APPENDIX A:

Field Data Collection Methods for the Minnesota Stream Quantification Tool and Debit Calculator

Version 1.0

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1. Introduction and Purpose

The purpose of this document is to provide a compendium of field methods that can be used to collect data for the Minnesota Stream Quantification Tool and Debit Calculator (MNSQT). Individuals collecting and analyzing these data should have experience and expertise in ecology, hydrology, and geomorphology. Interdisciplinary teams with a combination of these skill sets are beneficial to ensure consistent and accurate data collection and analysis. Field trainings in these methods and the Stream Functions Pyramid Framework are recommended to ensure that the methods are executed consistently.

This Appendix serves as a compliment to Chapter 2 of the User Manual, which provides information on how to select parameters, and calculate metric field values from field data. The MNSQT and Debit Calculator are not themselves assessment methods, but instead consolidate data and results from many methods and use them to calculate changes in stream condition and determine functional lift and loss. Methods are provided in this Appendix for reference and use in the field. Few measurements are unique to the MNSQT, and data collection procedures are often detailed in other instruction manuals or literature. Where appropriate, this appendix will reference the original methodology and explain differences in data collection or calculation methods needed for the MNSQT. This document is based on the Field Document Collection Methods for the Colorado SQT (CSQT) Beta Version (CSQT SC 2019 Appendix A) and has been edited for Minnesota with input from the Minnesota Stream Quantification Tool Steering Committee (MNSQT SC). The CSQT Beta Version user manuals served as the basis for the MNSQT Version 1.0 and many Chapters in this document are reproduced with minor edits from CSQT SC (2019) Appendix A.

A Parameter Selection Checklist and the data forms referenced in the relevant sections below are included in Appendix B. There is a shading key on some of the field forms that indicates which cells are intended to be filled out in the office versus the field, and which cells perform calculations. The calculation cells will automatically calculate values from provided field data in the workbook version. These cells can also be filled out on a printed field form. Prior to fieldwork, the user should complete the Parameter Selection Checklist, which will assist in determining the field methods and forms needed for data collection. Guidance on selecting appropriate parameters and metrics is provided in Chapter 2 of the User Manual. Several of the data forms are available as Microsoft Excel Workbooks where data can be entered upon returning from the field.[1] Other data processing tools, such as Mecklenberg (2004) and RIVER*Morph* software program (http://www.rivermorph.com) can be used to process field data and calculate metric values.

Note: One optional metric in the MNSQT requires data collection at a reference site *in addition* to data collection within the project area. For the bed material characterization metric, Bevenger and King (1995) provide a description of how to select and potentially combine reference reaches. For this metric, the reference reach should be located within the same stream and valley type, with a similar catchment area, gradient, and lithology. When possible, reference reaches should be located upstream of the project reach and upstream of the source of sediment imbalance.

[1] Microsoft Excel version of the field forms and the Mecklenburg (2004) Reference Reach Spreadsheet tool are available from the Stream Mechanics website: https://stream-mechanics.com/stream-functions-pyramid-framework/

At a minimum, the following field gear will be needed:

- Field forms and maps
- Waders
- Stadia rod
- Standard survey equipment or hand level/line level depending on selected method
- Metric ruler
- 100' tape (note: a tape with feet on one side and metric on the other is recommended)
- Enough 300' tapes for the assessment reach length (note: a tape with feet on one side and metric on the other is recommended)
- GPS unit (helpful with lateral migration and sinuosity field measurements)
- Calipers large enough to measure 50 cm diameter logs (helpful for the LWD assessment and DBH measurments)

For evaluating the following parameters and metrics, field methods are described briefly in this Appendix, however, users should be familiar with the following procedures and should review the following references prior to field sampling if that parameter will be assessed:

- Pebble Count:
    - River Stability Field Guide, Second Edition (Rosgen 2014)
    - A Pebble Count Procedure for Assessing Watershed Cumulative Effects (Bevenger and King 1995)
- Large Woody Debris Index:
    - Application of the Large Woody Debris Index: A Field User Manual Version 1 (Harman et al. 2017).
- Bank Erosion Hazard Index/Near Bank Stress:
    - Appendix D of Function-Based Rapid Field Stream Assessment Methodology (Starr et al. 2015), or
    - River Stability Field Guide, Second Edition (Rosgen 2014)
- Temperature:
    - Procedure for Temperature Logger Deployment at Stream Monitoring Sites (MPCA 2015)
    - Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b)Report and 303(d) List (MPCA 2018a)
    - Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component (MPCA 2018b)

  - Standard Operating Procedures, Water Quality Monitoring in Aquatic Invasive Species Infested Locations (MPCA 2018c)
  - Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams (USEPA 2014)

- Dissolved Oxygen:
  - Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b)Report and 303(d) List (MPCA 2018a)
  - Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component (MPCA 2018b)
  - Standard Operating Procedures, Water Quality Monitoring in Aquatic Invasive Species Infested Locations (MPCA 2018c)
- Total Suspended Solids:
  - Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b)Report and 303(d) List (MPCA 2018a)
  - Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component (MPCA 2018b)
  - Standard Operating Procedures, Water Quality Monitoring in Aquatic Invasive Species Infested Locations (MPCA 2018c)
  - Turbidity TMDL Protocols and Submittal Requirements (MPCA 2007)
- Macroinvertebrates:
  - Development of a Macroinvertebrate-Based Index of Biological Integrity for Minnesota's Rivers and Streams (MPCA 2014a)
  - Macroinvertebrate Data Collection Protocols for Lotic Waters in Minnesota (MPCA 2017a)
  - Standard Operating Procedures, Water Quality Monitoring in Aquatic Invasive Species Infested Locations (MPCA 2018c)
- Fish:
  - Development of a Fish-Based Index of Biological Integrity for Minnesota's Rivers and Streams (MPCA 2014b)
  - Fish Data Collection Protocols for Lotic Waters in Minnesota (MPCA 2017b)
  - Standard Operating Procedures, Water Quality Monitoring in Aquatic Invasive Species Infested Locations (MPCA 2018c)
  - Standard Methods for Sampling North American Freshwater Fishes (Bonar et al. 2009)

2. Reach and Representative Sub-Reach Assessments

Prior to field work, the user must determine whether the project area should be delineated into multiple project reaches (see Section 2.1 of the User Manual). The following sequence of steps is recommended for all evaluations. Based on parameter selection (Section 2.3 of the User Manual), not all steps will need to be completed for all projects. The Parameter Selection Checklist can be used to indicate which parameters are included within the field evaluation.

Additionally, before going in the field check any sampling windows or index periods for field data collection. The procedure below outlines a comprehensive assessment of most metrics in the MNSQT that can be completed in a single day or visit, but multiple days or visits may be required, depending on the metrics selected for analysis.

Procedure:

1. Conduct necessary pre-field desktop activities (see Chapter 2 of the User Manual). Complete the Parameter Selection Checklist and the Site Information section of the Project Reach form. All values in these sections should be filled in prior to completing fieldwork.
2. Walk along the stream throughout the project area to verify the delineation of project reaches. Determine whether additional segmentation is needed based on field conditions. Record the GPS location at the downstream end of the reach in Section I of the Project Reach form.
3. Within each project reach, walk along the stream length to view the locations and character of riffles, presence of beaver dams or other impoundments, and bankfull indicators.
    a. Measure difference between bankfull stage and water surface elevation at multiple points along the project reach (See Bankfull Elevation – Field Identification section on page A-7). These data can be recorded in the Project Reach form. Use these data to come to a consensus on the difference between the bankfull (BKF) elevation and water surface (WS) elevation and record the value in Section II of the Project Reach form.
    b. Consider possible locations for the representative riffle cross section (see Representative Riffle Survey on page A-10). The preference is for the riffle to be located within the representative sub-reach. However, in disturbed settings, this cross section may be located upstream or downstream of the sub-reach.
    c. Record number of concentrated flow points and length of any armored sections of bank in Section II of the Project Reach form (see Concentrated Flow Points and Armoring sections below).
    d. Measure slope and sinuosity for stream classification purposes (See Rosgen Stream Classification).
4. If the project reach is long, determine the location of the representative sub-reach. The sub-reach is at least two meander cycles or 20 bankfull widths in length, whichever is longer. The sub-reach should be representative of the typical bed form diversity in the project reach and should include the stretch of channel with the greatest amount of large woody debris.
5. Record the GPS location at the downstream end of the representative sub-reach in Section III of the Project Reach form.

6. Select the location within the sub-reach for biological sampling (if applicable). Refer to *Macroinvertebrate Data Collection Protocols for Lotic Waters in Minnesota* (MPCA 2017b) and *Fish Data Collection Protocols for Lotic Waters in Minnesota* (MPCA 2017a) for information on selecting a sample location.
7. Sample macroinvertebrates (see Macroinvertebrate Sampling in Section 9). Processed samples should be immediately preserved in sample containers with a final alcohol concentration of at least 70% and stored in a cool, shaded area for the remainder of data collection.
8. Sample fish (see Fish Sampling in Section 9). All fish that are alive after processing should be immediately returned to the stream. Considerable effort should be expended to minimize handling mortality, such as using a live well, quickly sorting fish into numerous wet containers, and replacing their water supply.
9. Survey the representative riffle cross section (see Representative Riffle Survey methods below). If located within the sub-reach, the same riffle used for biological sampling may be used for the cross section survey, or an alternative representative riffle can be selected. If the same riffle is used, locate the cross section in a portion of the riffle not substantially disturbed from biological sampling. Locate bankfull indicators using the Bankfull Elevation - Field Identification methods.
10. Conduct the Longitudinal Profile (see Section 3) or Rapid Survey (Section 4) for bed form diversity and floodplain connectivity data.
    a. Where a longitudinal profile is performed, additional cross section surveys may be required to quantify the entrenchment ratio.
11. Conduct a large woody debris assessment (Section 5), lateral migration evaluations (Section 6), pebble counts, and riparian vegetation survey (Section 7), as applicable based on parameter selection.
12. Install temperature sensors and dissolved oxygen sensors (Section 8) as applicable based on parameter selection and complete the Temperature Logger and Sensor Log form, respectively.

Concentrated Flow Points

This metric assesses the number of concentrated flow points caused by anthropogenic impacts that enter the project reach and is normalized per 1,000 linear feet of stream. Anthropogenic causes of concentrated flow include agricultural drainage ditches, impervious surfaces, storm drains, land clearing, and others.

Procedure:

1. During the initial reach walk, any observed concentrated flow points should be tallied and recorded on the Project Reach form. The reach walk should extend along the entire project reach and include both sides of the stream channel.

- Field calculation: The number of concentrated flow points is normalized to a count per 1,000 linear feet of stream. Divide the count by the reach length provided in Section 1 of the form and multiply the result by 1,000 linear feet. Space is provided for this calculation in Section II.B of the form; the workbook version of the form will automatically calculate this value.

