

- Using a GPS unit to map the stream centerline along the project reach length. The stream length and valley length can then be measured in the office using the GPS data and then used to calculate sinuosity and enter the value in the TN SQT.
- Using either a range finder or available tapes, measure the centerline channel distance and the valley length between two common points. There is space provided in Section X

<sup>7</sup> Guidance on calculating sinuosity also available from:

[https://nctc.fws.gov/courses/CSP/CSP3200/resources/documents/Geometry\\_AFG2013.pdf](https://nctc.fws.gov/courses/CSP/CSP3200/resources/documents/Geometry_AFG2013.pdf)

## Rapid Data Collection Methods

May 20, 2019

of the field form to record the stream length and valley length. The workbook version of the field form will automatically calculate sinuosity from these values.

### 3.12 Channel Evolution

Section XII of the field form provides space for the user to note the Stream Evolution Model Stage (SEM; Cluer and Thorne, 2013) and/or the Rosgen Channel Succession Stage (Rosgen, 2006). Figures from these publications are reproduced on the field sheet to assist users. The user shall determine the current and future potential Stream Evolution Model (SEM) and/or Rosgen Channel Succession Stages. This will provide information on questions such as:

- Is the stream trending towards greater or lesser functionality?
- What is the realistic final Stage or Stream Type as compared to the previously undisturbed Stage or Stream Type?

*Note: This information is also used to determine the proposed stream type in the TN SQT and the reference stream type in the Debit Tool.*

The SEM and Rosgen Channel Succession Stages are not described in this manual and users should consult the source material in applying these methods. The future SEM stage and/or Rosgen Stream Type can be determined by considering the reach-scale constraints, watershed stressors in combination with the baseline, existing condition data. The SEM provides more detail for systems that started as stream/wetland complexes (anastomosed) than the Rosgen method and provides functional descriptions for each stage. Table 6 provides a crosswalk to assist the user in determining the SEM stage from the existing stream type for the project reach. The Rosgen approach includes channel evolution changes in a wider range of valley types than the SEM, e.g., a single-thread mountain stream. It also includes responses to a wider range of disturbances.

**Table 6.** Crosswalk Linking Stream Evolution Model Stages to Rosgen Stream Type Succession

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

### 4. Populating the TN SQT and Debit Tool

The TN SQT is a reach-based assessment methodology, and each reach is evaluated separately. The TN SQT and Debit Tool are Microsoft Excel Workbooks that contain condition assessments to score individual stream reaches within a larger project. For more information on the structure of these workbooks and the worksheets within the TN SQT and Debit Tool workbooks, see the TN SQT User Manual (TDEC, 2018a).

The TN SQT is a stream-based workbook that requires a minimum of one workbook for each stream contained within a project. There are five copies of the quantification tool worksheets in one TN SQT workbook, allowing for data input on up to five reaches in each stream. For streams with more than five reaches, users should open a new workbook or contact **TDEC or the USACE**. Users should not copy tabs to create additional reaches.

The Debit Tool is a project-based workbook that requires one workbook for each project. All reaches within the project are entered into the Debit Calculator worksheet. For each reach within a project, the user can choose to assess the existing conditions (refer to the Stream Mitigation Guidelines for debit calculation options). The Existing Conditions worksheet within the Debit Tool contains ten condition assessments. For projects that require more than ten condition assessments, users **can** make copies of the Existing Condition Worksheet within the Debit Tool.

This section will describe the desktop component of the rapid method and outline where the data collected during the field work component will be entered into the TN SQT or Debit Tool. There are several metrics that can be calculated from a desktop review. These are: watershed land use runoff score, stormwater infiltration, sinuosity, E. coli, nitrate-nitrite, total phosphorus, and Tennessee Macroinvertebrate Index.

#### 4.1 Reach Information and Reference Standard Stratification

The reach information and reference standard stratification sections of the TN SQT and Debit Tool are shown in Figures 2 and 3, respectively. The TN SQT captures both the existing and proposed conditions, while the Debit Tool only requires information based on the existing condition.

When the field work component is complete, the user can complete portions of the Reach Information and Reference Standard Stratification section (Figure 2). The Tennessee Macroinvertebrate Index (TMI) is used in the rapid method assessment for both loss and lift. Stratification for this metric is by ecoregion. The stratification for data collection season and macroinvertebrate collection method pertains to macroinvertebrate sampling of mitigation projects post construction when reporting the condition based on a limited suite of biometrics



## Rapid Data Collection Methods

May 20, 2019

(percent clingers; EPT-Cheumatopsyche; and Oligochaeta and Chironomidae). The remaining fields will be determined based on the design approach implemented for the stream reach and existing conditions. Note that in the TN SQT, some measurement methods in the existing condition assessment may return an error message instead of an index value unless the proposed slope and/or proposed stream type are provided.

