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Streamflow Duration Assessment Methods for the Northeast and Southeast of the United States

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Streamflow Duration Assessment Methods for the Northeast and Southeast of the United States

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Section 1: Introduction and Background

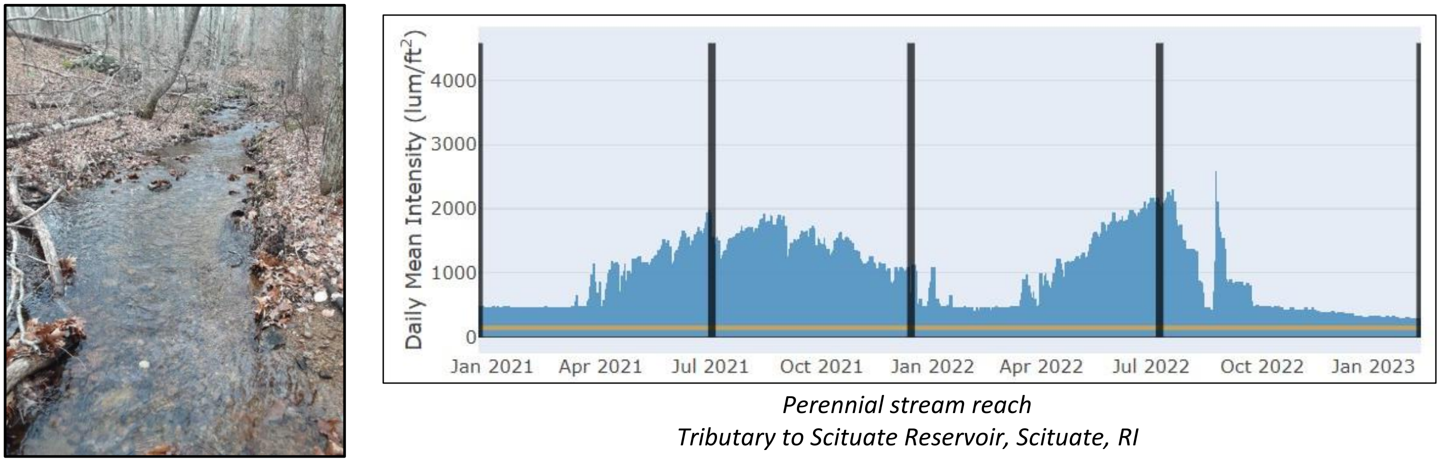
Streams exhibit a diverse range of hydrologic regimes, and the hydrologic regime strongly influences the physical, chemical, and biological characteristics of active stream channels and adjacent riparian areas. Thus, information describing a stream's hydrologic regime is useful to support resource management decisions, including Clean Water Act Section 404 decisions. One important aspect of the hydrologic regime is streamflow duration—the length of time that a stream sustains surface flow. However, hydrologic data to determine flow duration has not been collected for most stream reaches nationwide. Although maps, hydrologic models, and other data resources exist (e.g., the National Hydrography Dataset, Moore et al. 2019), these may exclude small headwater streams and unnamed second- or third-order tributaries, and limitations on accuracy and spatial or temporal resolution may reduce their utility for many management applications (Hall et al. 1998, Nadeau and Rains 2007, Fritz et al. 2013). Therefore, rapid, field-based methods are needed to determine flow duration class at the reach scale (defined in Section 2: Overview of the NE and SE SDAMs and the Assessment Process) in the absence of long-term hydrologic data (Fritz et al. 2020).

These methods are intended to classify stream reaches into one of three streamflow duration classes[1]:

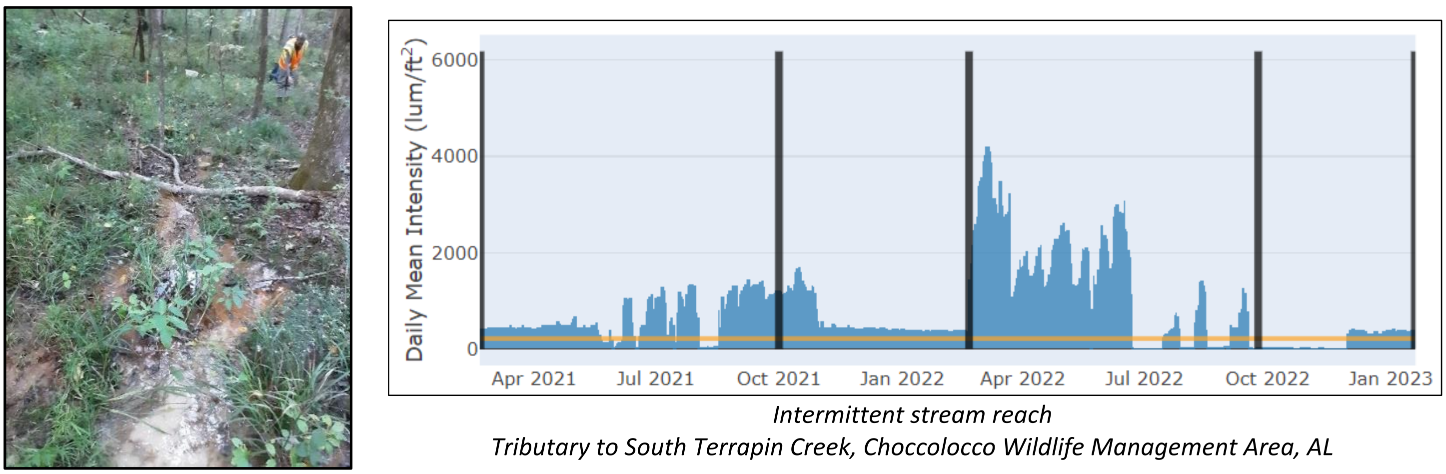
> *Ephemeral reaches* are channels that flow only in direct response to precipitation. Water typically flows only during and/or shortly after large precipitation events, the streambed is always above the water table, and stormwater runoff is the primary water source.
>
> *Intermittent reaches* are channels that contain sustained flowing water for only part of the year, typically during the wet season, where the streambed may be below the water table and/or where the snowmelt from surrounding uplands provides sustained flow. The flow may vary greatly with stormwater runoff.
>
> *Perennial reaches* are channels that contain flowing water continuously during a year of normal rainfall, often with the streambed located below the water table for most of the year. Groundwater typically supplies the baseflow for perennial reaches, but the baseflow may also be supplemented by stormwater runoff and/or snowmelt.

Example photographs and hydrographs of stream reaches in each class are shown in Figure 1.

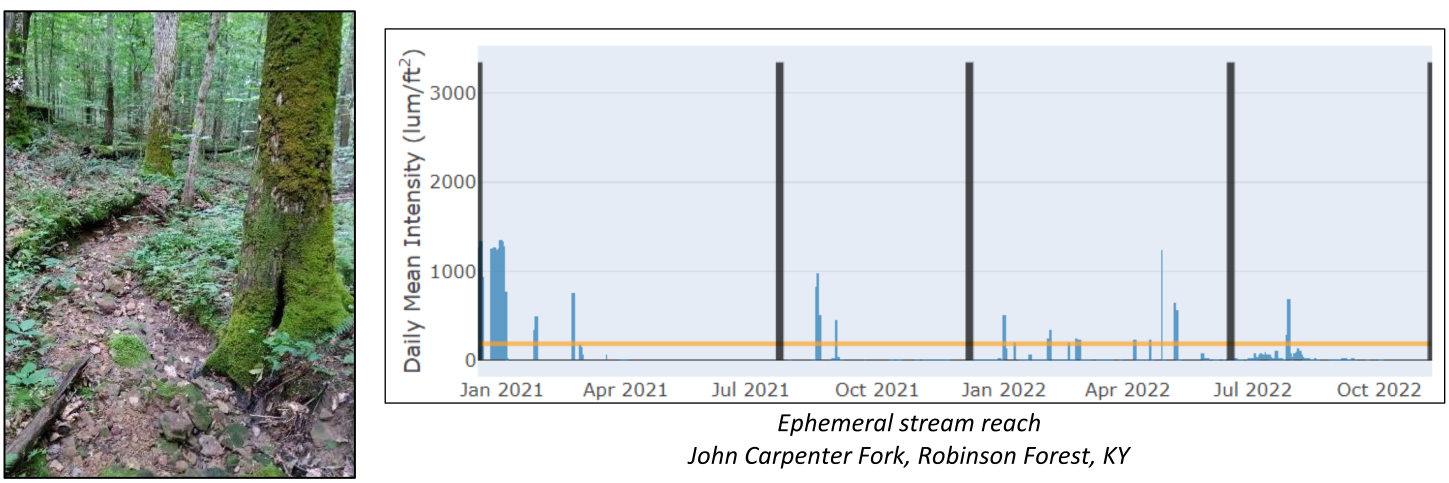
[1] The definitions used for development of this manual are consistent with the definitions used to develop the SDAMs for the Pacific Northwest, Arid West, Western Mountains, and Great Plains.