Percent Armoring

Percent armoring is a metric that must be assessed on reaches where armoring is present or proposed. If armoring is not present or proposed this metric is not assessed. Examples of armoring include rip rap, gabion baskets, concrete, and other engineered materials that prevent streams from meandering and are located within the channel banks. Typically, toe wood with transplants or bioengineering is not counted as armoring. However, if toe wood or stone-toe used for bioengineering extends from the bed to more than one-third the bank height, it is counted as armoring. Engineered log jams that are mechanically anchored to the bed/banks and extend to the top of the streambank are considered armoring. Armoring should be measured along the entire project reach and include both sides of the stream channel.

Procedure:

1. During the initial reach walk, measure and record the length of each bank that is armored and record that length on the Project Reach form. The reach walk should extend along the entire project reach and include both sides of the stream channel.

Bankfull Elevation – Field Identification

Multiple parameters in the MNSQT require bankfull dimensions to calculate metrics, including floodplain connectivity, large woody debris, lateral migration, and bed form diversity. Bankfull dimensions are also needed to determine the Rosgen stream type. Prior to making field measurements for these parameters and determining stream type, the user should identify and verify the bankfull stage and associated dimensions. Methods to establish and verify bankfull elevation in the field can be found in the *Fisheries Stream Survey Manual* (MN DNR 2007) and the Bankfull Elevation – Field Identification section of the *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ/WQD 2018). The text from the WDEQ/WQD manual (2018) is duplicated here with minor modifications; photographs from the original reference are not included.

Quality Control: Appropriate use of bankfull elevation indicators requires adherence to the following principles which can also serve as quality control for this method:

1. Seek indicators appropriate for specific Rosgen stream types.
2. Know the recent flood and drought history of the area to avoid being misled by spurious indicators. This includes conducting site reconnaissance during bankfull discharge events.
3. Use multiple indicators wherever possible as reinforcement of a common stage or elevation.
4. Exercise caution when identifying bankfull elevation in reaches of the stream that are subject to frequent inundation caused by beaver dams, diversion structures, etc.
5. Bankfull elevation above and below hydrologic anomalies that influence the entire active channel such as natural controls (boulders, bedrock), headcuts, dams, and similar features

will likely be different. These breaks in bankfull elevation should be accounted for at all site visits.

6. Except in cases noted above, bankfull indicators should be at a consistent elevation relative to the water surface along an individual stream reach.
7. Reachwide bankfull slope should be similar to the reachwide water surface slope, assuming both variables were measured on the same day and rapid aggradation or degradation is not occurring. This can be determined from the longitudinal profile and difference in measurements between the bankfull indicator and water surface.
8. Bankfull indicators along pools, particularly along the outside of meander bends, may be at a higher elevation than indicators at riffles. However, there should still be consistency in elevation of bankfull indicators along the entire reach. The flat surface along the top of a point bar is often a good bankfull indicator. Point bars are depositional features found along the inside of a meander bend.
9. Where possible, calibrate field-determined bankfull stage elevation and corresponding bankfull channel dimensions to known recurrence interval discharges (refer to Section 2.6.c in Chapter 2 of the User Manual) and/or with applicable regional curves. In using regional curves to verify bankfull, the bankfull area is typically used for the comparison. Lines E, F, and G of Section III of the Project Reach form should be populated with the bankfull area, width, and mean depth as calculated from these resources before going out in the field.
10. Persistent long-term drought conditions may create a false “bankfull” elevation that does not correspond to the actual bankfull elevation under the current climatic regime. See step 9.

Introduction: Bankfull discharge is a frequently occurring peak flow whose corresponding stage or elevation often represents the incipient point of flooding associated with a return period of 1-2 years. Bankfull elevation (and its associated discharge) serves as a consistent reference point which can be related to the formation, maintenance, and dimensions of the channel as it exists under the current climatic regime. Bankfull elevation often represents the break point between processes of channel and floodplain formation. Correctly identifying bankfull elevation is crucial and serves as the foundation for all subsequent geomorphic methods used in the determination of channel classification, dimension, pattern, and profile.

Bankfull discharge can occur at any time during the year. Because site visits are often not conducted during a bankfull event, bankfull indicators must be relied on to correctly identify bankfull elevation. There are several bankfull indicators though no one indicator is suitable in all circumstances. Use the following common bankfull indicators to identify bankfull elevation, many of which have been adapted from Rosgen (2008). In all cases, multiple bankfull indicators should be used to identify bankfull elevation. Primary indicators should always be sought out at the site; secondary indicators should be used only as supplemental information to support primary indicators as described in the *Fisheries Stream Survey Manual* (MN DNR 2007) or the *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ/WQD 2018).

Primary Indicators:

1. Floodplains – Bankfull elevation is often associated with the point at which water begins to spread out onto the floodplain. This may or may not be the top of the bank. This is one of

the best indicators of bankfull elevation for use on Rosgen C, D, DA and E stream types which often have well-developed floodplains. Floodplain indicators do not apply to entrenched Rosgen A, F and G stream types which generally do not have floodplains. Moderately entrenched streams (B stream types) have bankfull or floodplain benches. Most streams in alluvial/colluvial valleys have three distinct terraces. Do not confuse the low terrace with the floodplain, which may be close in elevation. The low terrace is an abandoned floodplain often characterized by upland or a mixture of upland and facultative riparian vegetation.

2. Breaks in Slope – A change in slope from a near vertical bank to a more horizontal bank is often the best indicator of the incipient point of flooding, or the transition from the bankfull channel to a floodplain. Such changes in slope often correspond to the “bankfull bench”. However, streams that have undergone physical alterations in the past or are actively degrading or aggrading can have multiple slope breaks that represent abandoned floodplains or terraces, rather than the bankfull elevation. For incised channels with near vertical banks, the first substantial break in slope (example: transitioning from 90° to 45°) at the bottom of the near vertical bank can be the bankfull elevation.
3. Scour Lines – A scour line at a consistent elevation along a reach that lies below an intact soil layer can represent bankfull elevation. Scour lines may or may not have exposed root hairs.
4. Undercuts – On bank sections where the perennial vegetation forms a dense root mat, the upper extent or top of the undercut is normally slightly below bankfull elevation. Undercuts are best used as indicators in channels lacking obvious floodplains.
5. Depositional Features – The elevation on top of the highest depositional feature (point bar or mid-channel bar) within the active channel is often associated with the bankfull elevation. However, in streams that have experienced recent record flood events, the tops of the highest depositional features may be above bankfull elevation. In streams that are rapidly degrading (downcutting), the tops of the highest depositional features may also be above the bankfull elevation.
6. Particle Size Demarcation – The point at which there is a distinct change in particle size of the active channel bed at a consistent elevation along a reach is often associated with bankfull elevation. Changes in particle size can be from coarse to fine or from fine to coarse and may also correspond to a break in slope or the top of a depositional feature.

Secondary Indicators:

1. Vegetation - Using vegetation to identify bankfull elevation must be done cautiously. When vegetation is used as a sole indicator, bankfull is frequently underestimated. Riparian species common for each ecological province can be used as supplemental indicators of bankfull elevation in Minnesota streams. Generally, bankfull elevation is located at or just under the base of riparian vegetation often associated with a scour line. Saplings of species such as willow (*Salix* sp.) and cottonwood (*Populus* sp.) should not be used as indicators as they can colonize within the bankfull channel. Mature woody species are generally found above the bankfull elevation and should not be used. Vegetation generally is not an appropriate indicator in streams where active degradation such as bank sloughing is occurring.

2. Lichens or Mosses – A noticeable change in color, pattern and/or species of lichens or mosses on boulders or bedrock at a consistent elevation along a reach may represent bankfull elevation.
3. Debris Lines - The top of a debris line consisting of leaf and woody litter, dead algae, fecal material, trash or other floating debris at a consistent elevation along a reach may represent bankfull elevation. However, do not confuse debris deposited by flow events larger than bankfull to represent bankfull elevation.

Procedure:

1. Determine whether hydrologic anomalies such as natural controls (boulders, bedrock), headcuts, dams, and similar features exist in the reach and account for their influence on bankfull elevation accordingly.
2. Using the bankfull indicators described above, walk the entire length of the reach, multiple times if needed, and identify primary and secondary bankfull indicators where applicable. Care should be taken to use only the best bankfull indicators that provide the strongest evidence of bankfull elevation.
3. Mark the locations of both primary and secondary bankfull indicators with pin flags.
4. Use a pocket rod or stadia rod to measure the distance from the current water surface to the estimated bankfull elevation at each of the best bankfull indicators. Bankfull indicators should follow a generally consistent elevation relative to the water surface throughout the reach. As such, distances from the current water surface to the estimated bankfull elevation should be similar among all measurements. Outlying distances will be evident and should be removed or revisited and verified.
5. Use a weighted (primary indicators have greater weight than secondary indicators) average distance between water surface and bankfull elevation as a reference point when conducting subsequent geomorphic survey procedures such as cross sections and longitudinal profiles on the same day the average value was measured.
6. If desired for future reference, photo document the location of the bankfull elevation using the pin flags as reference points, making sure the entire bankfull channel is visible in the photograph. If a measurement tape has been stretched longitudinally along the entire reach, record the distance along the tape where the bankfull indicator in the photograph is located.

Representative Riffle Survey

A representative riffle should be surveyed to calculate the bankfull dimensions of area, width, and mean depth and to determine the Rosgen Stream Classification type (see following section). Bankfull dimensions from the representative riffle should be compared to estimated bankfull dimensions from other references such as return interval analysis or bankfull regional curves to verify the bankfull indicator (see Bankfull Elevation – Field Identification, Quality Control section above). The bankfull width and mean depth from the representative riffle survey are used to calculate pool spacing and pool depth ratios. These are the primary reasons for surveying the representative riffle and the selection of the representative riffle should keep these objectives in mind.

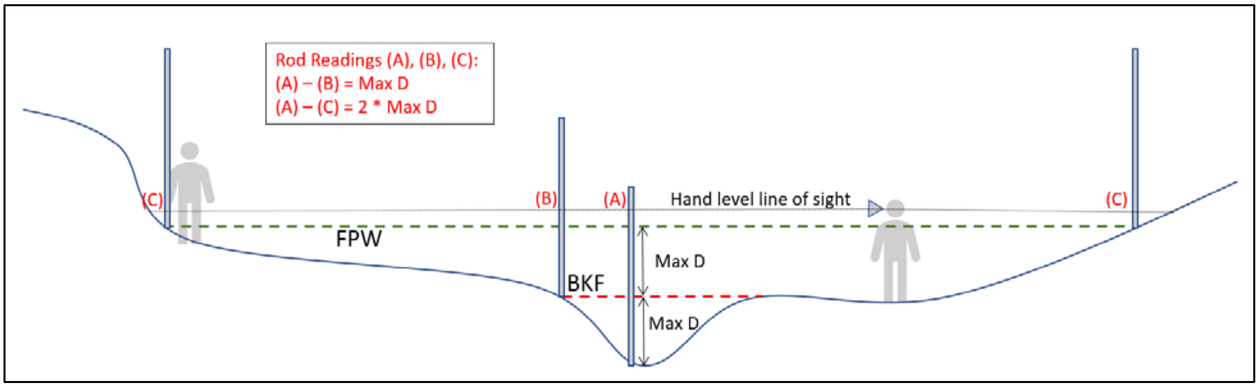
Two representative riffle cross sections may be required in severely degraded systems where the first cross section is a different stream type than the assessment reach. In this case, the two cross sections should be measured following the procedures below. The first is used for bankfull verification and to calculate dimensionless ratios for the bed form diversity parameter. The second riffle is measured within the assessment reach to characterize the existing Rosgen stream type[2].