**Figure 2.** TN SQT Reach Information and Reference Standard Stratification.

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

**Figure 3.** Debit Tool Reach Information and Reference Standard Stratification.

Reach ID:	Swift Creek Reach 4	Drainage Area (sqmi):	5.6
Existing Stream Type:	G	Existing Bed Material:	Gravel
Reference Stream Type:	C	Existing Stream Slope (%):	0.3
Ecoregion:	66e	Flow Type:	Perennial/Intermittent

		Upstream Latitude:	35.89596
Data Collection Season:		Upstream Longitude:	-89.65309
Macro Collection Method:		Downstream Latitude:	35.88964
Valley Type:	Unconfined Alluvial	Downstream Longitude:	-89.66013

The user can complete portions of the Reach Information and Reference Standard Stratification section (Figure 3) after the field work component for the Debit Tool for proposed impact projects (described in Sections 2 and 3 of this manual) has been performed. The data collection season and macroinvertebrate collection method, as mentioned above, are not necessary to score the macroinvertebrate measurement method utilized in the rapid method assessment (i.e. the TMI). Note that the reference stream type and the existing stream type in this section may be the same

## Rapid Data Collection Methods

May 20, 2019

for stream resources that are minimally impacted. However, the user must determine a reference stream type where anthropogenic stressors have caused stream degradation and the existing stream type is not stable. Determining the reference stream type is based largely on the natural valley type, channel evolution, and the existing stream type. The entrenchment ratio measurement method in the TN SQT and Debit Tool do not contain reference standards for F and G stream types since these stream types typically indicate instability.

Table 7 provides a guide on how to fill out the Reach Information and Reference Standard Stratification section in the TN SQT and Debit Tool based on the data collected during the field work component.

**Table 7.** Populating the Reach Information and Stratification Section

	Field Form
Project Name	Match what is on the field forms and site maps.
Reach ID	
Upstream Lat/Long Downstream Lat/Long	SQT & Debit Tool will reflect reach extents. Field forms document the extent of the assessment segment within the reach.
Existing Stream Type	Determined in the field. Rapid Assessment Form – Section VI
Proposed Stream Type (TN SQT)	Based on valley type, existing stream type, channel evolution scenario, and proposed restoration activities.
Reference Stream Type (Debit Tool)	Based on the valley type, existing stream type, and channel evolution scenario.
Ecoregion	Determined before fieldwork.
Drainage Area (sq.mi.)	Rapid Assessment Form – Section I
Existing Stream Length	Equivalent to the Stream Reach Length on the field form, is not equal to the assessment segment. Rapid Assessment Form – Section I
Proposed Stream Length Proposed Stream Slope	Based on existing values and proposed restoration activities.
Proposed Flow Type (TN SQT)	Based on existing flow type and proposed restoration activities.
Flow Type (Debit Tool)	Determined during fieldwork. See Section 3. of this manual.
Data Collection Season Macro Collection Method	Refer to Sections 4.6 and 4.7 of this manual.
Valley Type	Determined before fieldwork. Rapid Assessment Form – Section I

## Rapid Data Collection Methods

May 20, 2019

### 4.2 Field Data

The data collected during the field work component is used to determine the field values of the existing condition assessment for a project reach. The existing condition assessments in the TN SQT and Debit Tool are identical. An example existing condition assessment, filled in with data from the field work component of the rapid data collection methods, is shown in Figure 4. Table 8 summarizes the measurement methods assessed and where the data is located on the field forms. Please note that if an excel version of the field form, is used, there are cases where the automatic calculations may need to be revised. Refer to the instructions in Section 3 for each measurement method.

**Table 8.** Populating the Existing Condition Assessment

Parameter	Measurement Method	Field Form
Floodplain Connectivity	BHR	Rapid Assessment Form – Section IV
	ER	
LWD	# Pieces	Rapid Assessment Form – Section VIII
Lateral Migration	Dominant BEHI/NBS	BEHI/NBS Field Form OR Rapid Assessment Form – Section IX
	Percent Streambank Erosion	Rapid Assessment Form – Section IX
	Percent Armoring	Rapid Assessment Form – Section II
Riparian Vegetation	L/R Average DBH	Riparian Vegetation Rapid Plots
	L/R Buffer Width	
	L/R Tree Density	
	L/R Native Herbaceous Cover	
	L/R Native Shrub Cover	
Bed Form Diversity	Pool Spacing Ratio	Rapid Assessment Form – Section VII
	Pool Depth Ratio	
	Percent Riffle	Rapid Assessment Form – Section IV
	Aggradation Ratio	
Plan Form	Sinuosity	Rapid Assessment Form – Section X

**Rapid Data Collection Methods**  
May 20, 2019

**Figure 4. Existing Condition Assessment Example**

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
		Percent Armoring (%)	20
	Riparian Vegetation	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	
	Aggradation Ratio	1.1	
Plan Form	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 (%)	
		Percent Oligochaeta and Chironomidae (%)	
	Fish	Native Fish Score Index	
		Catch per Unit Effort Score	