Perennial stream reach
Tributary to Scituate Reservoir, Scituate, RI



Intermittent stream reach
Tributary to South Terrapin Creek, Choccolocco Wildlife Management Area, AL



Ephemeral stream reach
John Carpenter Fork, Robinson Forest, KY

Figure 1. Streams of different flow classes. Photos of stream reaches in each streamflow duration class are shown at left, with corresponding visualizations of daily flowing vs dry periods of these reaches, including flow classification, on the right. Daily flowing vs dry observations are derived from Stream Temperature, Intermittency, and Conductivity (STIC) loggers deployed in the channel thalweg in erosional or riffle habitat in each study reach (Chapin et al. 2014, Kelso et al. 2023). For these loggers, the presence of flowing surface water is inferred from raw intensity values that are higher than logger-specific intensity values calibrated to distilled water (yellow lines). Blue areas above the yellow lines denote flowing periods and black bars denote field visits when logger data were downloaded, and indicator data were collected.

These classes describe the typical patterns exhibited by a stream reach over multiple years, although observed patterns in a single year may vary due to extreme and transient climatic events (e.g., severe droughts). Although flow duration classes are not strictly defined by their sources of flow (e.g., storm runoff, groundwater, snowmelt), the duration is often related to the relative importance of different flow sources to stream reaches and the stability of their contributions. Perennial reaches have year-round surface flow in the absence of drought conditions. Intermittent reaches have one or more periods of extended surface flow in most years, where the flow is sustained by sources other than surface runoff in direct response to precipitation, such as groundwater, melting snowpack, irrigation, reservoir operations, or wastewater discharges. Ephemeral reaches have a surface flow for short periods and only in direct response to precipitation.

This manual describes the final Streamflow Duration Assessment Methods (SDAMs) intended to distinguish flow duration classes of stream reaches in the Northeast (NE) and Southeast (SE) regions of the United States as defined in *Synthesizing the Scientific Foundation for Ordinary High-Water Mark Delineation in Fluvial Systems* (Wohl et al. 2016), which is based largely on vegetation type and precipitation levels (Figure 2). In the Northeast, snowmelt contributes at least some flow to streams and rivers during the year while the Southeast is dominated by rainfall runoff other than snowmelt, including tropical storms and hurricanes.

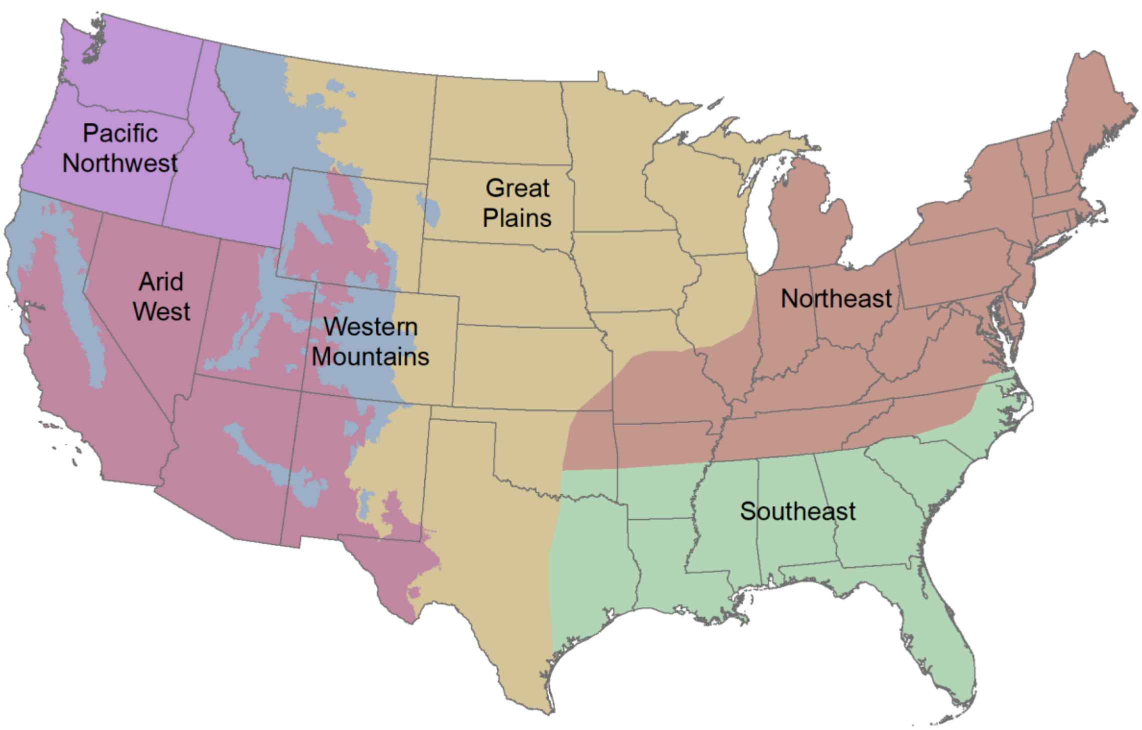


Figure 2. Map of regional streamflow duration methods.

Based on data analysis, distinct NE and SE SDAMs provide higher classification accuracy than a single stratified method, though certain indicators are used in both methods. The NE and SE SDAMs are based on biological and geomorphological indicators measured in the field as well as geospatial and climatic indicators determined using desktop methods. Biological indicators, known to respond to gradients of streamflow duration (Fritz et al. 2020, Fritz et al. 2023), have notable advantages for assessing natural resources. The primary advantage is their ability to reflect long-term environmental conditions (e.g., Karr et al. 1986, Rosenberg and Resh 1993). This characteristic makes them well suited for assessing streamflow duration, because some species reflect the aggregate hydrologic conditions that a stream has experienced over multiple years. As a result, relatively rapid field observations of biological indicators made at a single point in time can provide long-term insights into streamflow duration and other hydrological characteristics of a stream reach. Geomorphological, geospatial, and climatic indicators can also be rapidly measured and provide information about the hydrologic drivers of streamflow duration (Fritz et al. 2008, Olson and Brouillette 2006, Russell et al. 2014, Jensen et al. 2018). For example, wide channels in areas with low precipitation are associated with shorter durations of streamflow; in contrast, in wetter areas, narrow channels are typically associated with headwaters, where the contributing catchments may be too small to generate long-duration flows.

1.1 The SDAMs for the NE and SE

This manual describes two methods that use a small number of indicators to predict the streamflow duration class of stream reaches in the NE and SE. Beta SDAMs for the NE and SE were released in April 2023 (James et al. 2023). After additional data collection, analysis, and user feedback, the final SDAMs were developed, reflecting somewhat different indicators from the beta methods. For more information on the development of these SDAMs or SDAMs for other U.S. regions, please refer to the U.S. Environmental Protection Agency's (EPA's) SDAM website.

The NE and SE SDAMs assign reaches to one of six possible classifications: ephemeral, intermittent, perennial, at least intermittent, less than perennial, and needs more information. An at least intermittent classification occurs when an intermittent or perennial classification cannot be made with high confidence, but an ephemeral classification can be ruled out. A less than perennial classification occurs when an ephemeral or intermittent classification cannot be made with high confidence, but a perennial classification can be ruled out. If no class can be determined with confidence, the stream is classified as needs more information.

Indicators of the NE and SE SDAMs

Biological indicators

- Benthic Macroinvertebrate Index (BMI)
- Total aquatic macroinvertebrate abundance (SE only)
- Shading
- Prevalence of rooted upland plants in the streambed (SE only)
- Prevalence of fibrous roots in the streambed (SE only)

Geomorphological indicators

- Bankfull channel width
- Entrenchment ratio (NE only)
- Slope (NE only)
- Particle size of stream substrate (SE only)

Geospatial/Climatic indicators

- Drainage area
- Elevation
- Average monthly precipitation (May-July) (SE only)

Because the NE and SE SDAMs share many indicators in common, and because many practitioners work in both regions, the two methods are presented in a combined manual. When assessing reaches near the boundary between regions or in areas more closely matching the characteristics of a different SDAM region, practitioners are encouraged to measure all indicators required for both methods, although some indicators may only be used for one method.

The NE and SE methods were developed using a machine learning model known as a random forest. Random forest models are increasingly common in the environmental sciences because of their superior performance in handling complex relationships among indicators used to predict classifications (Cutler et al. 2007). In some cases, a random forest model can be simplified into a decision tree or table (e.g., Nadeau et al. 2015, Mazor et al. 2021); however, that was not possible for the NE or SE models. To obtain a flow classification for an individual assessment reach, there is an open-access, user-friendly web application for entering indicator data and running the region-specific random forest model. No data entered into the web application are visible to or stored by the EPA or any other agency.