The representative riffle survey can be completed with either standard survey equipment or a stadia rod and level tape for rapid surveys. Methods to set up and measure the representative riffle cross section using standard surveying equipment are derived from the *Fisheries Stream Survey Manual* (MN DNR 2007) or Channel Cross Section Survey methods outlined in the *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ/WQD 2018). Text from the WDEQ/WQD (2018) manual is duplicated here with minor modifications; information on quality control and photographs from the original reference are not included. A rapid method using a tape and stadia rod follow.

Note: The flood prone width should be recorded for all riffle cross sections and measured perpendicular to the fall line of the valley. Entrenchment ratio is a metric in the MNSQT for the floodplain connectivity parameter and is necessary to determine the stream type. Independent of whether the representative riffle is surveyed following the WDEQ/WQD procedure, rapid survey methods, or Minnesota state specific stream data collection protocols, the cross section flood prone width is required. This means that either the cross section should extend far enough into the floodplain to capture the flood prone width OR the distance from the channel bank to the elevation that is twice the max bankfull depth should be recorded for each side of the channel. Where it is not feasible to survey the entire flood prone width, the cross section should span a width that is at least 3 times the width of the channel. Figure A.1 demonstrates how to measure the flood prone width with a hand level.

Figure A.1. Surveying Flood Prone Width

[2] The second riffle can also be used to characterize reach conditions for the return interval, average depth, and average velocity metrics if applicable. Additional cross sections may be necessary, refer to the User Manual instructions for these metrics.



Procedure (WDEQ/WQD 2018):

Identify the riffle within the project area that will be used as the representative riffle. Where possible, the representative riffle should be located within the representative sub-reach. However, in a highly degraded reach, a stable riffle cross section from an adjoining upstream or downstream sub-reach may be used.

1. Following the procedure in Bankfull Elevation–Field Identification, identify bankfull elevation in the reach.

2. Determine the location of the cross section within the representative riffle. Cross sections should not be placed over riffles or other features that have been substantially disturbed by biological sampling, animal or human activity or similar causes. Avoid placement of the cross section at the top or bottom of a riffle feature. In streams with active physical degradation and/or aggradation, features may migrate longitudinally within the reach from one year to another. Place the cross section across the mid-point of the feature to increase the likelihood that the facet type you measure will be the same type you measure in subsequent years. Make sure that the cross section is perpendicular to the direction of flow at bankfull. Where possible, cross section endpoints should be located above the bankfull elevation and preferably above the flood prone elevation (twice the maximum bankfull depth, see Figure A.1).

3. If possible, establish permanent markers at the cross section endpoint locations by driving rebar vertically in the ground. Attach either plastic or metal end caps on the tops of rebar for identification. This step is only needed if repeat surveys are anticipated.

4. Stretch the measurement tape or tag line (tape) across the channel with zero always beginning on the left bank as you are facing downstream. The zero mark on the tape should be placed over the left cross section endpoint. The tape can be secured to the ground with range pins. Make sure to stretch and secure the tape tight between both endpoints; sagging tapes are unacceptable. During windy conditions, flagging ribbon can be attached at regular intervals on the cross section tape to minimize tape “waving”.

5. Record the station ID of the cross section using the tape stretched along the length of the representative sub-reach (see Longitudinal Profile and Rapid Bed Form Survey Method) and sketch the cross section location as part of the site map with associated landmarks. Document as much information as possible about the cross section location on the datasheet so it can be relocated for future surveys or site visits.

6. Starting with the top of the left endpoint at 0, begin the cross section survey. Proceed with rod readings at breaks in slope; record important features such as terraces, top of bank, low bank, bankfull, edge of water, inner berm, and thalweg. If undercuts are present, use a combination of the stadia rod and pocket rod to accurately characterize the undercut. Otherwise, take survey readings at regular intervals of generally one to five feet, with wider intervals used for wider channels. Record any features along the cross section tape in the notes section of the datasheet. Complete the survey by taking rod readings at the right endpoint. Record all features on the datasheet next to their corresponding rod readings.

Rapid Cross Section Survey Procedure:

1. Follow steps 1-3 in the above procedure.
2. Stretch 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 Project Reach form as the control.
3. Record the bankfull width. Space is provided on the Project Reach form.
4. 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.
5. Working from left to right, record the station from the tape and the depth from the tape to the ground using a stadia rod. Include bankfull, major breaks in slope, the thalweg, and other points along the channel bottom. Record this data on the Project Reach form.
6. Space is provided on the Project Field form to calculate the bankfull mean depth and area. These calculations are automatically performed in the Microsoft Excel Workbook version of the Project Reach form. A rough estimate of the mean depth can be calculated by adding all the depth measurements (except for zeros at bankfull) and dividing by the number of observations.
7. Compare the bankfull width, mean depth, and area to the regional curve values on the field form.
8. Measure the flood prone width on either side of the bankfull channel as shown in Figure A.1. The flood prone width should be measured perpendicular to the fall line of the valley.

Rosgen Stream Classification

The MNSQT requires that the existing stream type be determined according to the Rosgen classification system (Rosgen 1996). Stream classification is based on entrenchment ratio, width depth ratio, sinuosity, slope, and channel material. Section V of the Project Reach form provides space to collect these data based on measurements from the sub-reach assessment.

Methods to determine Rosgen Stream Classification are derived from the Rosgen Stream Classification section in the *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ/WQD 2018). The text below is modified from this reference. This section is included in the field data collection methods to ensure that sufficient data are collected to classify the existing stream type. As shown in the procedures below, determining the stream type is based on values derived from data collected as described elsewhere in this appendix. As such, determining the stream type can be done in the office after the data are collected and processed.

Field Measurements:

1. Entrenchment Ratio (ER): Unitless measure of flood prone area width (Wfpa) divided by bankfull width (Wbkf).
    a. Values are measured or calculated from the Representative Riffle Survey.
2. Width to Depth Ratio (Wbkf / dbkf): Unitless measure of bankfull width (Wbkf) divided by bankfull mean depth (dbkf).
    a. Values are measured or calculated from the Representative Riffle Survey.
3. Channel Sinuosity. Unitless measure of channel length divided by valley length.
4. Channel Materials (Particle Size Index) (D50): Perform a pebble count procedure following guidance in Rosgen (2014) or Harrelson et al. (1994). For the rapid assessment, a visual inspection is sufficient for determining the bed material category (e.g. gravel, sand) if the determination is only used for stream classification purposes. However, experience performing quantitative grain-size distributions is required in order to make accurate estimates.
5. Water Surface Slope (S): Measure of water surface slope from the top of a riffle to the top of another riffle at least twenty bankfull widths in length. This measurement is a surrogate for the water surface slope at bankfull stage. Measure in ft/ft.
    a. See Longitudinal Profile and Rapid Survey Methods.
    b. Note if baseflow is not present, the bottom of the channel should be used. However, care must be taken to not create large elevation changes due to localized scour or fill. One method to avoid localized scour or fill is to use the edge of channel rather than the thalweg. In both cases (with and without baseflow), the measurements should be made at the top of a feature, e.g. the top or beginning of a riffle.

3. Longitudinal Profile

This method will provide data to inform the floodplain connectivity and bed form diversity parameters within the MNSQT. Additionally, data from the longitudinal profile can be used to calculate average reach slope.

There are two methods that can be used to collect bed form diversity and floodplain connectivity data for the MNSQT, the Longitudinal Profile (described in this section) and the Rapid Survey (described in Section 4). For CWA Section 404 or RHA Section 10 projects, it is recommended the user coordinate with the Corps and other state or local regulatory authorities prior to selecting between these methods. The rapid survey techniques for collecting the bed form diversity and floodplain connectivity data are considered more rapid than surveying the longitudinal profile and require little post-processing of the field data.

Field forms for the longitudinal profile include the Longitudinal Profile form and the Cross Section form and are provided in Appendix B. Data collected using these forms will require post-processing to calculate MNSQT metric field values for pool spacing ratio, pool depth ratio, percent riffle, and bank height ratio. Data analysis should follow the methods described in Chapter 2 of the User Manual. The Reference Reach Spreadsheet version 4.3 developed by Dan Mecklenburg with the Ohio Department of Natural Resources (DNR) is a free, user-friendly tool for entering survey and pebble count data and can be used to calculate these metrics.[3] The RIVER*Morph* software program (http://www.rivermorph.com) can also be used to calculate these metrics. Users should provide the raw survey data, longitudinal profile plots at legible scales, and bed form identification callouts that indicate where measurements were taken to calculate field values.

Quality Control: Following the process described in Harrelson et al. (1994), no longitudinal profile is complete without checking the accuracy of the survey with a survey closure. To close the survey, take a foresight reading at the benchmark, compute the elevation, and compare the difference to the original benchmark elevation at the start of the survey. Typically, a closure of no more than 0.05 feet is acceptable when conducting stream surveys. The survey closure error shall be documented on the longitudinal profile datasheet.

Introduction: The longitudinal profile documents the existing water surface, bankfull, low bank, terrace, and thalweg elevations of a stream reach. Longitudinal profile data is used to calculate average bankfull and water surface slopes of a reach, along with maximum, minimum, and average slopes of features such as riffles, runs, pools, and glides (also known as facet slopes). Maximum, minimum, and average bankfull depths and spacing measures are obtained from longitudinal profile data. These data are useful in geomorphic assessments of streambed stability and sediment supply and may be useful for design objectives. Longitudinal profiles require basic surveying skills and equipment. Survey basics such as establishing benchmarks, foresights, positioning the level, turning points, and others are not covered here. For more information on survey basics consult Harrelson et al. (1994).

[3] The spreadsheet is no longer available from the DNR web page, but is available at https://stream-mechanics.com/resources/under spreadsheet tools.