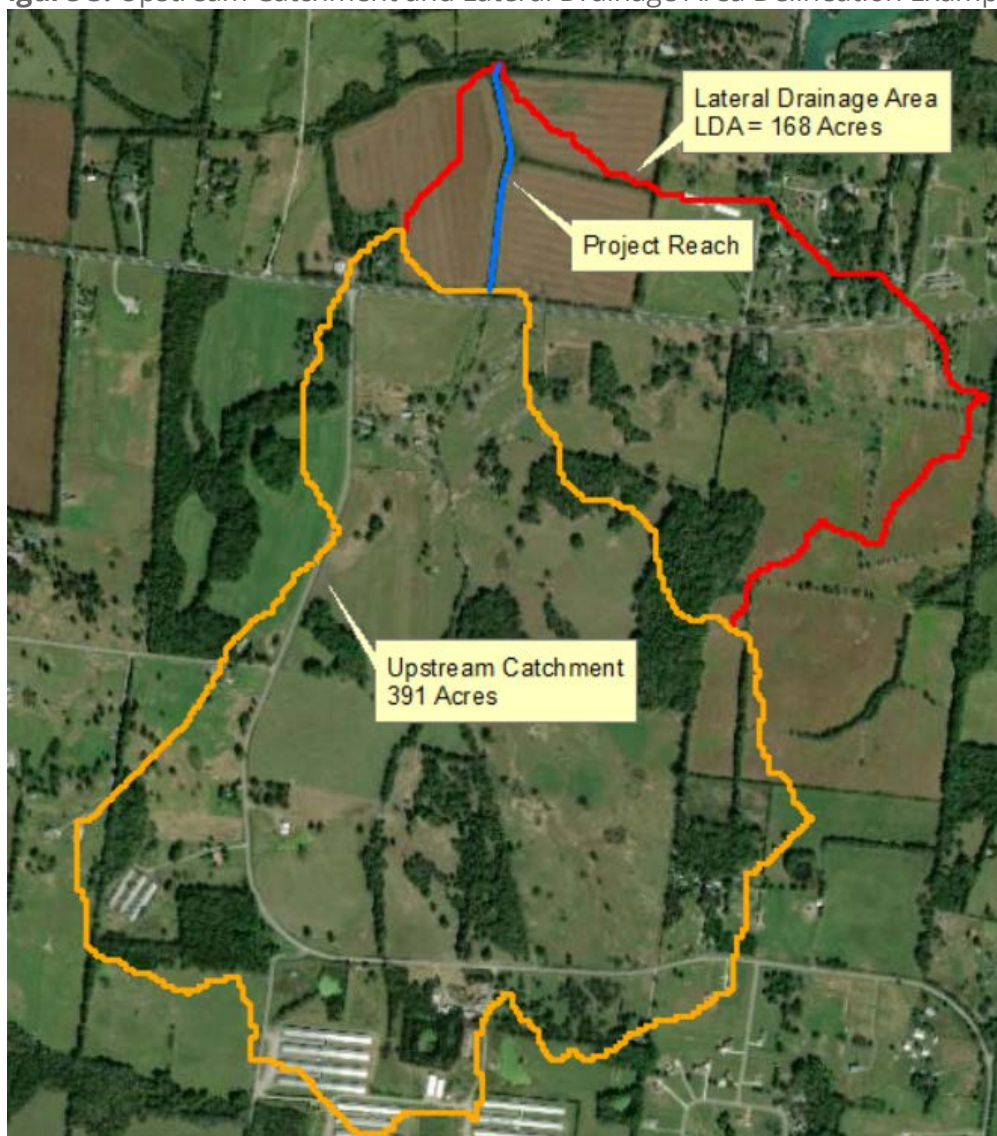
The remainder of this section will provide instruction on how to perform the desktop component of the rapid data collection methods and describe how to determine the field values for the following metrics:

- Watershed land use runoff score
- Stormwater infiltration
- E. coli
- Nitrate-Nitrite
- Total Phosphorus
- Tennessee Macroinvertebrate Index

### 4.3 Watershed Land Use Runoff Score

The watershed land-use is an area-weighted value used to characterize the catchment land use *upstream* of the project reach (Figure 5) and is required for the catchment hydrology parameter of the TN SQT. This metric is based on the headwater stream variable called Watershed Land-Use and quantifies the land uses in a catchment that are known to affect the quality and quantity of runoff (impervious cover, agricultural, pasturelands, industrial, or residential lands; Summers et al., 2017)

**Figure 5.** Upstream Catchment and Lateral Drainage Area Delineation Example



## Rapid Data Collection Methods

May 20, 2019

To determine the field value:

1. Delineate the catchment for the reach.
2. Delineate the different land use types. This can be accomplished using recent aerial imagery of the site or, less accurately, using land use data from the National Land Cover Dataset (NLCD).<sup>8</sup>
3. Record the area in acres that is occupied by each land use.
4. Match each land use to the best fitting description from Table 9.
5. For each land use, multiply the acreage (step 3) by the coefficient that corresponds to the land use from step 4.
6. Calculate an area-weighted watershed land use value for the upstream drainage area of the reach by summing the results from step 5 and dividing by the total catchment area. This is the field value for the watershed land use runoff score in the existing condition assessment. An example calculation is shown in Table 10.

**Table 9.** Watershed Land-Use Coefficients from Summers et al. (2017)

Land-Use	Coefficient
Forest and native range	1.0
Low density residential (> 1-acre lots)	0.3
Open space (pasture, lawns, parks, golf courses, cemeteries)	0.2
High density residential (< 1-acre lots)	0.1
Impervious cover	0
Gravel	0
Industrial, commercial and business	0
Newly graded areas (bare soil, no vegetation or pavement)	0

**Table 10:** Watershed Land-Use Runoff Score Example

Land-Use	(A) Runoff Coefficient	(B) Catchment Area (Acres)	(C) = (A) * (B)	Field Value
Forest and native range	1.0	50	50	
Low density residential	0.3	10	3	
Pasture	0.2	90	18	
Sum		150	71	

<sup>8</sup> <https://gapanalysis.usgs.gov/gaplandcover/data/download/>

## Rapid Data Collection Methods

May 20, 2019

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### 4.4 Stormwater Infiltration

Stormwater infiltration of small, frequent rainfall events supports stream function by sustaining baseflow, attenuating hydromodification, replenishing soil moisture for riparian vegetation, and removing stormwater pollutants. The stormwater infiltration measurement method characterizes the amount of stormwater runoff from the lateral drainage area (LDA; see Figure 5) that is able to infiltrate as groundwater flow rather than as surface flow throughout the reach. The Tennessee Permanent Stormwater Management and Design Guidance Manual (TDEC, 2014) serves as the primary resource for designing and assessing existing best management practices (BMPs). Note that BMPs include stormwater control measures (SCMs) described in the design guidance manual.