1.2 Intended use and limitations

The NE and SE SDAMs are intended to support field classification of streamflow duration at the reach scale in streams with defined channels (having a bed and banks) in the NE and SE regions. Section 3.5 Assessment reach considerations discusses when more than one reach should be assessed to classify streamflow duration for a stream segment longer than the assessment reach. Use of the SDAMs may inform a range of activities where information on streamflow duration is useful, including jurisdictional determinations under the Clean Water Act; however, the classification resulting from use of an SDAM is not in itself a jurisdictional determination. SDAMs are not mandatory for completing a Clean Water Act jurisdictional determination, nor are they intended to supersede more direct measures of streamflow duration (e.g., long-term records from stream gages). Other sources of information, such as aerial imagery, reach photographs, traditional ecological knowledge, and local expertise, can supplement the SDAMs when classifying streamflow duration (Fritz et al. 2020).

Although the NE and SE SDAMs are intended for use in both natural and altered stream systems, some alterations may complicate the interpretation of field-measured indicators or potentially lead to incorrect conclusions. For example, streams managed as flood control channels may undergo frequent maintenance to remove some or all vegetation in the channel and along the banks of the assessment reach. Although some biological indicators recover quickly from these disturbances, the results from assessments conducted shortly after such disturbances may be misleading. In addition, these types of channels may not display channel features that result from natural geomorphic processes, such as a typical particle size of stream substrate and entrenchment ratio.

1.3 Development of the NE and SE SDAMs

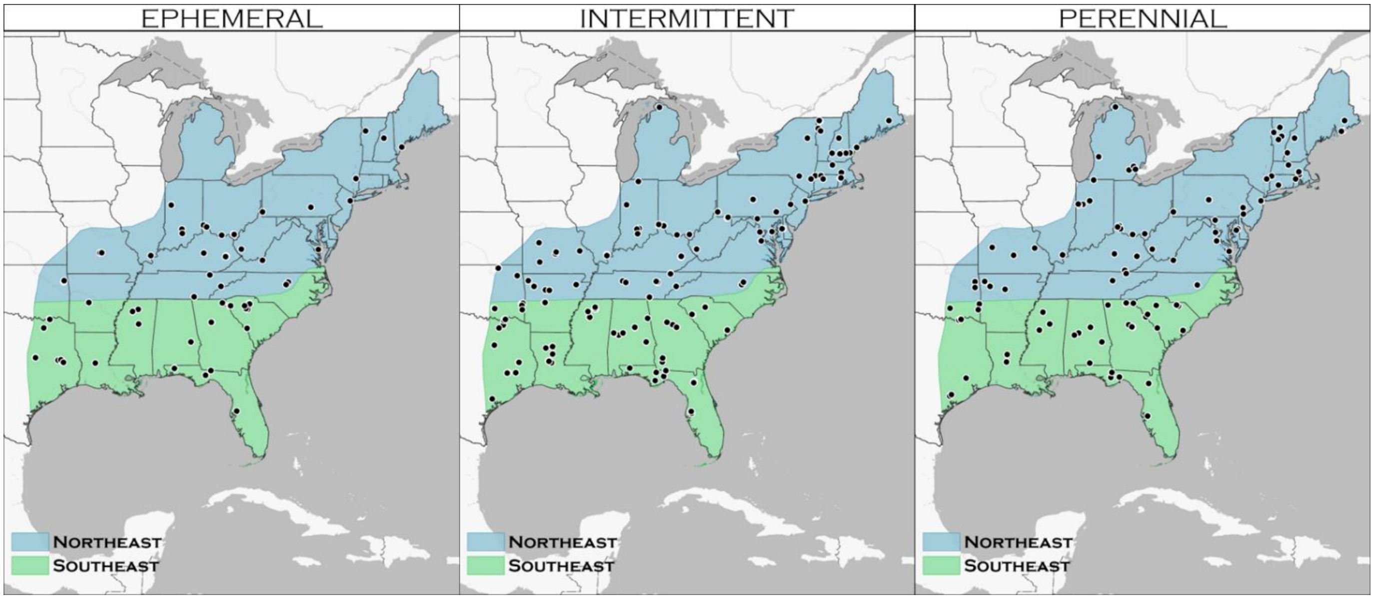


Figure 3. Locations of ephemeral, intermittent, and perennial stream reaches used to calibrate the NE and SE SDAMs. (Note, due to map scale some dots represent more than one site).

These methods resulted from a multi-year study conducted in 366 total study reaches across the NE region (209) and SE region (157) following the process described in Fritz et al. (2020). Of these, data from 358 sites (or reaches) where streamflow duration class could be determined from hydrologic data were used to develop the SDAMs (Figure 3). Streamflow duration class was determined using continuous (hourly interval) hydrological data from loggers deployed at 213 study reaches during the data collection period. Streamflow duration classes were determined at an additional 40 study reaches from U.S. Geological Survey (USGS) stream gages. Multiple sources of hydrologic data (e.g., inactive USGS stream gage data, published studies, consultation with local experts) were used to classify the remaining study reaches (105), for which data from continuous loggers were not available. Reaches were distributed across flow duration classes as shown in Table 1.

Table 1. Distribution of streamflow duration classes across the NE and SE study reaches.

Stream Class	Northeast	Southeast
Ephemeral	41	34
Intermittent	95	72
Perennial	69	47
Total	205	153

Development of the SDAMs followed the process steps below (Fritz et al. 2020):

Preparation

- Conducted a literature review (James et al. 2022):
  - Identified existing SDAMs, focusing on those originating in the NE or SE or developed using a similar approach (see Nadeau 2015; NCDWQ 2010).
  - Identified 40 potential field biological, hydrological, and geomorphological characteristics related to streamflow duration for evaluation in the NE and SE.
- Identified candidate study reaches with known streamflow duration class, representing diverse environmental settings throughout the region.

Data Collection: Beta Method Development

- Collected field data at 366 study reaches, visited up to 4 times (336 sites used for beta method development).

Data Analysis

- Evaluated 97 candidate metrics from the field data and GIS metrics for their ability to discriminate among streamflow duration classes. GIS metrics included climatic measures that characterize hydrologic drivers of streamflow duration (e.g., long-term precipitation and temperature) and are straightforward to calculate.
- Calibrated a classification model using a machine learning algorithm (i.e., random forest).
- Refined and simplified the beta method for rapid and consistent application.

Evaluation / Beta Implementation

- Published a beta method, data analysis report, and data used to develop the method.
- Trained the EPA and Corps staff on the beta method.
- Collected public comment and agency experience using the beta method for more than a year.
- Collected additional data at study reaches for a maximum of 5 visits.

Re-Analysis and Evaluation

- Evaluated 112 candidate metrics from the field data and GIS metrics for their ability to discriminate among streamflow duration classes. GIS metrics included climatic measures that characterize hydrologic drivers of streamflow duration (e.g., long-term precipitation and temperature) and are straightforward to calculate.
- Calibrated a classification model using a machine learning algorithm (i.e., random forest).
- Refined and simplified the final method for rapid and consistent application in light of the agency experience and public comments received on the beta method.

Implementation

- Publish User Manual, data analysis report, and data used to develop the method.
- Publish web application and code.
- Publish training materials to support implementation.
- Train the the EPA and Corps staff on the method and how to train others.

Eighty percent of sites in the development data set were used for method calibration, while twenty percent were withheld to provide an independent test of method performance.[2] Based on this withheld subset, the final methods correctly classified 73% of NE reaches and 67% of SE reaches among

[2] Note, Table 1 above includes all sites used in method development, those used to calibrate the model, and the subset of sites withheld for determining accuracy.

three classes (*perennial* vs. *intermittent* vs. *ephemeral*). Accuracy was much higher for differentiating *ephemeral* from *at least intermittent* reaches (88% for the NE and 91% for the SE), and moderately higher when differentiating *perennial* from *less than perennial* reaches (84% for the NE and 75% for the SE). Generally, misclassifications between intermittent and perennial reaches were more common than misclassifications between ephemeral and intermittent reaches in both regions. The ability of the NE and SE SDAMs to discriminate *ephemeral* more accurately and consistently from *at least intermittent* reaches is consistent with previous studies evaluating streamflow duration indicators and assessment methods (Fritz et al. 2008 and 2013, Nadeau et al. 2015, Mazor et al. 2021) and other regional SDAMs developed through this effort (Mazor et al. 2024, James et al. 2024).