Procedure:

1. Establish a representative sub-reach within the project reach, generally at least two meander cycles or 20 bankfull widths in length. The sub-reach should be representative of the typical bed form diversity in the project reach and should include the stretch of channel with the greatest amount of large woody debris.
2. Beginning at the upstream end of the sub-reach, stretch the tapes along either the left or right bank as close to the edge of the channel as possible and should be threaded through riparian vegetation or other obstructions if necessary. Tape(s) can be secured to the ground with survey pins, vegetation, or rocks. Stationing of features will be obtained from the tape.
3. If desired, establish permanent markers at the beginning and end of the longitudinal profile tape by driving rebar vertically in the ground. Attach either plastic or metal end caps on top of the rebar for identification.
4. The position of the longitudinal profile tape should be included on the site map along with associated landmarks, stream channel cross sections, and other relevant features. If desired, triangulate the top and bottom of the longitudinal profile between the benchmark and another permanent feature and record on the datasheet. GPS locations of the top and bottom of the longitudinal profile can be used in place of triangulation. Document as much information as possible about the longitudinal profile tape location on the datasheet so it can be relocated for future surveys.
5. Follow the procedure in Bankfull Elevation – Field Identification section above to identify bankfull elevation in the reach.
6. Follow the process described by Harrelson et al. (1994) to establish a benchmark and height-of-instrument.
7. Begin the longitudinal profile survey at station 0 on the longitudinal profile tape. Record (at a minimum) rod readings of water surface, thalweg and low bank. Only take rod readings of bankfull where indicators are present. Record the quality of the bankfull indicator(s) (good, fair, etc.) and the type of feature in the notes column of the datasheet.
8. Continue the survey, working in a downstream direction. Collect readings at the top and mid-point of each riffle, run, and glide feature along with any other major bed features (dams, weirs, etc.). For pools, take a reading at the top and maximum depth location and note whether the pool is a geomorphic pool (refer to Pool Identification below). For streams with long features or a homogeneous bed, take rod readings at regular intervals, generally spaced no more than one to three bankfull widths.
9. Note the stationing of all cross section locations (if present) on the longitudinal profile tape and record on the datasheet. Take rod readings at the tops of all cross section endpoints located along the bank with the longitudinal profile tape and record on the datasheet.
10. Close the survey according to the process described in the Longitudinal Profile Quality Control section of this document.

Pool Identification

Geomorphic pools are a term used in the Stream Quantification Tool to differentiate between major and minor pools. Geomorphic pools are associated with planform features that create large pools and patterns that remain intact over many years and flow conditions. Examples include pools associated with the outside of a meander bend and downstream of a large cascade or step. These pools are included in the pool spacing ratio metric. Micro pools within riffles are small, typically between one-third and half the width of the channel and may not last for a long period of time or after a large flow event. An example is a scour pool downstream of a single piece of large woody debris. These pools are not included in the pool spacing ratio metric.

If a pool is not associated with a meander bend or cascade/step, it should still meet the following criteria: the pool must be deeper than the riffle, have a concave bed surface, have a water surface slope that is flatter than the riffle, and a width that is at least one-third the width of the channel.

Cross Section Surveys

Data should be collected from cross sections at multiple riffles within the representative sub-reach to inform MNSQT metric field values. A Cross Section form is provided in Appendix B to collect these data. Data collected using these forms will require post-processing to calculate MNSQT metric field values. Cross sections should be collected following the procedures described in the Representative Riffle Survey section above. The detailed (surveyed) or rapid cross section survey method, or a combination of the two, can be used based on best professional judgement.

- For the entrenchment ratio, it is recommended that the entrenchment ratio be measured at each riffle unless the valley width is consistent throughout the representative sub-reach. If the width of the valley is uniform, then one entrenchment ratio value can be used to represent the project reach. The flood prone width should be measured perpendicular to the fall line of the valley.
- For the aggradation ratio, it is recommended to measure this metric at multiple riffle cross-sections with aggradation features to ensure that the widest value for the sub-reach is obtained and to document the extent of aggradation throughout the project reach. Visual indicators of aggradation include mid-channel bars and bank erosion within riffle sections.

Users should provide the raw survey data, cross section plots at legible scales, and callouts for feature that indicate where measurements were taken to calculate field values.

4. Rapid Survey

This section outlines rapid survey methods to collect data to inform floodplain connectivity and bed form diversity parameters. There are two methods that can be used to collect bed form diversity and floodplain connectivity data for the MNSQT, the Longitudinal Profile (described in Section 3) and the Rapid Survey (described in this section). For CWA Section 404 or RHA Section 10 projects, it is recommended the user coordinate with the Corps and other state or local regulatory authorities prior to selecting between these methods. The rapid survey techniques for collecting the bed form diversity and floodplain connectivity data are considered more rapid than surveying the longitudinal profile and require little post-processing of the field data.

The Rapid Survey form is provided in Appendix B. There is a shading key on the field form that indicates which cells are intended to be filled out in the office versus the field, and which sections are for performing field calculations. The calculation cells can be filled out on a printed field form. In the workbook version, these cells will automatically calculate values from provided field data. Field values that can be entered directly into the Quantification Tool worksheet from this field form are bolded. These include: weighted BHR, weighted ER, maximum WDR, percent riffle, average pool depth ratio, and median pool spacing ratio.

Procedure:

1. Establish a representative sub-reach within the project reach, generally at least two meander cycles or 20 bankfull widths in length, whichever is longer. The sub-reach should be representative of the typical bed form diversity in the project reach and should include the stretch of channel with the greatest amount of large woody debris.
2. Beginning at the upstream end of the sub-reach, stretch tapes along either the left or right bank as close to the edge of the channel as possible, and should be threaded through riparian vegetation or other obstructions if necessary. Tape(s) can be secured to the ground with survey pins, vegetation, or rocks. Stationing of features will be obtained from the tape. Begin and end the representative sub-reach at the head of a riffle feature.
3. Record sub-reach length in Rapid Survey form.
4. Measure the slope of the sub-reach (see Reach Slope section below).
5. Working from upstream to downstream, take measurements at every riffle and pool within the sub-reach using a stadia rod and a hand level. A line level can be used instead of a hand level for small streams. Note: Review pool identification instructions provided below and in Section 2.6.d of the User Manual.
    a. Measure the following at every riffle within the sub-reach and record values in the Rapid Survey form. These data are used to calculate the bank height ratio, entrenchment ratio, aggradation ratio, and percent riffle metrics.
        i. Measure the length of the riffle, including runs, if present. Riffle length is measured by taking a station reading from the tape at the head (beginning) of the riffle and another station reading downstream at the head of the pool.

Field calculation: Percent riffle can be calculated by adding the length of all riffles within the sub-reach (total riffle length) and dividing by the total sub-reach length. Total riffle length is also used to calculate weighted entrenchment ratio and weighted bank height ratio below.

ii. Identify the middle of the riffle feature and bankfull elevation (see Bankfull Elevation – Field Identification section above).

iii. From mid-riffle, measure the difference in stadia rod readings from the thalweg to the top of the lower of the two streambanks. Record this value as the Low Bank Height on the rapid survey form. The low bank height is the lower of the left and right streambanks, indicating the minimum water depth necessary to inundate the floodplain.

iv. From mid-riffle, measure the difference in stadia rod readings from the thalweg to the bankfull indicator, and record this value as the bankfull maximum depth on the Rapid Survey form. Alternatively, measure the difference in stadia rod readings from the thalweg to the water surface then add the value recorded for the difference between bankfull stage and water surface (Section II on the Project Reach form).

Field calculation: bank height ratio can be calculated by dividing the low bank height by the bankfull maximum depth. Space is also provided to calculate the weighted bank height ratio: multiply the bank height ratio by the riffle length at each riffle and divide by the total length for the sub-reach.

v. From mid-riffle, measure the bankfull width and record this on the form.

vi. For sub-reaches with changes in valley width or a bank height ratio greater than 1.8, flood prone width should also be measured at each riffle. At mid-riffle, locate and flag the point along the cross section in the floodplain where the difference in stadia rod readings between the thalweg and that point is twice that of the bankfull maximum depth (see Figure A.1 for illustration). Record flood prone width on the rapid survey form.

Field calculation: entrenchment ratio can be calculated by dividing the flood prone width by the bankfull maximum depth. Space is also provided to calculate the weighted entrenchment ratio: multiply the entrenchment ratio by the riffle length at each riffle and divide by the total riffle length for the sub-reach.

vii. If evaluating the aggradation ratio, at the widest riffle in the sub-reach (or any riffle with aggradation features) the bankfull mean depth should also be measured and recorded. Visual indicators of aggradation include mid-channel bars and bank erosion within riffle sections. At candidate riffle features, estimate the mean depth as the difference between the edge of channel and the bankfull stage. This is measured by placing a stadia rod at the edge of channel, which is the breakpoint between the streambed and streambank. Measure the stadia rod height at the bankfull elevation and record as the mean depth. Note: It is recommended to collect data from multiple riffle cross sections with aggradation features to ensure that the widest value for the sub-reach is obtained and to document the extent of aggradation throughout the project reach.

Field calculation: width depth ratio can be calculated by dividing bankfull width by bankfull mean depth. The largest width depth ratio within the sub-reach is considered the maximum width depth ratio.

b. Measure the following at every pool within the sub-reach and record values in the Rapid Survey form. These data are used to calculate the pool spacing and pool depth ratio metrics.

   i. Determine the deepest point of the pool and record the station number from the tape on the form.

   Field calculation: The pool spacing ratio can be calculated by determining the distance between each pair of pools and dividing this distance by the bankfull riffle width (from Section IV of the Project Reach form). Space is provided to record the median pool spacing ratio on the Rapid Survey form.

   ii. Measure the maximum bankfull pool depth by placing the stadia rod at the deepest point in the pool and recording the depth to bankfull elevation. Alternatively, measure the difference in stadia rod readings from the deepest point in the pool to the water surface and then add the value recorded for the difference between bankfull stage and water surface recorded in Section II of the Project Reach form.

   Field calculation: The pool depth ratio can be calculated by dividing the bankfull pool depth by the mean bankfull riffle depth (from Section IV of the Project Reach form). Space is provided to record the average pool depth ratio on the Rapid Survey form.

Pool Identification

Pool-to-pool spacing is an indirect measure of how many geomorphic pools are present within a given reach and 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 include pools associated with the outside of a meander bend and downstream of a large cascade or step. Micro pools within riffles are small, typically between one-third and half the width of the channel and may not last for a long period of time or after a large flow event. An example is a scour pool downstream of a single piece of large woody debris.

For the pool depth ratio and percent riffle metrics, 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 (ex. meander bend or cascade/step), it should still meet the following criteria: the pool must be deeper than the riffle, have a concave bed surface, have a water surface slope that is flatter than the riffle, and a width that is at least one-third the width of the channel. If one or no geomorphic pools are observed in the representative sub-reach, the field value for this metric is 0.0.

Reach Slope

Average reach slope is part of stream classification and metric stratification. It is not used as a function-based parameter or metric. If a longitudinal profile is performed, slope can be calculated from that data and does not also need to be collected using the procedure below. If the rapid method is used, data should be collected using the following field procedure.

Procedure:

1. Take a stadia rod reading of the water surface elevation at the head of the first riffle and the head of the last riffle in the representative sub-reach. If limited by the line of sight and/or magnification of the hand level being used, take a stadia rod reading of the water surface elevation at the head of the first riffle and the head of the last riffle within a line of sight. Repeat as needed throughout project reach making sure that the total drop in elevation is recorded. Note, for streams with a uniform slope, a relatively short length of channel can be measured. For streams with large slope changes between riffles and pools, the entire sub-reach should be measured.