In order to calculate the field value for the TN SQT, the user must delineate the following variables within the LDA:

1. Runoff Source Area (RSA)
  - a. Drainage area from agricultural or urban land uses that increase runoff or generate pollutants. The RSA can and may be concentrating flow from these sources to outfalls.
2. Sub-Catchment Area for each BMP treating RSA within the LDA
  - a. Drainage area contributing runoff that is treated by BMPs.
  - b. BMPs include but are not limited to forested riparian zones, managed vegetated areas, filter strips, wetlands, vegetated swales, bioretention, and infiltration areas.

For identified BMPs, a Stormwater Infiltration Factor (SIF) should be determined to estimate how much of the runoff from the  $DA_{BMP}$  is being infiltrated by the BMP. The SIF is the ratio of the BMP design volume that will be infiltrated by the BMP. In order to determine the SIF, the user needs to determine the BMP design volume and net volume infiltrated for the design storm. Infiltration rates must come from documented and reviewable reference materials such as the Tennessee Permanent Stormwater Management and Design Guidance Manual (TDEC, 2014).

Once these values are determined, the equation below can be used to calculate the field value for this measurement method.

$$Field\ value = \frac{LDA - RSA + \sum(DA_{BMP} \times SIF)}{LDA}$$

Note that even though this metric is considered a desktop effort, some field investigation may be necessary to identify and characterize existing BMPs. If existing BMPs are identified, then the drainage area to each BMP must be delineated and the volume of the BMP measured.

## Rapid Data Collection Methods

May 20, 2019

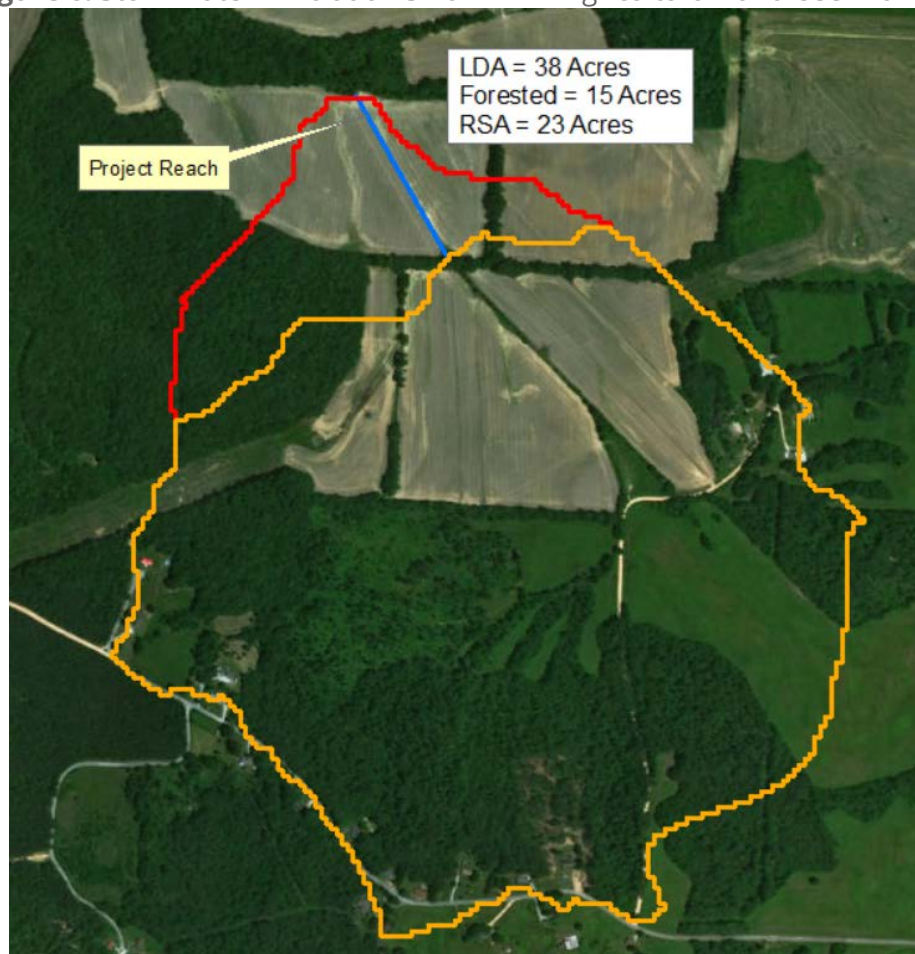
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Depending on the project and the BMP(s), it may not be necessary to determine the infiltration volume during a design storm event. Multiple examples are provided in this section to highlight the varying levels of detail that can be used to determine a field value for the TN SQT and Debit Tool. More examples are provided for the measurement method in the Data Collection and Analysis Manual. For BMPs that are installed within a Municipal Separate Storm Sewer System (MS4) community, the applicant shall coordinate with the local stormwater program or local government responsible for stormwater management regarding BMP design.