Section 2: Overview of the NE and SE SDAMs and the Assessment Process

2.1 Considerations for assessing streamflow duration and interpreting indicators

2.1.1 Clean Water Act jurisdiction

Regulatory agencies evaluate aquatic resources for jurisdiction based on applicable regulations, guidance, and policy. The NE and SE SDAMs do not incorporate that broad scope of analysis. Rather, the methods provide information that may be used to inform jurisdictional decisions because they help determine streamflow duration as ephemeral, intermittent, or perennial in the absence of a hydrologic record.

2.1.2 Scales of assessment

The NE and SE SDAMs apply to an assessment reach, the length of which should be 40x the mean bankfull channel width. Regardless of channel width, reaches must be a minimum of 40 m and no longer than 200 m. The minimum reach-length of 40 m ensures that a sufficient area has been assessed to evaluate indicators. Quantification and observations of indicators are focused on the bankfull channel. However, ancillary information from outside the assessment reach (such as surrounding land use) is also recorded.

2.1.3 Spatial variability

Indicators of streamflow duration (and other biological, hydrologic, and geomorphic characteristics of streams) vary in their strength of expression within and among reaches in a stream system. The main natural drivers of spatial variation are generally the physiographic province (e.g., geology and soils) and climate (e.g., seasonal patterns of precipitation, snowmelt, and evapotranspiration). For example, certain indicators, such as shading from riparian vegetation, may be more strongly expressed in a floodplain with deep alluvial soils than they would be in a reach underlain by shallow bedrock, even if both reaches have a similar duration of flow. Therefore, understanding the sources of spatial variability in streamflow indicators will help ensure that assessments are conducted within relatively homogenous reaches.

Common sources of variation within a stream system that may affect the expression of indicators include:

- Natural longitudinal changes in channel gradient and size, and valley width (e.g., going from a confined canyon to an alluvial fan, or going from wide to narrow valley).
- Other natural sources of variation, such as bedrock material (limestones, sandstones, shales, conglomerates, and lignite) or water source (runoff, springs, summer rains, and groundwater).
- Drought or unusually high precipitation.
- Transitions in land use with different water use patterns (e.g., from commercial forest to pasture, from pasture to cultivated farmland, or cultivated farmland to an urban setting), or changes in management practices (e.g., intensification of grazing).
- Stream management and manipulation, such as diversions, water importation, dam operations, and habitat modification (e.g., streambed armoring).

2.1.4 Temporal variability

Temporal variability in indicators may affect streamflow duration assessment in two ways: interannual (e.g., year-to-year) variability and intra-annual (e.g., seasonal) variability. These methods were developed to be robust to both types of temporal variability and are intended to classify streams based on their long-term patterns in either flowing or dry conditions. However, both long-term sources of temporal variability (such as El Niño-related climatic cycles) and short-term sources (such as scouring storms before sampling) may influence the ability to measure or interpret indicators at the time of assessment. Timing of management practices, such as dam operations, channel clearing, or groundwater pumping, may also affect the flow duration assessment.

Certain indicators are more sensitive to temporal variability than others. For example, after a scouring flood event aquatic macroinvertebrates may be displaced from a stream reach. In contrast, rooted upland plants, if present, will likely remain. Similarly, longer-lived aquatic macroinvertebrates may be able to colonize an ephemeral to intermittent reach during wet years, depending on the presence of upstream or downstream refugia; however, changes in flow regimes may take several years to result in changes to vegetation in the stream channel or the riparian corridor.

2.1.5 Ditches and modified natural streams

Assessment of streamflow duration is sometimes needed in canals, ditches, and modified natural streams that are primarily used to convey water. These systems tend to have altered flow regimes compared to natural systems with similar drainage areas (Bannister 1979, Buchanan et al. 2012, Davis and Harden 2012, Epting et al. 2018), and the NE and SE SDAMs may determine if these flow regimes support indicators consistent with different streamflow duration classes. Thus, the SDAMs may be applied to these systems when streamflow duration information is needed.

Geomorphological indicators (e.g., bankfull channel width and slope; sometimes drainage area if ditching is extensive) may be difficult to assess in straightened or heavily modified systems. Indicator measurements should be based on present-day conditions, not historic conditions. Assessors should note the degrees to which channel geomorphology reflects natural processes or if it reflects the effects of management activities.

2.1.6 Other disturbances

Assessors should be alert for natural or human-induced disturbances that either alter streamflow duration directly or modify the ability to measure indicators. Streamflow duration can be directly affected by groundwater withdrawals, flow diversions, urbanization and stormwater management, septic inflows, agricultural and irrigation practices, effluent dominance, or other activities. In the method development data set, disturbed reaches were identified as those in urban or agricultural settings or those with notable impacts from grazing, mining, or other human activities. The SE SDAM had slightly lower accuracy in assessing disturbed reaches compared to undisturbed reaches for identification between the three flow classifications and an even smaller difference in accuracy when assessing ephemeral versus at least intermittent flow. The opposite was true of the NE SDAM, where classification results for undisturbed sites had slightly lower accuracy than for disturbed sites for identification between the three flow classes, however like in the SE there was an even smaller difference in accuracy for when assessing ephemeral versus at least intermittent flow.

Streamflow duration indicators can also be affected by disturbances that may not substantially affect streamflow duration (for instance, grading, grazing, recent fire, riparian vegetation management, and bank stabilization); in extreme cases, these disturbances may eliminate specific indicators (e.g., absence of aquatic macroinvertebrates in channels that have undergone recent grading activity). Logging, mining, and impoundments can affect both vegetation and geomorphological indicators (e.g., Choi et al. 2012, Jaeger 2015). Some long-term alterations or disturbances (e.g., impoundments) can make streamflow duration class more predictable by reducing year-to-year variation in flow duration and/or indicators. Discussion of how specific indicators are affected by disturbance is provided below in Section 3: Data Collection. Assessors should describe disturbances in the "Notes on disturbances or difficult site conditions" section of the field form.

2.1.7 Multi-threaded systems

Assessors should identify the lateral extent of the active channel, based on the outer limits of ordinary high-water mark (OHWM), and apply the method to that area. That is, do not perform separate assessments on each of the main and secondary channels within a multi-threaded system. Some indicators may be more apparent in the main channel versus the secondary channels; note these differences on the field form. Upland islands within the OHWM should not be included in the assessment.

Section 3: Data Collection

3.1 Conduct desktop reconnaissance

Before an assessment, desktop reconnaissance helps ensure a successful assessment of a stream. During desktop reconnaissance, assessors evaluate reach accessibility and set expectations for conditions that may affect field sampling. In addition, assessors can begin to compile additional data that may inform determination of streamflow duration, such as location of nearby stream gages.

Desktop Reconnaissance for:

- Access, permissions and permits;
- Reach placement;
- Watershed and site context;
- Flora and fauna lists; and
- Drainage area

This stage of the evaluation is crucial for determining reach access. The reach or project area should be plotted on a map to determine access routes and whether landowner permissions are required. Safety concerns or hazards that may affect sampling should be identified, such as road closures, controlled burns, or hunting seasons. These access constraints are sometimes the most challenging aspect of environmental field activities, and desktop reconnaissance can reduce these difficulties. Also, assessors can determine if inaccessible portions of the reach (e.g., those on adjacent private property) have consistent geomorphology or other attributes, compared with accessible portions.

Desktop reconnaissance can also help identify features that may affect assessment reach placement or determine the number of assessment reaches required for a project. Look for natural and artificial features that may affect streamflow duration at the reach—particularly those that may not be evident during the field visit or that are on inaccessible land outside the assessment area. These features include sharp transitions in geomorphology, upstream dams or reservoirs, springs, storm drains and major tributaries. It may be possible to see bedrock outcrops or other features that modify streamflow duration in sparsely vegetated areas.

A preliminary assessment of adjacent land use may be ascertained during desktop reconnaissance. This preliminary assessment should be verified during the field visit.

Evaluating watershed characteristics during desktop reconnaissance can produce useful information that will help assessors anticipate field conditions or provide contextual data to help interpret results. The USGS StreamStats tool, as well as the EPA's WATERS GeoViewer, provide convenient online access to watershed information for most assessment reaches in the United States, such as drainage area, soils, land use or impervious cover in the catchment, or modeled bankfull channel dimensions and discharge.

Assessors should consider consulting local experts and agencies to gain further insights about reach conditions and request additional available data. For example, state agencies may have records on water quality sampling indicating times when the reach was sampled and when it was dry. Local experts may have information about changes in the reach's streamflow.

Local or regional flora lists of species known to grow in the vicinity of an assessment reach may be available to assist with plant identification, which can be helpful for determining whether a plant is considered an 'upland' plant (see 3.8.6 Prevalence of upland plants in the streambed). Several online databases can generate regionally appropriate flora lists and/or assist with identification (Table 2). Note that there are four National Wetland Plant List (NWPL) regions that overlap with the area covered by the NE SDAM and three that overlap with the area covered by the SE SDAM; consult the appropriate list for your location.