Field calculation: Calculate the difference in stadia rod readings, divide the difference in stadia rod readings by the channel length between these two points. Where multiple readings were taken, the sum of the elevation changes should be used in the numerator (total fall over the measured length). The denominator is the total stream length between the first and last measurement point. Space is available for calculations in the Project Reach form.

5. Large Woody Debris

Large Woody Debris Index
The Large Woody Debris Index (LWDI) is used to evaluate large woody debris within or touching the active channel of a stream. LWD that solely lies in the floodplain is not counted. Large woody debris is defined as dead and fallen wood over 1m in length and at least 10 cm in diameter at the largest end.[4] This index was developed by the USDA Forest Service Rocky Mountain Research Station (Pg. 73-77 in Davis et al. 2001). This method informs the large woody debris parameter in the MNSQT. It can be used instead of the large woody debris piece count. Both metrics should not be used at a site. The LWDI has a greater level of field effort but captures more information about large wood in the reach.

The Large Woody Debris Index data collection procedure is not included here. Users should download the *Application of the Large Woody Debris Index: A Field User Manual* prior to going out in the field (Harman et al. 2017).[5] Large Woody Debris Index data forms are included in Appendix B; or a fillable excel workbook that calculates LWDI is available with the User Manual.

Large Wood Piece Count
This method informs the large woody debris parameter in the MNSQT. It can be used instead of the LWDI metric. Both metrics should not be used at a site. The piece count has a reduced level of field effort but captures limited information about large wood in the reach.

Procedure:

1. Identify the 328-foot (100-meter) segment within the representative sub-reach that contains the most large woody debris. Record the station of the downstream end of the reach on the Project Reach form.
2. Count all pieces of large woody debris within this segment. Large wood is defined as dead wood over 3.3 feet (1m) in length and at least 3.9 inches (10cm) in diameter at the largest end. The wood must be within the stream channel or touching the top of the streambank. In a debris jam or dam, the number of individual pieces of large wood within the dam should be counted. The number of pieces should be tallied and totaled on the Project Reach form.

[4] Note: In willow-dominated systems, willow branches that form debris jams are included in the assessment even if they do not meet the minimum piece size. Additional discussion is provided in the LWDI manual.
[5] The manual is available here: https://stream-mechanics.com/wp-content/uploads/2017/12/LWDI-Manual_V1.pdf.

6. Lateral Migration

BEHI/NBS and Percent Streambank Erosion

The dominant BEHI/NBS and percent streambank erosion metrics within the lateral migration parameter are informed by an assessment of bank erosion hazard index (BEHI)/near bank stress (NBS). The BEHI/NBS is part of the Bank Assessment for Non-point Source Consequences of Sediment (BANCS) model (Rosgen 2014). Data forms are provided in Appendix B. **Detailed field procedures 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)

Procedure:

1. Evaluate the outside bank of every meander bend whether or not it is eroding. In addition, assess all other areas of active erosion regardless of their location. Depositional zones and riffle sections that are not eroding should not be evaluated.
2. Give each study bank an ID, e.g. L1 for left side, bank number 1. Determine the BEHI/NBS rating for each study bank. Record data on the Lateral Migration form.
3. Measure and record the length of each bank assessed using the station numbers from the tape(s) stretched along the sub-reach for the Longitudinal Profile or Rapid Survey. A GPS unit can also be used to map assessed banks.

Data can be recorded on the Lateral Migration form found in Appendix B. These data can be used to determine the field values following the instructions in Chapter 2 of the User Manual for the following metrics: dominant BEHI/NBS and percent streambank erosion.

Note: If a bank is armored, do not apply the dominant BEHI/NBS metric. Instead, assess using the percent armoring metric, which is described in Section 2 of Appendix A.

7. Riparian Vegetation

There are four metrics to assess the riparian vegetation parameter in the MNSQT: effective vegetated riparian area, canopy cover, herbaceous strata vegetation cover, and woody stem basal area. Field data for canopy cover, herbaceous strata vegetation cover, and woody stem basal area should be collected during the growing season at the same time of year for pre- and post-project evaluations. Forms are provided for all metrics in Appendix B.

Effective Vegetated Riparian Area

The method to determine the effective vegetated riparian area is described in Section 2.6.f of the User Manual. The process below describes how to apply the calculated effective riparian width to a particular stream reach such that a polygon representing the area can be defined and quantified (in square meters). The effective *vegetated* riparian area is then calculated as a percentage of the overall effective riparian area.

1. Gather Data Resources. Obtain aerial imagery and topographic information (preferably at least 2-foot contour intervals) of the stream reach and associated stream valley. GIS layers of these data sources are readily available for most areas of the state from MnTOPO, MnGEO and other publicly accessible websites.

2. Define Stream Valley. Use data sources to define the valley for the stream reach (see Figure A.2a and Figure A.2b for examples). This step is not necessary in alluvial valleys where the valley width clearly exceeds the calculated effective riparian area width on both sides of the stream channel. The valley edges will generally follow the base of an adjacent hillslope and/or the approximate extent of a 100-year flood. Consider the historic floodplain extent for incised channels that have been disconnected from their original floodplain.

Figure A.2a. Defining valley edge example.

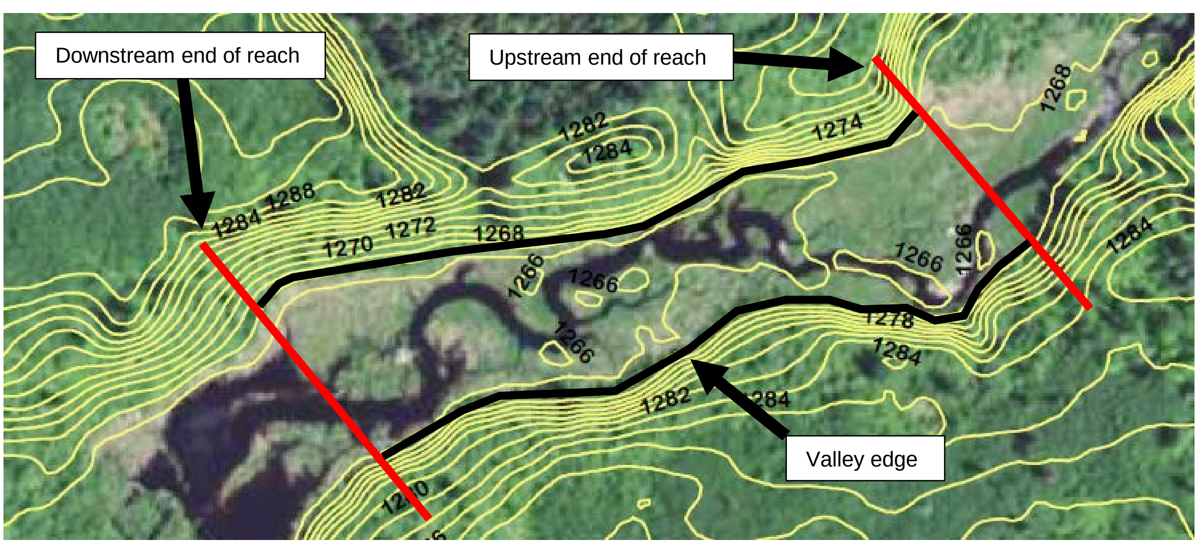
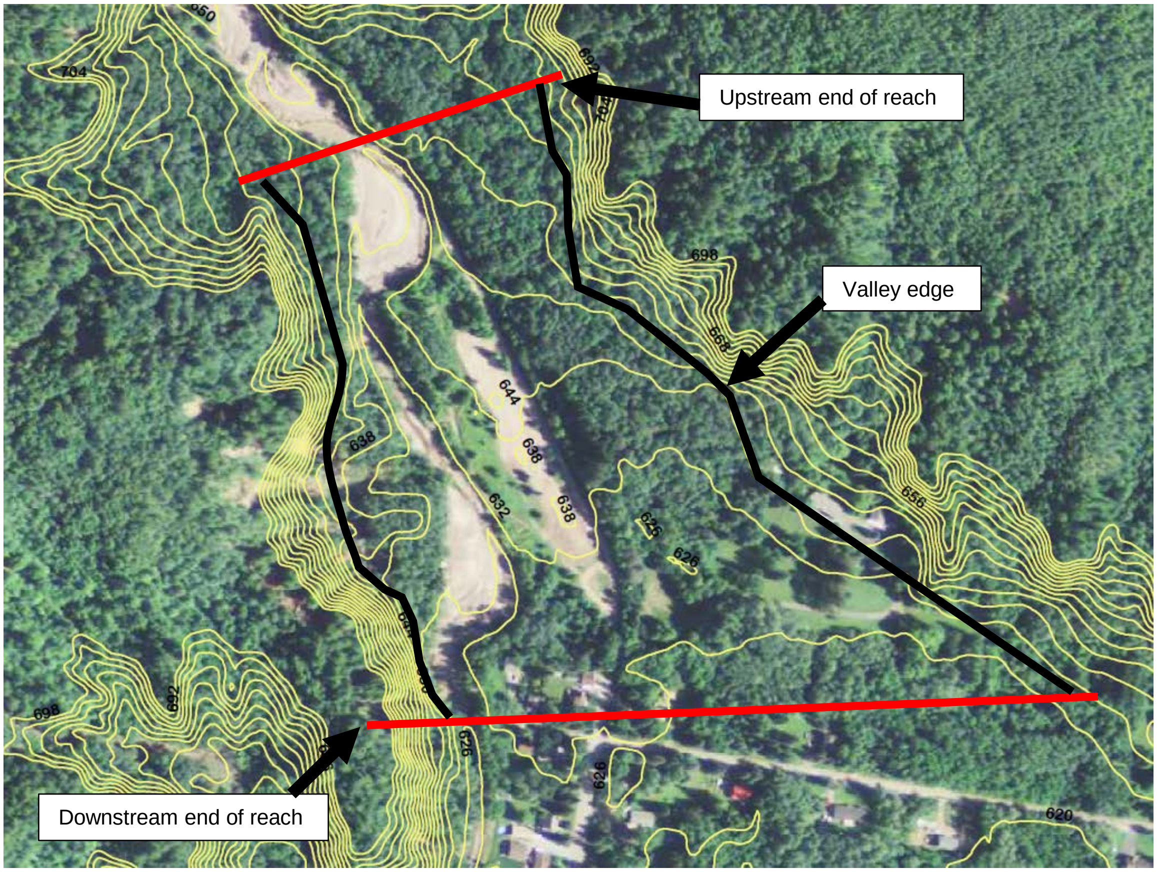
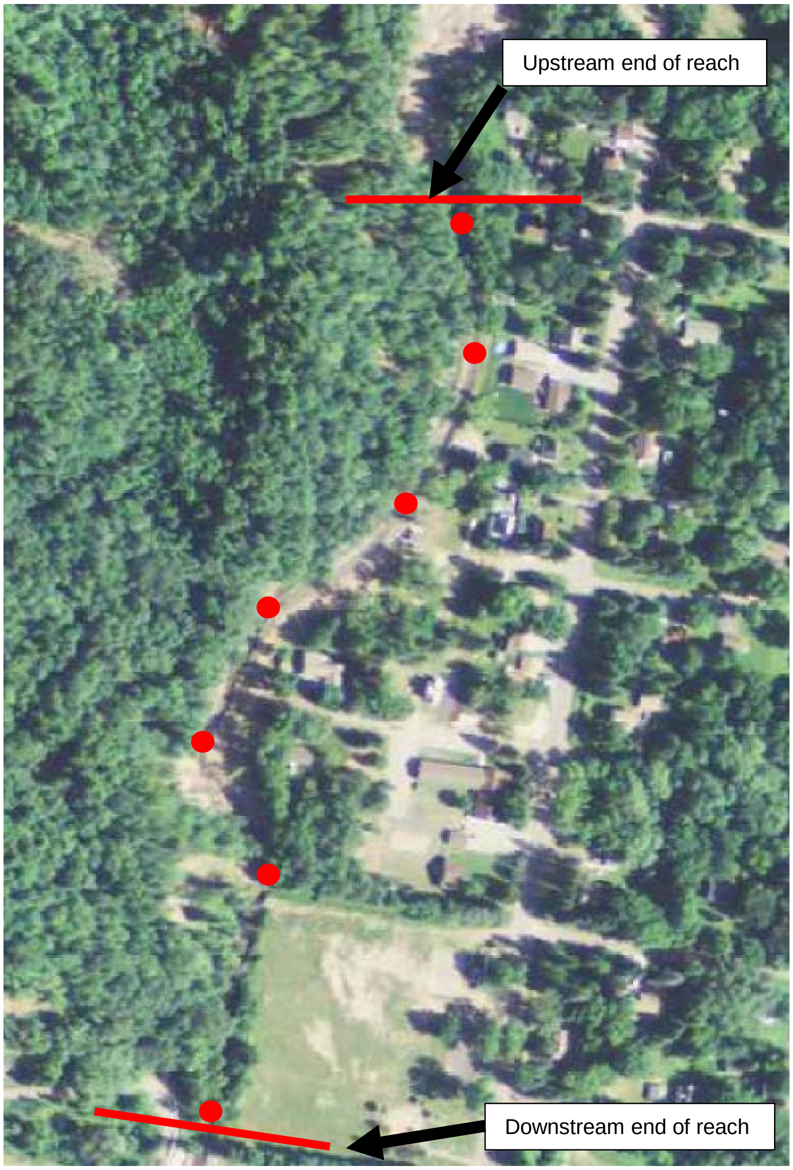