### Example 1 – Base Case

For a LDA that consists of natural cover land uses, the RSA is equal to 0 and no BMPs are necessary ( $DA_{BMP} = SIF = 0$ ). Using the equation above, the field value will be equal to 1.00.

**Figure 6.** Stormwater Infiltration Small LDA – Agricultural Land Use Example





## Rapid Data Collection Methods

May 20, 2019

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### Example 2 – Simplified Land Use Change – Small LDA

Referring to the agricultural example shown in Figure 6 with an LDA of 38 acres. The LDA consists of 23 acres of agricultural land uses and 15 acres of forested lands (unmanaged), thus the RSA is 23 acres. The stream restoration project will provide a 50-foot buffer on both sides of the stream reach, converting 3 acres of agricultural land use to forested land use. A simplifying assumption was made based on the design guidance for natural vegetated areas in the Tennessee Permanent Stormwater Management and Design Guidance Manual:

“While this practice is not approved to accept run-on water volumes, implementing managed vegetated areas will minimize the overall site generation of runoff.” (pg. 122 in TDEC, 2014)

Therefore, the  $DA_{BMP}$  and SIF are not necessary to calculate field values for the TN SQT. The field values for the existing and proposed conditions are 0.39 and 0.47 respectively, as shown in the equations below.

$$\begin{aligned} \text{Existing Condition Field value} &= \frac{38 \text{ acres} - 23 \text{ acres} + \sum(0 \times 0)}{38 \text{ acres}} = 0.39 \\ \text{Proposed Condition Field value} &= \frac{38 \text{ acres} - 20 \text{ acres} + \sum(0 \times 0)}{38 \text{ acres}} = 0.47 \end{aligned}$$

For this example, a 100-foot buffer on both sides of the creek would result in a difference of 0.16 instead of 0.08 shown above.

### Example 3 – Small BMP

The stream shown in Figure 7 has three stormwater outfalls delineated. The red  $DA_{BMP}$  (6 acres) has a detention basin that captures runoff coming from the outfall. Field surveys measured the volume of the detention basin as 0.10 ac-ft. The 1-inch depth of runoff was used as the design volume for the BMP instead of running a hydrologic model and a design storm event. Web soil survey was downloaded and used to determine that the soils underlying the detention basin were well drained and the distance to the confining layer was unlikely to inhibit the infiltration of the volume of water detained within the basin.

The design volume for the BMP using the 1-inch runoff depth over the 6-acre catchment to the BMP is 0.5 ac-ft and the SIF is 0.20 (0.10 BMP volume/0.5 runoff volume). The field value for the existing condition is calculated below.

$$\text{Field value} = \frac{121 \text{ acres} - 111 \text{ acres} + (6 \text{ acres} \times 0.10)}{121 \text{ acres}} = 0.09$$

## Rapid Data Collection Methods

May 20, 2019

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Due to the size of the BMP compared to the RSA and the LDA, the detention basin does not change the field value significantly. If the BMP were sized to infiltrate the entire design storm, then the SIF would equal 1.00 and the field value would be 0.13.

### ***Hydrologic Modeling to Determine Stormwater Infiltration Factor***

In Example 3, above, the 1-inch depth of runoff was used to calculate the design volume and SIF of the BMP. This is a simplifying assumption that will underestimate the amount of runoff that will be infiltrated by the BMP. Since rain events occur over a period of time (storm duration) and runoff from different portions of the sub-catchment have different travel times before arriving at the BMP, the 1-inch depth of runoff will not arrive at the BMP at a single point in time. Creating a hydrologic model of the BMP sub-catchment and the BMP would increase the accuracy of the SIF used to calculate the field value of the stormwater infiltration metric for the TN SQT or Debit Tool.

Hydrologic modeling must be performed by experienced professionals and detailed procedures to perform hydrologic modeling are outside the scope of this manual. This manual will mention two tools available for hydrologic modeling, the TN Runoff Reduction Assessment Tool (RRAT; SMART Center and TDEC, 2015) and Hydrologic Engineer Center Hydrologic Modeling System (HEC-HMS; USACE, 2000). The user should consult the source material in order to create a hydrologic model.

Note, the user does not need to use RRAT or HEC-HMS and can use another acceptable and technically equivalent method to estimate the design volume and SIF. BMP design volume calculations may be based on an 80<sup>th</sup> percentile storm, average annual runoff coefficient or the representative rain event used within the RRAT shown in Table 11 (page 42). It is important to note that for BMPs that are installed within a MS4 community, the applicant needs to coordinate with the local stormwater program or local government responsible for stormwater management regarding BMP design.

**Rapid Data Collection Methods**

May 20, 2019

**Figure 7. Urban Stormwater Infiltration Example**



**RRAT:** The TN Runoff Reduction Assessment Tool (RRAT; UT SMART Center and TDEC,2015) can be used to determine the SIF for either a single BMP or a series of BMPs. RRAT was developed to assist with urban site design and is not applicable for rural projects. Detailed procedures to run RRAT are not provided below but are available through TDEC (UT SMART Center and TDEC,2015; TDEC, 2014). The output from RRAT can be used to determine the SIF as follows:

$$SIF = \frac{\text{Net Volume Reduced}}{\text{Net Volume Reduced} + \text{Net Runoff Depth}}$$

RRAT has defined the design storm for major cities within Tennessee as the 95<sup>th</sup> percentile storm depth for a duration that is equal to the median value of the storms in the percentile range from 92.5 and 97.5. The RRAT implements a time-mass infiltration modeling approach and the SCS Type II distribution is used to calculate rainfall intensity over time. The depth and duration for design storms used in the RRAT are provided in Table 11 and can be used in other hydrologic models to generate the design storm.