Table 2. Examples of online resources for generating local flora lists.

Resource	Geographic coverage
National Wetland Plant List	United States and territories
The Biota of North America Program (BONAP) Vascular Flora Taxonomic Data Center	United States and territories
USDA Plants Database	United States and territories
Lady Bird Johnson Wildflower Center	Continental U.S. (native species only)
Atlas of Florida Plants	Florida
Tennessee-Kentucky Plant Atlas	Tennessee and Kentucky

Preliminary assessments of drainage area, which are used in the both the NE and SE SDAMs as an indicator, can also be completed before visiting the site. However, this calculation may need to be adjusted later depending on the reach's location confirmed in the field.

Lastly, desktop reconnaissance helps determine if permits are required to collect aquatic macroinvertebrates. Threatened and endangered species may be expected in the area, and stream assessment activities may require additional permits from appropriate federal, Tribal, and state agencies. Additional information on threatened or endangered species may be found on the U.S. Fish and Wildlife Service's Environmental Conservation Online System, as well as at state resource agencies and natural heritage programs.

Additional desktop reconnaissance tools can be found on the SDAM training and support materials website.

3.2 Prepare sampling gear

The following gear is suggested for completion of the NE and SE SDAMs:

- This manual and field forms (paper or digital).
- Clipboard, pencils, permanent markers, field notebook.
- Flagging tape.
- Maps and aerial photographs (1:250 scale if possible).
- Global Positioning System (GPS) to identify the downstream boundary of the reach assessed. A smartphone that includes a GPS may be a suitable substitute.
- Tape measures – for measuring bankfull channel width and reach length.
- Clinometer or range finder with slope measurement and stadia rod – for measuring slope (NE Only).
- Kick-net or small net and tray to sample aquatic macroinvertebrates.
- Hand lens – to assist with plant and aquatic macroinvertebrate identification.
- Digital camera (or smartphone with camera) plus charger. Ideally, use a camera that automatically records metadata, such as time, date, directionality, and location, as part of the EXIF data associated with the photograph.
- Shovel, soil auger, rock hammer, hand trowel, pick or other digging tools to facilitate hydrological observations of subsurface flow.
- Convex spherical densiometer, taped to restrict assessment to the forward-facing 17 grid intersections (see the Shading indicator for information on how to prepare the densiometer).
- Appropriate regional plant field guides and/or web applications (e.g., iNaturalist).
- Plastic bags or plant press for collecting plant vouchers.
- Benthic macroinvertebrate field guides (e.g., *A Guide to Common Freshwater Invertebrates of North America*, Voshell 2002) and/or web applications (e.g., PocketMacros[3]).
- Vials filled with 70% ethanol and sealable plastic bags for collection of biological specimens, with sample labels printed on waterproof paper.
- The U.S. Army Corps of Engineers List of wetland plants for sites to be visited.
- Boots or waders.
- First-aid kit, sunscreen, insect repellant, and appropriate clothing.

Ensure that all equipment is functional before each assessment visit and has been cleaned off-site between assessment visits to prevent the spread of invasive species. Sampling gear that comes into contact with the water (such as nets and boots or waders) should be properly decontaminated to prevent the spread of aquatic invasive species. Stop Aquatic Hitchhikers, an initiative of Aquatic Nuisance Species Task Force sponsored by USFWS, provides resources and links.

3.3 Order of operations for completing the NE and SE SDAM field assessments

After completing the in-office activities described above, the following general workflow is recommended for efficiency in the field:

[3] https://www.macroinvertebrates.org/app/download

1. Walk Assessment Reach (avoid walking in channel)

- Confirm assessment reach placement in the field (3.5.1).
- Measure the bankfull channel width at 3 locations and calculate average to determine assessment reach length and identify reach boundaries (3.5.2). Record average bankfull channel width in Step 2. Measure or visually assess flood prone width at each of the bankfull locations, making sure it is representative of the reach overall (NE only).
- Record coordinates of downstream reach boundary from center of channel and photograph reach.
- Begin to note expression and strength of field indicators.
- Take photographs at middle and upstream end of reach.
- Start sketching assessment reach on field form.

2. Record General Reach Site Information on Field Form (3.7.1)

3. Evaluate Indicators (3.8)

- Collect aquatic macroinvertebrates from reach, starting from downstream end.
- Measure slope (NE only).
- Sort/identify and count aquatic macroinvertebrates. If two practitioners are available, one should proceed with other measurements while the other conducts this step.
- Measure percent shading at top, middle and bottom of reach.
- Determine prevalence of upland plants in the channel (SE only).
- Assess the particle size of stream substrate and/or difference of channel substrate material from surrounding uplands (SE only).
- Assess the expression and degree of fibrous roots in the streambed (SE only).
- Complete sketch of the assessment reach on the field form.

4. Review Field Form for Completeness

5. Calculate Drainage area and enter Data into Web Application (in office)

- Calculate drainage area using StreamStats or the National Map viewer.
- Elevation and average monthly precipitation May-July (SE only) wil be automatically retrieved when coordinates are input into web application.

3.4 Timing of sampling

Ideally, application of the NE and SE SDAMs should occur during the growing season when many aquatic macroinvertebrates are most active and when any plants rooted in the channel are more readily identifiable. Assessments may be made during other times of the year, but there is an increased likelihood of specific indicators being dormant or difficult to observe at the time of assessment, especially in northern parts of the NE, where the presence of snow and channel ice during the colder months may also be a factor. That said, most of the indicators included in the methods persist well beyond a single growing season (e.g., rooted upland plants) or are not dependent on the growing season (e.g., geomorphological indicators), reducing the sensitivity of the methods to the timing of sampling.

The protocol may be used in flowing streams as well as in dry or drying streams. However, care should be taken to avoid sampling during flooding conditions and assessors should wait at least one week after large storm events that impact vegetation and sediment in the active stream channel before collecting data to allow aquatic macroinvertebrates and other biological indicators to recover (e.g., Angradi 1997, McCord et al. 2009, Smith et al. 2019). In general, aquatic macroinvertebrate abundance is suppressed during and shortly after major channel-scouring events, potentially leading to inaccurate assessments. Recent rainfall can interfere with measurements (e.g., by washing away aquatic macroinvertebrates). Assessors should note recent rainfall events on the field form and consider the timing of field evaluations to assess each indicator's applicability. Local weather data and drought information should be reviewed before assessing a reach or interpreting indicators. Evaluating antecedent precipitation data from nearby weather stations after each sampling event helps to determine if storms may have affected data collection and informs interpretation of SDAM data. The Antecedent Precipitation Tool (APT; U.S. Army Corps of Engineers 2023) can also be helpful for evaluating recent precipitation conditions at a site relative to the 30-year average.

3.5 Assessment reach considerations

3.5.1 Reach placement

Stream assessments should begin by first walking the channel's length, to the extent feasible, from the target downstream end to the top of the assessment reach. This initial review of the reach allows the assessor to examine the channel's overall form, landscape, parent material, and variation within these attributes as they develop or disappear upstream and downstream. This helps determine whether adjustments to assessment reach boundaries are needed, or whether multiple assessment reaches are needed to adequately characterize streamflow duration throughout the project area. Walking alongside, rather than in, the channel is recommended for the initial review to avoid unnecessary disturbance to the stream. Walking alongside the channel also allows the assessor to observe the surrounding landscape's characteristics, such as land use and sources of flow (e.g., stormwater pipes, springs, seeps, and upstream tributaries).

The assessor should document the areas along the stream channel where various sources (e.g., stormflow, tributaries, or groundwater) or sinks of water (alluvial fans, abrupt changes in bed slope, etc.) may cause abrupt changes in flow duration. When practical, assessment reaches should have relatively uniform channel morphology. When evaluating the reach's homogeneity, focus on permanent features that control streamflow duration (such as valley gradient and width) rather than on the presence or absence of surface water. Project areas that include confluences with large tributaries, significant changes in geologic confinement, or other features that may affect flow duration may require separate assessments above and below the feature.

For some applications, reach placement is dictated by project requirements. For example, a small project area may be fully covered by a single assessment reach. In these cases, assessment reaches may contain diverse segments with different streamflow duration classes (e.g., a primarily perennial reach with a short intermittent portion where the flow goes subsurface). In these cases, the portions of the reach with long-duration flows will likely have a greater influence on the outcome than the portions with short-duration flows, depending on each portion's relative size.