Figure A.2b. Defining valley edge example.



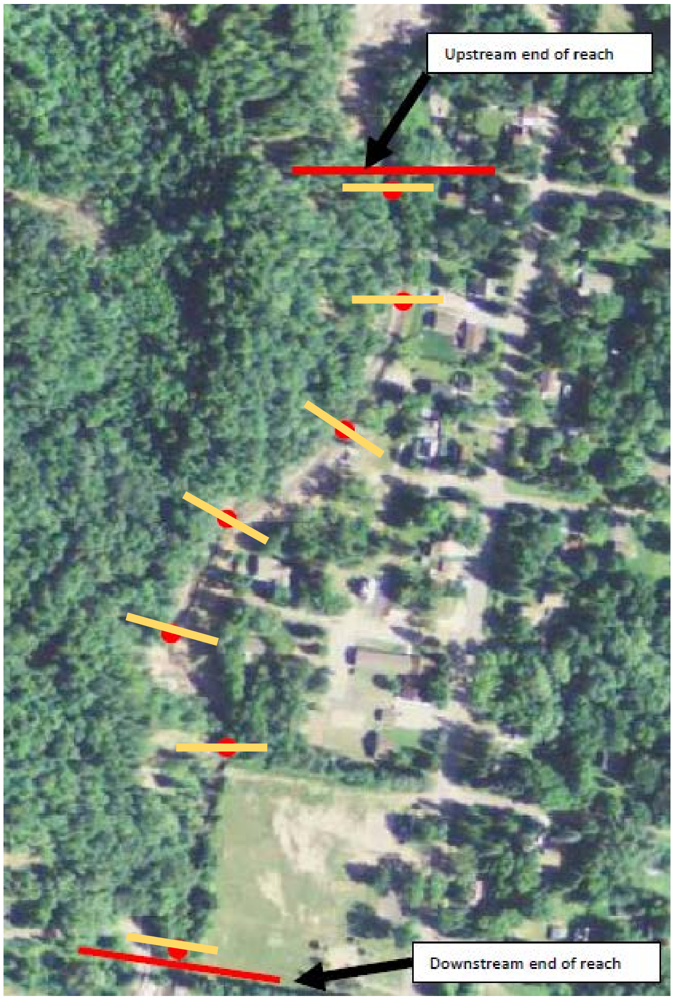
3. Mark Center of Stream Channel. Using an aerial image of the reach, mark the center of the stream channel at the upstream and downstream ends of the reach as well as the farthest landward point of each outside meander bend on both sides (Figure A.3). Long meander bends will require multiple points to capture stream sinuosity. These points may need to be located in the field and imported into the base map for small streams where the channel is not discernable on aerial imagery.

Figure A.3. Points marking the center of the stream channel at upstream and downstream ends of the reach and the farthest landward point of each meander bend.



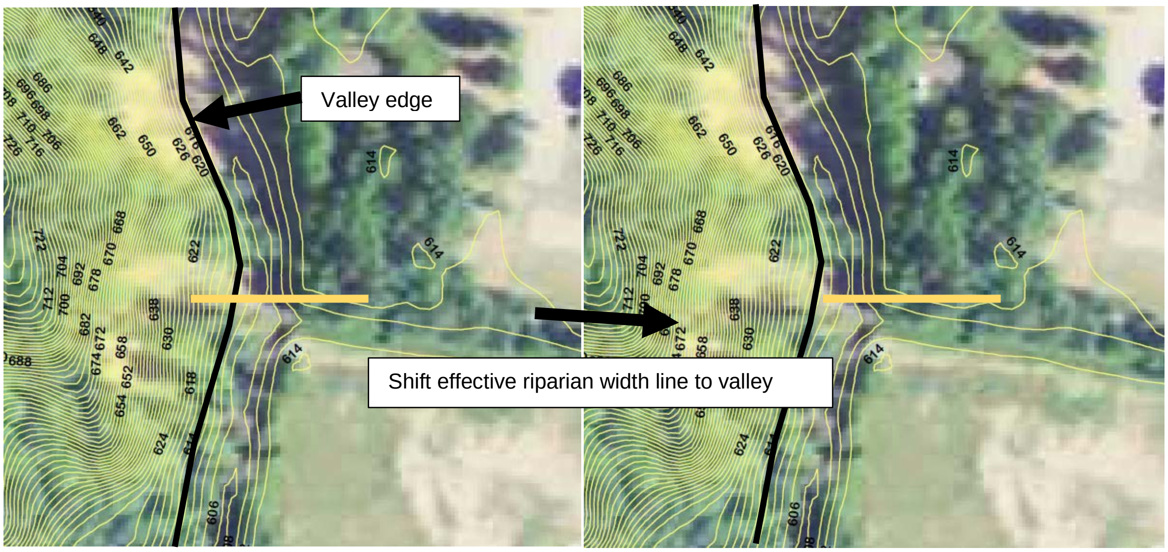
4. Apply Effective Riparian Width to Channel. At each point, draw a line with a length equivalent to the effective riparian width (calculated using methods from Section 2.6.f of the User Manual) perpendicular to the direction of flow within the channel centered on the point (Figure A.4).

Figure A.4. Drawing effective riparian width at each point.



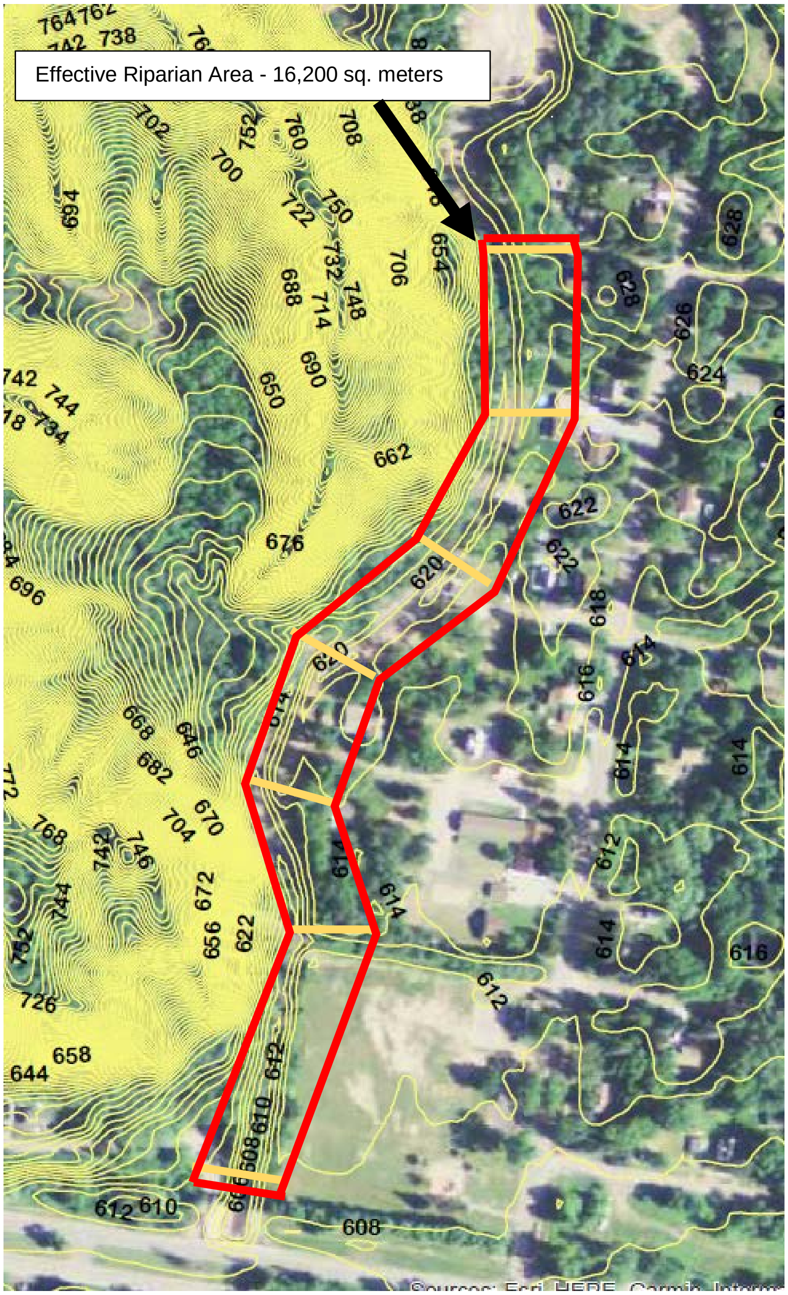
5. Adjust Effective Riparian Width to Valley Edge. This step is only necessary if the effective riparian width as applied to the channel center overlaps the edge of the stream valley as mapped in step 2. Shift lines representing the effective riparian width at all points where they extend beyond the valley edge (Figure A.5).