**Table 11.** Design Storm Depth and Durations for TN Cities (TNRRAT, 2015)

City	Rainfall Depth (in)	Duration (hr)
Bristol	1.18	13.0
Knoxville	1.45	15.4
Chattanooga	1.74	16.0

## Rapid Data Collection Methods

May 20, 2019

Monterrey/Crossville	1.80	14.4
Nashville	1.65	14.0
Jackson	1.91	16.5
Memphis	1.94	14.0

### Example 4

Figure 7 (page 41) shows an urban stream reach between two culverts with a LDA of 121 acres. Stormwater outfalls that discharge to the stream were identified and three were noted to have practices that detain stormwater at their outfall. Instead of modeling each house and lot within RRAT, HEC-HMS was used to determine the BMP design volume for each BMP using the design storm data in Table 11. The web soil survey was used to estimate the infiltration rate and depth to confining layer for the underlying soils while field visits determined the dimensions and slope of the BMPs and verified that the BMPs were unlined. The results of the hydrologic modeling and field value calculations are shown below.

$$\begin{aligned}
 DA_{BMP} \times SIF &= 6 \text{ acres} \times 1.00 = 6 \\
 DA_{BMP} \times SIF &= 7 \text{ acres} \times 1.00 = 7 \\
 DA_{BMP} \times SIF &= 11 \text{ acres} \times 0.30 = 3.3
 \end{aligned}$$

$$\text{Field value} = \frac{LDA - RSA + \sum(DA_{BMP} \times SIF)}{LDA} = \frac{121 - 111 + (6 + 7 + 3.3)}{121} = 0.22$$

Were the example above implemented as a mitigation project, the existing condition without BMPs would yield a field value of 0.08 and installing the three BMPs would yield 0.14 of lift for the Stormwater Infiltration measurement method in the TN SQT.

## 4.5 Sinuosity

Sinuosity is measured from the plan form of the stream reach and calculated by dividing the centerline channel distance by the straight-line valley length between two common points. Sinuosity calculations are described in more detail on pages 2 through 32 of Rosgen (2014); however, the TN SQT calculates sinuosity for the project reach length rather than a length that is 40 times the bankfull width.<sup>9</sup>

The rapid assessment method is to measure sinuosity from recent aerial imagery. The TDEC [Water Resources mapviewer](#)<sup>4</sup>, Google Earth, and other online sources may be useful.

1. Download recent aerial imagery available for the project site.
2. Trace out the centerline path of the reach on the recent aerial imagery

<sup>9</sup> Guidance on calculating sinuosity also available from:

[https://nctc.fws.gov/courses/CSP/CSP3200/resources/documents/Geometry\\_AFG2013.pdf](https://nctc.fws.gov/courses/CSP/CSP3200/resources/documents/Geometry_AFG2013.pdf)

## Rapid Data Collection Methods

May 20, 2019

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3. Measure the straight-line valley distance between the beginning and the end of the traced stream path.
4. Calculate sinuosity by dividing the stream length by the valley length.

These procedures will provide the existing condition field value for the sinuosity measurement method. The proposed condition field value would be determined based on the design.

### 4.6 Bacteria, Nitrogen, and Phosphorus Measurement Methods

TDEC maintains a [dataset and map](#) of the Use Support Assessment status of Waterbodies within the state. Data for the physicochemical functional category may be available through TDEC water quality monitoring databases. These data are updated daily and can be viewed online.<sup>10</sup> Information may also be retrieved from the TDEC database, [Waterlog](#).<sup>11</sup>

These data should be reviewed for the project reaches or surrounding water bodies to determine whether physicochemical parameters are likely functioning, functioning-at-risk, or not functioning for each reach. Data from sites outside of the project reach should be presented with discussion and justification of the assumptions made in interpreting the available data to score the project reach.

### 4.7 Macroinvertebrates

Data for measurement methods within the biology functional category may also be available through [state monitoring databases](#).<sup>4</sup> In addition to water quality, macroinvertebrate communities are evaluated as part of the Surface Water Classifications assessment. These data can be retrieved from the TDEC Integrated Report published every two years on EPA STORET. Information may also be retrieved from the TDEC [dataviewer](#) for Ambient Water Quality Monitoring Data.

These data should be reviewed for the project reaches or surrounding water bodies to determine whether macroinvertebrate communities are likely functioning, functioning-at-risk or not functioning for each reach. Data from sites outside of the project reach should be presented with discussion and justification of the assumptions made in interpreting the available data to score the project reach. The fish parameter is not included in the rapid method.

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<sup>10</sup> <http://tdeconline.tn.gov/dwr/>

<sup>11</sup> [http://environment-online.tn.gov:8080/pls/enf\\_reports/f?p=9034:34510:.....](http://environment-online.tn.gov:8080/pls/enf_reports/f?p=9034:34510:.....)