Natural features, such as bedrock outcrops or valley confinements, and non-natural features like culverts or road crossings may alter hydrologic characteristics in their immediate vicinity. For example, culverts may create plunge pools, and drainage from roadways is often directed to roadside ditches that enter the stream near crossings, leading to a potential increase in indicators of long streamflow duration. Specific applications may require that these areas be included in the assessment, even though they are atypical of the larger assessment reach. For other applications, the area of influence may be avoided by moving the reach at least 10 m upstream or at least 10 m downstream.

3.5.2 Reach length

An assessment reach should have a length equal to ***40 bankfull channel-widths,*** with a minimum length of 40 m and a maximum of 200 m. An assessment reach should not be less than 40 m in length to ensure that sufficient area is assessed to observe and appropriately measure indicators. Assessments based on reaches shorter than 40 m may not detect all indicators and could provide inaccurate classifications.

Bankfull channel width is averaged from measurements at three locations: at the bottom of the reach, 15 m upstream, and 30 m upstream from the bottom of the reach, or at three locations that are representative of the reach as a whole. See Section 3.7.1 General reach information and Section 3.8.1 Bankfull channel width for more guidance on measuring bankfull channel width. Width measurements are made at bankfull elevation, perpendicular to the thalweg (i.e., the deepest point within the channel that generally has the greatest portion of flow); how to determine bankfull elevation is discussed in Section 3.7.1 General reach information. In multi-thread systems, the bankfull width is measured for the entire active channel, based on the outer limits of the OHWM. Reach length is measured along the thalweg (Figure 4). If access constraints require a shorter assessment reach than recommended above, the actual assessed reach-length should be noted on the field form along with an explanation for why a shortened reach was necessary.

Note that bankfull channel width is also an indicator of streamflow duration, as described below in Section 3.8.1 Bankfull channel width.

3.5.3 How many assessment reaches are needed?

The outcome of an assessment applies to the assessed reach and may also apply to adjacent reaches some distance upstream or downstream if the same conditions are present. The factors affecting spatial variability of streamflow duration indicators (described above) dictate how far from an assessment reach a classification applies. More than one assessment may be necessary for a large or heterogenous project area and multiple assessments are usually preferable to a single assessment. In areas that include the confluence of large tributaries, road crossings, or other features that may alter hydrology, multiple assessment reaches may be required (e.g., one above and one below the feature).

3.6 Photo-documentation

Photographs can provide strong evidence to support conclusions resulting from application of the NE and SE SDAMs, and extensive photo-documentation is recommended. Taking several photos of the reach condition and any disturbances or modifications relevant to making a final streamflow duration classification is strongly recommended. Specifically, the following photos should be taken as part of every assessment:

- A photograph from the top (upstream) end of the reach, looking downstream.
- Two photographs from the middle of the reach, one looking upstream and one looking downstream.
- A photograph from the bottom (downstream) end of the reach, looking upstream.

Photographs that illustrate the following are also strongly recommended:

- Extent of rooted upland plants in channel.
- Prevalence of fibrous roots in streambed.
- Particle size and/or stream substrate sorting.
- Disturbed or unusual conditions that may affect the measurement or interpretation of indicators.

3.7 Conducting assessments and completing the field form

3.7.1 General reach information

After walking the reach and determining the appropriate boundaries for the assessment area, record on the field form the project name, reach code or identifier, waterway name, assessor(s) name(s), and the date of the assessment visit. These data provide essential context for understanding the assessment but are not indicators for determining streamflow duration class.

Coordinates

Record the coordinates (latitude and longitude) of the downstream end of the reach from the center of the channel. When determining Global Positioning System (GPS) coordinates in the field for the assessment reach, use the World Geodetic System 1984 (WGS84) datum and record coordinates in decimal degrees format; this information is used for entering coordinates into the web application (see Section 4 Data Interpretation and Using the Web Application). If possible, set the GPS receiver setting to use the Wide Area Augmentation System (WAAS) or Differential GPS (DGPS) augmentation systems to increase coordinate accuracy. Record the GPS unit used and any information your GPS or cell phone application has regarding signal strength or spatial uncertainty with the obtained coordinates. Document nearby roads, buildings, tributary confluences, and other features that can help corroborate the geospatial location of the assessment reach with the coordinates recorded in the field with your planned assessment location by confirming them on a topographic map, aerial imagery, or Geographic Information System (GIS) software.

Weather conditions

Note current weather conditions (e.g., rain and intensity, sun, clouds, snow). If known, note precipitation within the previous week on the datasheet, and consider delaying sampling, if appropriate (see Section 3.4 Timing of sampling). If rescheduling is not possible, note whether the streambed is recently scoured, or if turbidity or high water is likely to affect the measurement of indicators.

Surrounding land use

A preliminary assessment of surrounding land use should be conducted during desktop reconnaissance (see Section 3.1 Conduct desktop reconnaissance). Once at the site, verify whether the preliminary assessment is correct, making sure to note evidence of human activities that may not be evident in aerial imagery.

Indicate the dominant land-use around the reach within a 100-m buffer. Check up to two of the following:

- Urban/industrial/residential (buildings, pavement, or other anthropogenically hardened surfaces).
- Agricultural (e.g., farmland, crops, vineyard, pasture).
- Developed open space (e.g., golf course, sports fields).
- Forested.
- Other natural.
- Other (describe).

Bankfull channel width

Measure bankfull channel width values (to nearest 0.1 m) at 0, 15, and 30 m above the downstream end of the reach or at three locations spread out over approximately one-third of the expected reach length and record values on the field form (Figure 4 and Figure 5). Note, this approach replicates how the data used to develop these SDAMs were collected at study reaches across the NE and SE regions. Widths should be measured perpendicular to the thalweg. In multi-threaded systems, width measurements should span all channels within the OHWM. Calculate the average width.

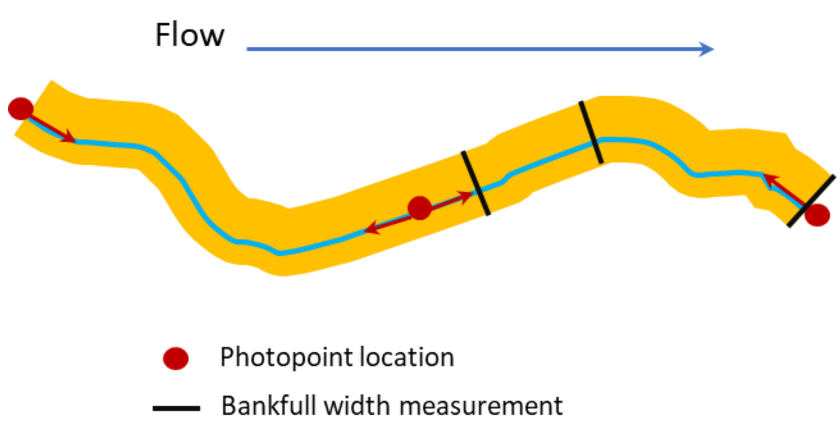


Figure 4. Bankfull measurement and photo point locations. Bankfull is represented by the yellow area and the blue line represents the thalweg of the channel. Bankfull width should be measured at three locations that are representative of the expected reach length.

Figure 5. Measuring bankfull width. Image credit: James Treacy

The bankfull width[4] is the portion of the channel that contains the bankfull discharge, which is a flow event that occurs frequently (typically every 1.01 to 5 years; David and Hamill 2024), but that does not include larger flood events. The bankfull discharge has an important role in forming the physical dimensions of the channel. For many stream channels, the bankfull elevation (from where bankfull width is measured) can be identified in the field by an obvious slope break that differentiates the channel from a relatively flat floodplain terrace higher than the channel or by a transition from exposed stream sediments or more water- and scour-tolerant vegetation (e.g., willows) to terrestrial and intolerant vegetation (David et al. 2025). In locations without vegetation, moss growth on rocks along the banks can be an indicator of bankfull height as can breaks in bank slope or changes in substrate composition.

Certain indicators of bankfull height may be more or less evident in different stream types, so assessors should evaluate multiple bankfull indicators when measuring bankfull channel width. The bankfull width should be measured in a straight section of the stream (e.g., riffle, run, or glide if present) that is representative of the study reach. Pools and bends in the stream or areas where the stream width is affected by the deposition of rocks, debris, fallen trees, or other unusual constrictions or expansions should be avoided. In the field, it may often be possible to determine the bankfull channel width using bankfull indicators on only one bank of the stream. This point can be used as a reference to determine the bankfull elevation on the opposite bank by creating a level line across the stream from the identified bankfull elevation perpendicular to the stream flow.

[4] Resources for bankfull identification are found on the SDAM training materials site.