Figure A.5. Adjusting effective riparian width lines to valley edge.



6. Define Effective Riparian Area. Connect the endpoints of the lines from step 5 on each side of the stream to form a polygon from the upper to lower reach limits (Figure A.6).

Figure A.6. Connecting the end points of the effective riparian width lines to form a polygon representing the effective riparian area.



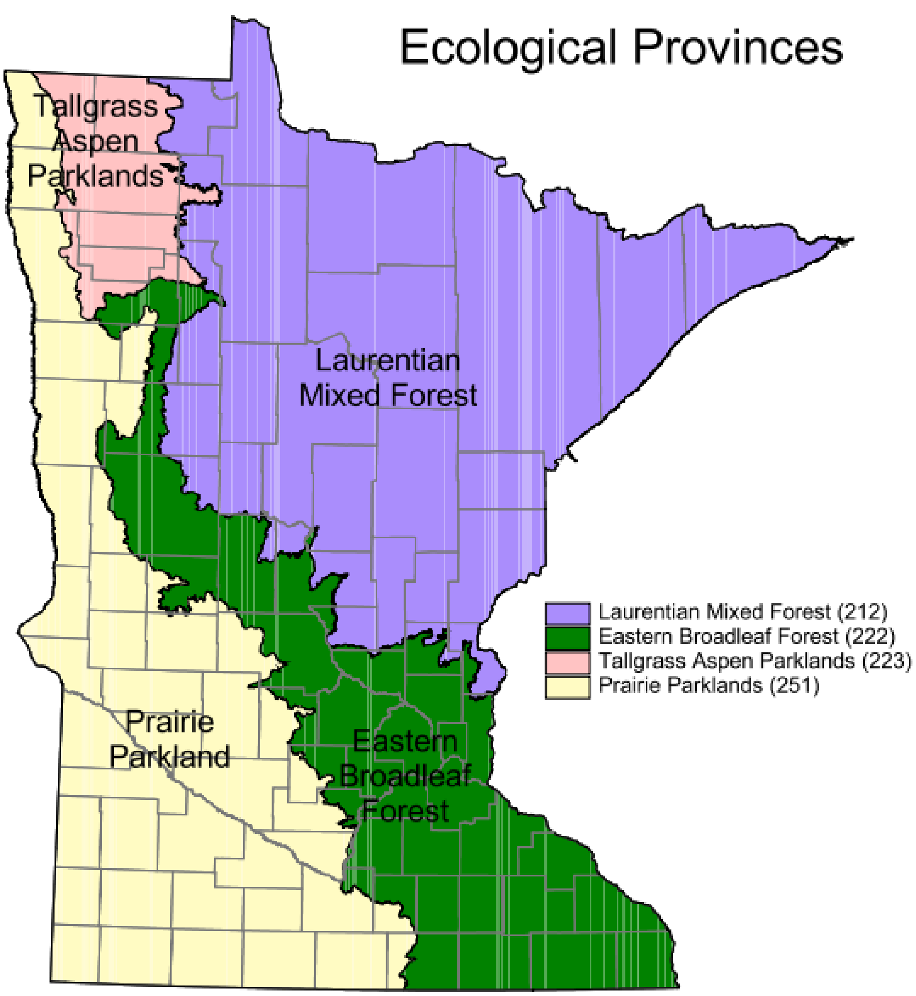
7. Document and Record Methodology. Complete the Effective Vegetated Riparian Area data form and include the data form with the SQT scores.

Herbaceous Strata, Canopy Cover and Woody Stem Basal Area

Herbaceous strata vegetation cover is assessed for all stream types. Canopy cover and woody stem basal area are assessed if woody vegetation is a significant natural component of the effective riparian area as determined using the procedure described below.

1. Examine a reference natural stream reach. Woody vegetation is a natural component of the effective riparian area if the reference natural stream reach includes a significant proportion of shrub and/or tree species. If there is not an appropriate reference reach, then proceed to step 2.
2. Use the *Field Guides to the Native Plant Communities of Minnesota* (MN DNR, 2003, 2005a, 2005b) for the project-specific ecological province to help make this determination. Use a field guide as follows:
    a. Select the field guide associated with the ecological province the stream reach is located in. The ecological provinces are shown in Figure A.7.

Figure: A.7 MN Ecological Provinces (MN DNR website)



b. Use the map on the inside cover of the field guide to determine the ecological section the stream reach is located in and consult the associated key for that section (Keys A through D).

c. Determine which system is associated with the effective riparian area of the stream reach based on field properties, soil and hydrological properties, landform affinity and plant indicators as described in the key.

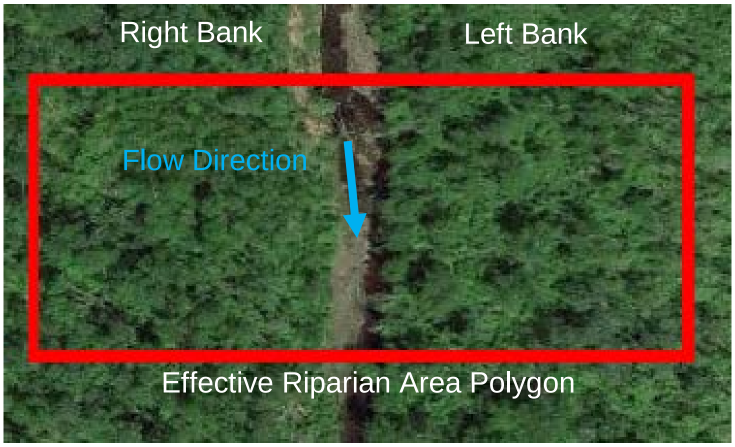
d. Based on the vegetation structure and composition description of the system or applicable subsystem as well as the natural history description, determine if woody vegetation is a significant natural component of the effective riparian area of the stream reach.

Herbaceous strata vegetation cover, canopy cover and woody stem basal area are assessed at vegetation plots. Field values will need to be averaged across plots before entering into the Quantification Tool spreadsheet (see Section 2.6.e in Chapter 2 of the User Manual). The user should provide a figure that shows the location and extent of the vegetation plot grid layout and identification of the sampled plots. To begin, the location of the vegetation plot must be determined using the following procedure:

Plot Establishment Procedure:

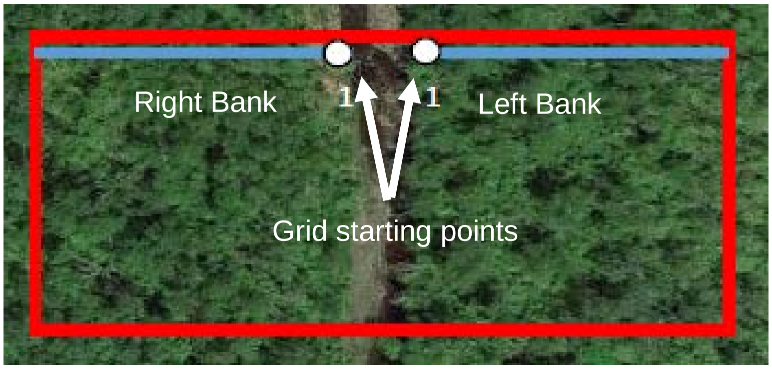
1. Start with the polygon representing the effective riparian area as determined for the effective vegetated riparian area metric (Figure A.8). This polygon is the area for establishing a sampling grid.

Figure A.8. Stream Reach with Effective Riparian Area



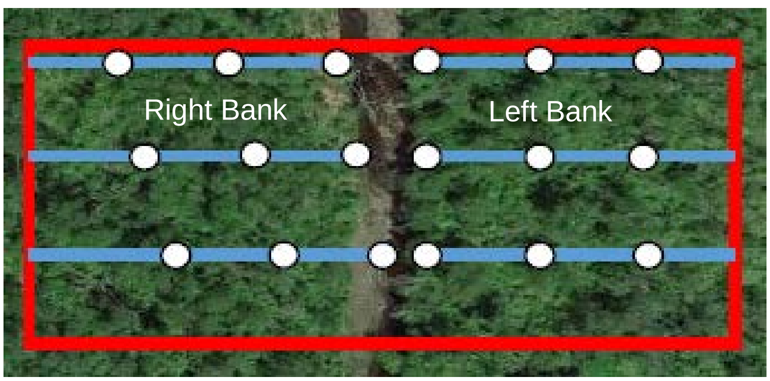
2. Establish the grid starting points on the right and left channel bank, beginning at the upstream end of the reach. Establish initial transect by drawing a straight line from each grid starting point to the effective riparian area limits as shown in Figure A.9.

Figure A.9.   Grid Starting Points



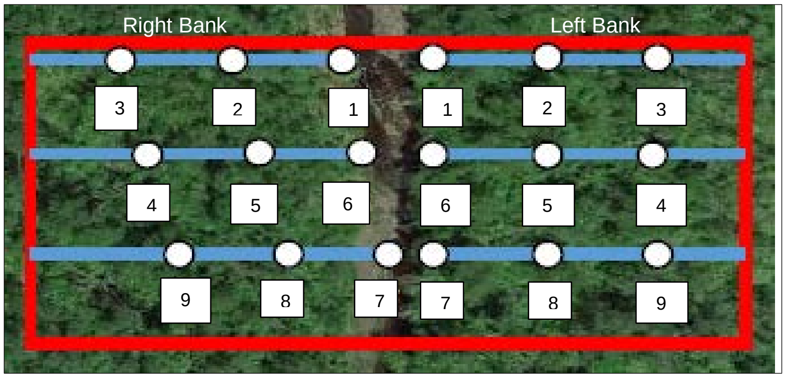
3. Establish additional parallel transects progressively downstream every 5 meters for both right and left banks. The last transect cannot be closer than 5 meters from the downstream end of the stream reach. Begin each transect by establishing initial plot anchor points on the right and left channel bank. Mark additional plot anchor points every 5 meters along each transect, starting from the channel edge and moving towards the expected riparian boundary (Figure A.10). The last anchor point cannot be closer than 5 meters from the effective riparian area limit. In Figure A.10, the white circles are plot anchor points and the blue lines are transects.