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May 20, 2019

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## 6. TN SQT Rapid Assessment Forms



Date:  
Investigators:

# TN SQT and Debit Tool Rapid Assessment Form

Version 1.0 May 2019

## I. Reach Information and Stratification

Project Name:			<b>Shading Key</b>
Reach ID:			Desktop Value
Upstream Latitude:			Field Value
Upstream Longitude:			Calculation
Downstream Latitude:			
Downstream Longitude:			
Ecoregion:			
Drainage Area (sq. mi.):			
Stream Reach Length (ft):			
Flow Type:			
Valley Type:			

## II. Reach Walk

	Length of Armoring on banks (ft)						
A.	Total (ft)						
	Percent Armoring (%)						
B.	Difference between BKF stage and WS (ft)	Describe the bankfull indicator					

## III. Bankfull Verification and Stable Riffle Cross Section



Date:

# TN SQT and Debit Tool Rapid Assessment Form

Investigators:

Version 1.0 May 2019

**B. Bank Height & Riffle Data**

	R1	R2	R3	R4	R5	R6	R7	R8
Begin Station (Distance along tape)								
End Station (Distance along tape)								
Low Bank Height (ft)								
Bankfull Max Depth (ft)								
Bankfull Width (ft)								
Flood Prone Width (ft)								
Bankfull Mean Depth (ft)								
Riffle Length (ft) <i>Including Run</i>								
Bank Height Ratio (BHR) Low Bank H / BKF Max D								
BHR * Riffle Length (ft)								
Entrenchment Ratio (ER)								
ER * Riffle Length (ft)								
WDR BKF Width / BKF Mean D								

**IV. Riffle Data (Continued)**

C.	Total Riffle Length (ft)	
D.	<b>Weighted BHR</b> $\frac{\sum(\text{Bank Height Ratio}_i \times \text{Riffle Length}_i)}{\sum \text{Riffle Length}}$	
E.	<b>Weighted ER</b>	
F.	<b>Maximum WDR</b>	

Date:

# TN SQT and Debit Tool Rapid Assessment Form

Investigators:

Version 1.0 May 2019

G. 

<b>Percent Riffle (%)</b>	
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## V. Slope

A.	Begin	End	Difference	Slope (ft/ft)
Station along tape (ft)				
Stadia Rod Reading (ft)				

## VI. Stream Type Classification

	Assessment Segment
A. Entrenchment Ratio (ft/ft)	
B. Width Depth Ratio (ft/ft)	
C. Channel Material Estimate	
D. Stream Type (Rosgen, 1996)	

## VII. Pool Data (Bed Form Diversity)

	P1	P2	P3	P4	P5	P6	P7	P8
Geomorphic Pool?								
Station At maximum pool depth								
A. P-P Spacing (ft)	X							
Pool Spacing Ratio Pool Spacing / BKF Width	X							
Pool Depth (ft) Measured from Bankfull								
Pool Depth Ratio Pool depth/BKF mean D								
B. Average Pool Depth Ratio			C. Median Pool Spacing Ratio					

## VIII. Large Woody Debris

A. Number of Pieces per 100m	
------------------------------	--

## IX. Lateral Migration

A. Bank Data			
BEHI/NBS Score	Bank Length (ft)	BEHI/NBS Score	Bank Length (ft)

Date:

# TN SQT and Debit Tool Rapid Assessment Form

Investigators:

Version 1.0 May 2019


B.	Dominant BEHI/NBS Score	
C.	Total Eroding Bank Length (ft)	
D.	Total Bank Length (ft)	
E.	Percent Streambank Erosion (%) Total Eroding Bank Length/ Total Bank Length	

## X. Riparian Vegetation

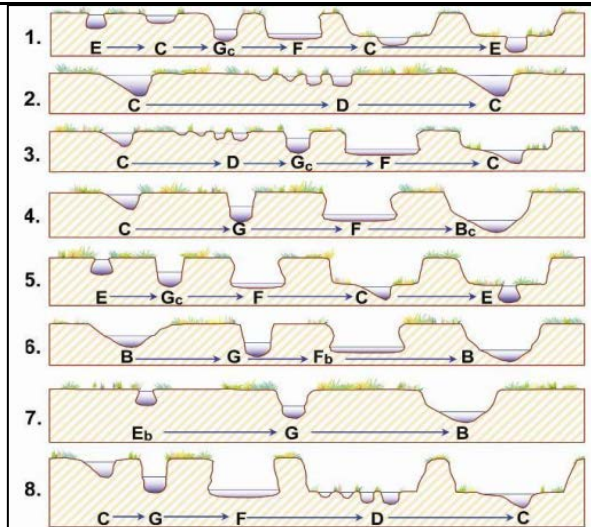
A.	Buffer Width	Buffer Width Measurements (ft)							Avg.
		1	2	3	4	5	6	7	
	Left (looking downstream)								
	Right (looking downstream)								

## XI. Sinuosity

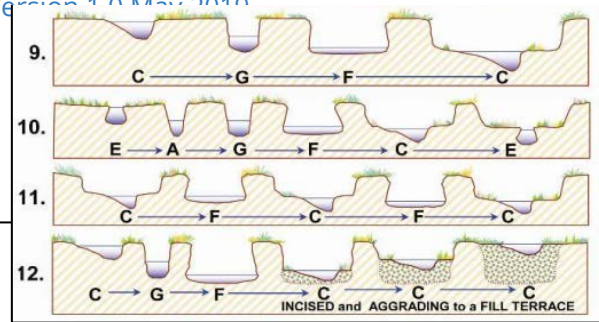
A.	Stream Length (ft)	
B.	Valley Length (ft)	
C.	Sinuosity	