In larger systems (e.g., drainage area > 0.5 square miles), it may be helpful to compare field measurements to bankfull channel dimensions derived from regional curves relating bankfull dimensions to watershed characteristics. These models may be derived at a national or regional scale (e.g., StreamStats; U.S. Geological Survey 2025) or a local scale (e.g., Texas: Asquith et al. 2020; North Carolina: Harman et al. 1999). Bieger et al. (2015) provides regional curves for several regions of the continental United States. If observed bankfull dimensions are substantially different from estimated bankfull dimensions derived from regional curves (e.g., more than twice the maximum or less than half the minimum estimates), it may be helpful to re-evaluate bankfull indicators that were used to establish bankfull channel height. Although regional curve estimates for bankfull dimensions of small channels (small drainage areas) may be extrapolated outside the range used to develop relationships, such estimates have unknown errors (bias) associated with them and should be used with caution if at all.

Note that bankfull channel width is also an indicator of streamflow duration, as described below in Section 3.8.1 Bankfull channel width.

Describe reach length and boundaries

Record the reach length in meters as described in Section 3.5.2 Reach length. Record observations about the reach on the field form, such as changes in land use, disturbances, or natural changes in stream characteristics that occur immediately up or downstream. If the reach is less than 200 m and shorter than 40 times the average bankfull channel width, explain why a shorter reach length was appropriate. For example: “The downstream end is 30 m upstream of a culvert under a road. The upstream end is close to a conspicuous dead tree just past a large meander, near a fence marking a private property boundary. The reach length was shortened to 150 m to avoid private property.”

Photo-documentation of reach

Record the photo ID or number on the designated part of the field form for required photographs taken from the bottom (facing upstream), middle (facing upstream and downstream), and top (facing downstream) of the reach (see Figure 4).

Disturbed or difficult conditions

Note any disturbances or unusual conditions that may create challenges for assessing flow duration. Common situations include practices that alter hydrologic regimes, such as diversions, culverts, discharges of effluent or runoff, and drought. Note circumstances that may affect stream geomorphology, such as channelization, or vegetation removal that may affect the measurement or interpretation of several indicators (Figure 6). Also note if the stream appears recently restored, for example, stream armoring with large substrate or wood additions and recently planted vegetation in the riparian zone.

Figure 6. Examples of difficult conditions that may interfere with the observation or interpretation of indicators. Left: This stream reach in the North Carolina Piedmont is heavily impacted by cattle through input of nutrients as well as trampling, which may affect abundance and richness of aquatic macroinvertebrates and obscure identification of bankfull elevation. Image credit: EPR. Right: This stream in a park in South Bend, Indiana, is surrounded by urban land uses; the addition of urban non-point source discharges may also impact aquatic invertebrate communities.

Observed hydrology

Surface flow

Visually estimate or use a tape measure to determine the percentage of the reach length that has flowing surface water or subsurface flow. The reach sketch should indicate where surface flow is evident and where dry portions occur.

Subsurface flow

If the reach has discontinuous surface flow, investigate the dry portions to see if subsurface flow is evident. Examine below the streambed by turning over cobbles and digging with a trowel. Resurfacing flow downstream may be considered evidence of subsurface flow (Figure 7). Other evidence of subsurface flow includes:

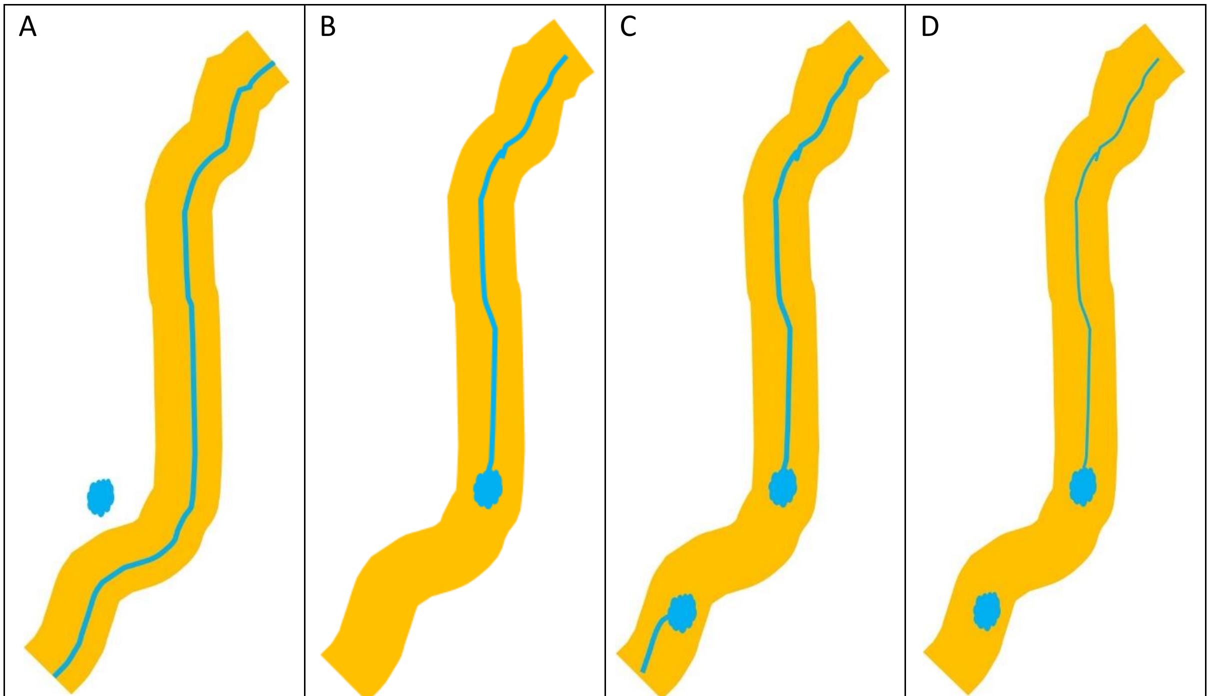
- Flowing surface water disappears into alluvial deposits and reappears downstream. This scenario is common when a large, recent alluvium deposit created by a downed log or other grade-control structure creates a sharp transition in the channel gradient or in valley confinement.
- Water flows out of the streambed (alluvium) and into isolated pools.
- Water flows below the streambed and may be observed by moving streambed rocks or digging a small hole in the streambed.
- Shallow subsurface water can be heard moving in the channel, particularly in steep channels with coarse substrates.

Record the percent of the reach length with subsurface and surface flow (combined). That is, the percent of reach length with subsurface flow should be greater than or equal to the percent of reach length with surface flow (Figure 7).

The reach sketch should indicate where subsurface flow is evident.

Number of isolated pools

If the reach is dry or has discontinuous surface flow, look for isolated pools within the channel that provide aquatic habitat. If there is continuous surface flow throughout the reach, enter 0 (zero) isolated pools. The reach sketch should indicate the location of pools in the channel or on the floodplain (Figure 7). However, only isolated pools within the channel are counted, including isolated pools within secondary channels that are part of the active channel and within the OHWM. Pools connected to flowing surface water and isolated pools on the floodplain do not count. Dry pools (i.e., pools that contain no standing water at the time of assessment) do not count.



100% surface flow **100%** surface + subsurface flow **0** isolated pools	**70%** surface flow **70%** surface + subsurface flow **0** isolated pools	**80%** surface flow **100%** surface + subsurface flow **0** isolated pools	**70%** surface flow **70%** surface + subsurface flow **1** isolated pool

Figure 7. Examples of estimating surface and subsurface flow, and isolated pools. Orange represents the dry channel, and blue represents surface water in the channels. White represents the floodplain outside the channel. The pool in A does not count because it is outside the channel, whereas the pools in B and C do not count because they are connected to flowing surface water. In contrast, the lower pool in D counts because it is isolated from any flowing surface water and is within the channel.

3.7.2 Assessment reach sketch

Sketch the assessment reach on the field form, indicating important features, such as access points, important geomorphological features, the extent of dry or aquatic habitats, riffles, pools, etc. Note locations where photographs are taken and where channel measurements are made.

3.8 How to measure indicators of streamflow duration

Seven indicators are required for the NE SDAM, and ten indicators are required for the SE SDAM; five indicators are shared by both methods. All must be evaluated to determine a flow classification.