Figure A.10.   Anchor Points and Transects



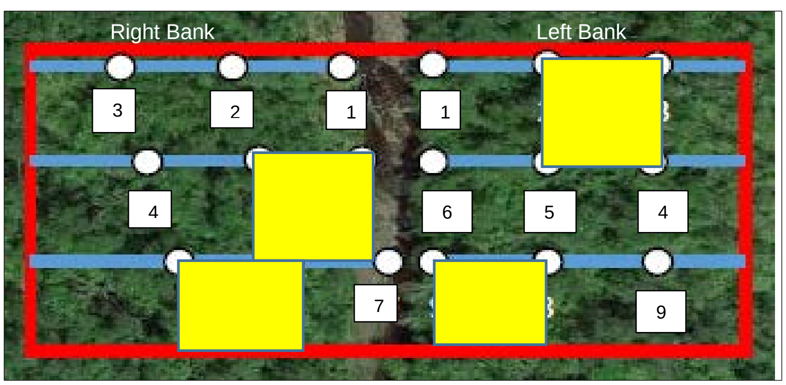
4. For each side separately (right and left banks) number the grid points sequentially starting from the grid anchor point at the channel and proceeding landward. Then continue the labeling down to next transect, then toward channel, down to next transect and repeat until complete (Figure A.11).

Figure A.11. Grid Point Labels



5. Use a random number table or generator to randomly select grid point numbers. The randomly selected grid points identify the top left corner of the grid that will be sampled (as viewed in plan view). A minimum of 2 plots per side is required unless the effective riparian area on one side of the stream is less than 5 meters wide, preventing plot establishment. For example, plots L2, L7, R5, and R9 are shown as randomly selected sampling plots in Figure A.12. Continue selecting grid numbers until the sampling area is equal to a minimum of 2% of the effective riparian area on each side of the channel and excluding the active channel area. To calculate the percent sampling area, multiply the number of plots by 25 square meters and divide the result by the total area (in square meters) of the effective riparian area for the applicable bank (right or left), then convert to a percentage. If there is considerable variation in the composition of the effective riparian area vegetation which is not adequately captured by the randomly selected sample plots, consider adding additional plots and/or establishing sub-reaches for separate sampling using the same procedures.

Figure A.12. Random Grid Selection



6. Locate the randomly selected plots in the field using appropriate measurement methods. Mark plot corners and subplot locations as applicable and begin sampling. Label plots with R and L plus the number to distinguish right and left bank samples (i.e. L2, R5, etc.). Attach a figure to the MNSQT riparian vegetation data forms showing the grid layout and selected sample plots (see Figure A.12) with labels.

Canopy Cover

Canopy cover is determined by assessing the relative areal cover of the shrub and tree vegetation strata. Data can be recorded on the Riparian Vegetation form found in Appendix B. This data can be used to determine the field values following the instructions in Chapter 2 of the User Manual for Canopy Cover.

Procedure:

1. Visually estimate the percent of the relative areal cover provided by the shrub strata (woody vegetation greater than or equal to 1.37 m in height with a diameter at breast height (dbh) less than 7.62 cm). The relative areal cover is the proportional cover provided by the shrub vegetation strata as a percentage of the total plot, ranging from 0 - 100%. Use the cover class ranges in Table A.1 for the estimates. Enter the cover midpoint estimate in the Riparian Vegetation Form. Fill out one Riparian Vegetation form for each sampling plot.
2. Estimate the percent of the relative areal cover provided by the tree vegetation strata (woody vegetation greater than or equal to 1.37 m in height with a dbh greater than or equal to 7.62 cm). The relative areal cover is the proportional cover provided by the tree vegetation strata as a percentage of the total plot, ranging from 0 - 100%. Use the cover class ranges in Table A.1 for the estimates. Enter the cover midpoint estimate in the Riparian Vegetation Form.

Table A.1 Cover Class Descriptions

Cover Class Range	Midpoint
>95 - 100%	97.5%
>75 - 95%	85%
>50 - 75%	62.5%
>25 - 50%	37.5%
>5 - 25%	15%
>1 - 5%	3%
>0 - 1%	0.5%

3. Determine the canopy cover for each plot by adding the shrub strata and tree strata midpoint values.
4. Average the canopy cover estimates across all plots.

Herbaceous Strata Vegetation Cover

Visually estimate the percent of the relative areal ground cover that is covered by the herbaceous vegetation strata in the plot. This includes all above ground plant material (leaves, branches, stems) less than 1.37 m in height regardless of it being woody or herbaceous. The relative areal cover is the proportional cover provided by the vegetation strata as a percentage of the total plot, ranging from 0 - 100%. Use the cover class ranges in Table A.1 for the estimates. Enter the cover midpoint estimate in the Riparian Vegetation Form (Appendix B). Fill out one Riparian Vegetation form for each sampling plot.

Woody Stem Basal Area

For purposes of the MNSQT, woody stem basal area is determined by sampling woody stems that are greater than 1.37 meters high. The resulting sampling values are expressed as an area (m^2) per hectare and averaged across sampling plots for the reach. The data collection method provided below is based on the *CVS-EEP Protocol for Recoding Vegetation* (Lee et al. 2008) and modified for use in Minnesota.

Procedure:

1. Determine if the entire plot (5m x 5m) will be sampled or if subsampling within the plot is appropriate. Subsampling involves stem counts and measurements along a one meter wide strip along the right and left sides of the 5m x 5m plot as opposed to sampling the entire plot. If stem densities are relatively high and somewhat uniform within the plot, subsampling within the plot can be conducted, however, subsampling cannot be used to estimate basal area of planted trees and shrubs for a post-project assessment.

2. Count and record dbh of all woody stems within the plot and/or subplots. Stems must be from woody, perennial species and at least 1.37 meters high. Height refers to the length of the stem (rather than the actual height above ground) and should be determined based on the length from the ground to the end of the terminal bud. **Multiple stems from the same plant are not counted if they split above 1.37 meters high.** For stems up to 30.5 cm dbh, use the following dbh classes in Table A.2 to determine the midpoint value. The user may need to calibrate themselves by measuring several stems before visual grouping stems into dbh classes. Measure and record the exact dbh of all woody stems exceeding 30.5 cm dbh to one decimal place.

Table A.2: DBH Classification

DBH (cm)	DBH Midpoint (cm)
0 – 2.5	1.25
2.5 – 5	3.75
5 – 7.5	6.75
7.5 – 12.5	10
12.5 – 20.5	16.5
20.5 – 30.5	25.5
>30.5	Measure

3. Calculate basal area for each dbh midpoint or measured dbh in m^2, using the formula below to convert from cm to m^2.

$$Stem\ Basal\ Area = (DBH^2) * 0.00007854$$

4. Multiply the number of stems for each dbh midpoint / measured dbh by the individual stem basal area to determine the total stem basal area. Sum all the total stem basal area values to determine the total basal area for each sampling plot as shown in the example in Table A.3.

Table A.3: Basal Area for each Plot (example)

DBH Classes (cm)	DBH Midpoint (cm)	Individual Stem Basal Area (m^2)	No. of Stems	Total Stem Basal Area (m^2)
0 – 2.5	1.25	0.000123	12	0.001473
2.5 - 5.0	3.75	0.001104	2	0.002209
5.0 – 7.5	6.75	0.003578	3	0.010735
7.5 – 12.5	10	0.007854	0	
12.5 – 20.5	16.5	0.021383	0	
20.5 – 30.5	25.5	0.051071	0	
			Subtotal 1	*0.014417*
Size	**DBH (cm)**	**Individual Stem Basal Area (m^2)**	**No. of Stems**	**Total Stem Basal Area (m^2)**
Stems > 30.5 cm	32	0.080425	1	0.080425
			Subtotal 2	*0.080425*
			Total Plot Basal Area (m^2)	**0.094842**

5. Divide the total basal area for each plot (m^2) by the sampling plot size in hectares (ha) to adjust the plot values to a hectare basis. Use the formula shown below to calculate basal area (m^2/hectare). Example plot size shown is 5m x 5m, which equals 0.0025 ha. The Riparian Vegetation Form found in Appendix B allows the user to enter dbh data, stem counts and sampling plot size to determine basal area (m^2/hectare).

$$Basal\ Area\ (\mathrm{m^2/ha}) = \frac{Total\ Plot\ Basal\ Area\ (\mathrm{m^2})}{\text{Plot size (hectares)}}$$

$$Basal\ Area\ (\mathrm{m^2/ha}) = \frac{0.094842\ \mathrm{m^2}}{0.0025\ \text{hectares}}$$

$$Basal\ Area\ (\mathrm{m^2/ha}) = 37.9$$

6. Average all of the sampling plot basal areas that were measured across the Site. This value will be your Woody Stem Basal Area (m^2/ha) metric.

8. Physicochemical Parameters

Temperature
Placement and use of in-water temperature sensors should follow *Procedure for Temperature Logger Deployment at Stream Monitoring Sites* (MPCA 2015). This procedure covers equipment selection, deployment methodologies, temperature logger form, and data QAQC. **Methods are not provided in this section.**

Record the time and date of temperature sensor deployment on the Sensor Log form in Appendix B.

Dissolved Oxygen
This metric is a direct measure of the concentration of dissolved oxygen (mg/L) in in the project reach collected according to procedures outlined in the *Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component* (MPCA 2017b). **Methods are not provided in this section.**

Record the time and date of dissolved oxygen sensor deployment on the Sensor Log in Appendix B. As noted in the User Manual, measurements in open-water months (April through November) should be made before 9:00 a.m. Please refer to the assessment guidance manual (*Guidance Manual For Assessing the Quality of Minnesota Surface Waters* (MPCA 2018a)) regarding the importance of dissolved oxygen measurements collected before 9:00 a.m. (e.g. to measure impact from streams impacted by eutrophication). The MPCA can provide recommendations for suitable Sonde deployment sites.

Total Suspended Solids (TSS)
This metric is a direct measure of the concentration of total suspended soilds (mg/L) in the project reach collected according to procedures outlined in the *Guidance Manual For Assessing the Quality of Minnesota Surface Waters* (MPCA 2018a), and *Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component* (MPCA 2018c). The State also uses turbidity as a surrogate for TSS. The protocol for turbidity sampling is described in *Turbidity TMDL Protocol Guidance and Submittal Requirements* (MPCA 2007).document (https://www.pca.state.mn.us/sites/default/files/wq-iw1-07.pdf)

Methods are not provided in this section.

Record the time and date of the sample collection on the Sensor Log in Appendix B.

9. Biological Parameters

Macroinvertebrate Sampling

Detailed macroinvertebrate surveys should be conducted using *Macroinvertebrate Data Collection Protocols for Lotic Waters in Minnesota* (MPCA 2017). **Specific macroinvertebrate sampling procedures are not provided in this section.**

Record information related to macroinvertebrate sampling on the Stream Invertebrate Visit Form, Stream Sample External Label, and Physicochemical and Macroinvertebrate Sampling Sorting Bench Sheet forms in Appendix B.

Fish Sampling

Detailed fish surveys should be conducted using *Fish Data Collection Protocols for Lotic Waters in Minnesota* (MPCA 2017a) and standard methods (Bonar et al. 2009). **Specific fish sampling procedures are not provided in this section.**

Record information related to fish sampling on the Fish Survey Record form in Appendix B. In addition, the visit summary form found in the *Water Chemistry Assessment Protocol for Stream Monitoring Sites* (MPCA 2014c), which summarizes sampled stream condition/water quality information, should be filled out. This form is also included in Appendix B.

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