## XII. Channel Evolution

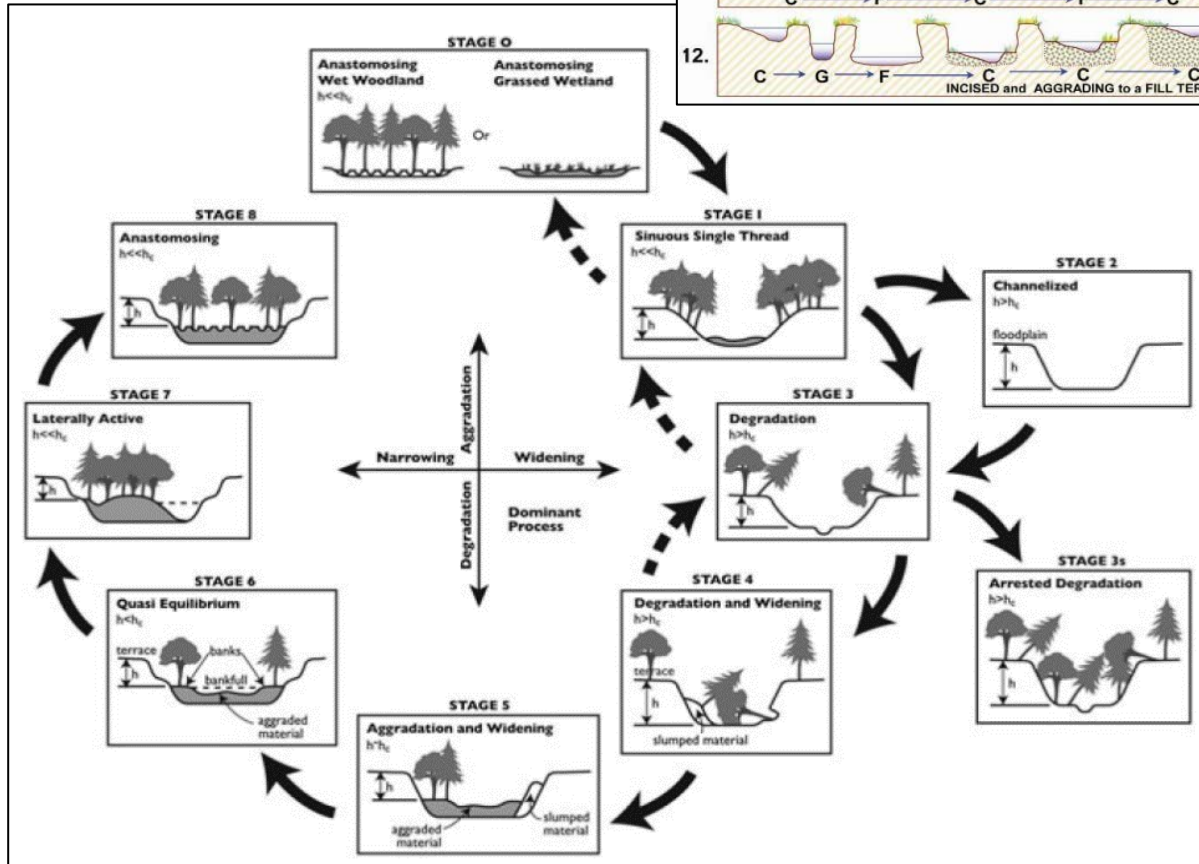
A.	Rosgen Channel Type Succession	
	Simon Channel Evolution Model (Stage)	



Rosgen Channel Type



Stream Evolution Model



1 Figure 7-48, *Watershed Assessment of River Stability and Sediment Supply (WARSSS)*, by David L. Rosgen, Wildland Hydrology, 2009, p. 7-175.  
 2 B. Cluer, C. Thorne. "A Stream Evolution Model Integrating Habitat and Ecosystem Benefits." *River Research and Applications*. 2013.



Date:  
Investigators:  
Project Name:

## TN SQT and Debit Tool Riparian Vegetation Rapid Plots

Plot ID	Native Cover		Saplings DBH (cm)		Trees DBH (cm)									Plot ID				
	Herbaceous Strata	Shrub Strata	0 - 1	1 - 2.5	2.5 - 5	5 - 10	10 - 15	15 - 25	20 - 25	25 - 30	30 - 35	35 - 40	≥40					
Latitude: Long:			Notes:															
Latitude: Long:			Notes:															
Latitude: Long:			Notes:															
Latitude: Long:			Notes:															

Strata	Height Range (ft)	Description
Herb	< 3.28	Can also include shrubs within height class
Shrub	3.28 - 16.4	Shrubs only, no tree saplings

Tally Method	= 1	= 2	= 3	= 4	= 5	= 6
	•	••	•••	••••	•••••	••••••
	┌┐	┌┐┌┐	┌┐┌┐┌┐	┌┐┌┐┌┐┌┐	┌┐┌┐┌┐┌┐┌┐	┌┐┌┐┌┐┌┐┌┐┌┐
	┌┐ = 7	┌┐ = 8	┌┐ = 9	┌┐ = 10	┌┐ = 11	┌┐ = 12, etc.

Note: Latitude and Longitude should be recorded for the point of origin (double circle) for each plot in decimal degrees