Biological indicators

- Aquatic macroinvertebrate indicators
    - Benthic macroinvertebrate index (BMI)
    - Total aquatic macroinvertebrate abundance (SE only)
- Shading
- Prevalence of rooted upland plants in the streambed (SE only)
- Prevalence of fibrous roots in the streambed (SE only)

Geomorphological indicators

- Bankfull channel width
- Entrenchment ratio (NE only)
- Slope (NE only)
- Particle size of stream substrate (SE only)

Geospatial/climatic indicators

- Drainage area
- Elevation
- Average monthly precipitation May-July (SE only)

BMI score and aquatic macroinvertebrate total abundance, drainage area, bankfull width, and particle size/stream substrate sorting are positive indicators of streamflow duration. That is, a greater abundance, strength, or size of these indicators is generally associated with longer duration flows (e.g., Delucchi 1988, Fritz et al. 2008, Smith et al. 2017). For example, higher benthic macroinvertebrate abundance is associated with perennial reaches. The relationship between streamflow duration and bankfull channel width is less straightforward. In general, in the NE and SE, wider channels are more likely to be perennial and positioned lower in the watershed than narrower non-perennial channels (e.g., Fritz et al. 2008, Ohio EPA 2020, Svec et al. 2005). Rooted upland plants and fibrous roots in the streambed are negative indicators of streamflow duration. Greater abundance or expression of rooted upland plants or fibrous roots in the assessment reach is associated with shorter flow duration classes. For consistency with the other indicators in terms of its relationship to evidence of perennial flow, the scoring for both indicators is reversed by characterizing its rarity or absence. Climatic indicators, like precipitation, have been shown to be highly correlated with flow duration and the timing of drying (Hammond et al. 2021). The average precipitation across certain months may be fundamental to whether and/or when drying will occur in SE streams.

These indicators are based on what is observed at the time of assessment, not on what would be predicted to occur if the channel were wet, or in the absence of disturbances or modifications. Disturbances and modifications (e.g., vegetation management, channel hardening, diversions) should be described in the "Notes" section of the datasheet and are considered when drawing conclusions. Common ways that disturbances can interfere with indicator measurement are described within each indicator description, where applicable. The indicators are presented below in the order they appear on the field forms, reflecting the recommended order of operations for efficiency in the field.

Geospatial and climatic indicators are presented last; though for drainage area, a preliminary assessment may be completed prior to visiting the field, as discussed in Section 3.1 Conduct desktop reconnaissance.

3.8.1 Bankfull channel width

Bankfull channel width is generally associated with streamflow duration, as wider channels tend to reflect longer-lasting flows. However, this pattern is sometimes reversed in more arid regions and in regions overlying alluvial geology. Bankfull channel width is measured (to the nearest 0.1 m) at three locations during the initial layout of the assessment reach and then averaged, as described in Section 3.5 Assessment reach considerations. In multi-threaded channels, the width of the entire active channel is measured, based on the outer limits of the OHWM. Wohl et al. (2016) describe the active channel as the portion of the valley bottom distinguished by one or more of the following characteristics:

- Channels defined by erosional and depositional features created by river processes (as opposed to upland processes, such as sheet flow or debris flow).
- The upper elevation limit at which water is contained within a channel.
- Portions of a channel generally without trunks of mature woody vegetation.

3.8.2 Entrenchment Ratio (NE only)

Entrenchment is qualitatively defined as the vertical containment of a river and the degree to which it is incised in the valley floor (Kellerhals et al. 1972). The entrenchment ratio is the ratio of the width of the flood-prone area to the width of the bankfull channel (Rosgen 1994). The flood-prone area width is measured perpendicular to the reach length at the elevation that is twice the maximum bankfull depth (Figure 8). Bankfull is the height on the streambanks during moderate high-water events when water begins to overflow onto the floodplain and should be measured at relatively straight sections of the stream, avoiding pools and areas where the stream width is affected by the deposition of rocks, debris, fallen trees, or other unusual constrictions. See Section 3.7.1 General reach information and Section 3.8.1 Bankfull channel width for more on how to identify and measure bankfull elevation. In incised entrenched streams, it is important to note that the elevation of bankfull discharge may not be at the top of the stream bank.

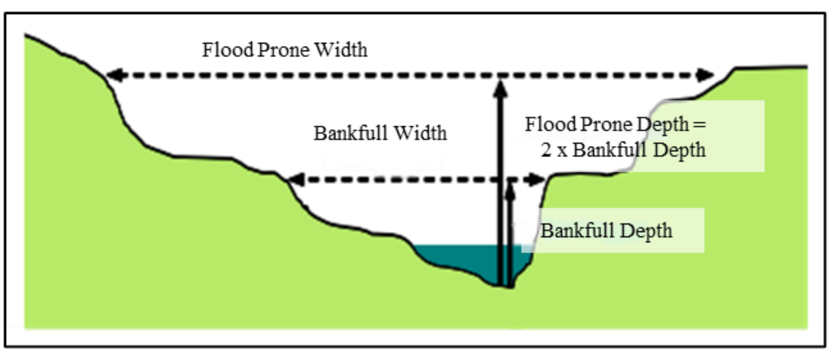


Figure 8. Measurement of entrenchment is based on the ratio of the flood-prone width to the bankfull width.

After determining bankfull width at a representative location, the flood-prone width is measured to the nearest tenth of a meter up to a maximum of 2.5 times the bankfull width:

1. Measure bankfull width at the chosen location and determine the bankfull maximum depth.
2. Identify the flood-prone depth at twice the bankfull maximum depth.
3. Measure the flood-prone width at the flood-prone depth.
4. If the flood-prone width is >2.5 times the bankfull width, record as >2.5 X bankfull width.
5. Repeat measurement of flood-prone width at each location where bankfull width is measured, making sure that these locations are representative of overall valley conditions. Avoid assessing flood-prone width in places where the degree of valley constriction (whether from natural or man-made constrictions, like hillslopes or buildings) is not characteristic of the reach.

3.8.3 Aquatic macroinvertebrate indicators

The SE SDAM has two indicators based on aquatic macroinvertebrates, and one of these indicators is also used in the NE SDAM. Both aquatic macroinvertebrate indicators are measured from the same sample collection effort described below.

Sample Collection Instructions

Aquatic macroinvertebrates are assessed within the defined reach. A kick-net or D-frame net is used to collect specimens. Assessors begin sampling at the most downstream point in the assessment reach and proceed to sample the upstream direction. Where there is rapidly flowing water, the net is placed perpendicular against the streambed while the substrate is disturbed upstream of the net for a minimum of one minute. This disturbance will dislodge and suspend aquatic macroinvertebrates such that they are carried by the stream flow into the net. For slower flowing or standing water areas, jab the net under banks, overhanging terrestrial and aquatic vegetation, leaf packs, and in log jams or other woody material to dislodge and capture aquatic macroinvertebrates and the leaves or other light materials the aquatic macroinvertebrates may be clinging to. Samples should be collected from **at least six** distinct locations representing the different habitats occurring in the reach. Without releasing aquatic macroinvertebrates, strain the net contents to remove fine sediments that would interfere with observing them. Empty contents of the net into a white tray with fresh stream water for determining abundance of individuals present.

Searching is complete when:

- **At least six different locations within the reach have been sampled** across the range of habitat types **and** a minimum of **15 minutes** of effort expended (not including sample sorting to facilitate enumeration), **or**
- **All available habitat in the assessment reach has been completely searched** in less than 15 minutes. A search in dry stream channels with little bed or bank development and low habitat diversity may be completed in less than 15 minutes.

During the 15-minute sampling period, search the full range of habitats present, including: water under overhanging banks or roots, in pools and riffles, accumulations of leaf packs, woody debris, and coarse inorganic particles (i.e., pick up rocks and loose gravel). If a reach contains both dry and wet areas, focus on searching the wet habitats, as these are the most likely places to encounter aquatic macroinvertebrates, but do not ignore dry areas.

Dry channels: Focus the search on areas serving as refuge, such as any remaining pools or areas of moist substrate for living aquatic macroinvertebrates, and under cobbles and other larger bed materials for evidence such as caddisfly casings (Figure 9) and snail shells. Exuviae of emergent mayflies or stoneflies may be observed on dry cobbles or stream-side vegetation (Figure 9). In summary, a sampling methodology consistent with the Xerces Society's recommendations on using aquatic macroinvertebrates as indicators of streamflow duration (Blackburn and Mazzacano 2012), as developed for the Pacific Northwest SDAM (Nadeau 2015), is recommended. Take care, especially in dry channels, to only collect aquatic species and life stages. Field guides (e.g., Voshell 2002) and identification keys (e.g., Merritt et al. 2019) and/or web applications (e.g., PocketMacros[5]) are recommended, especially if users are unfamiliar with common types of aquatic macroinvertebrates.

Figure 9. Examples of evidence of aquatic macroinvertebrates in dry channels. Left: Caddisfly cases may persist under large cobbles or boulders well after the cessation of flow. Right: Stonefly (Plecoptera) exuvia. Exuviae are left behind when aquatic nymphs or pupae emerge from the stream and go through a final molt to metamorphose to winged adults. Image credits: Raphael Mazor.

When searching dry channels (or dry portions of partially wet channels), be sure to avoid counting terrestrial macroinvertebrates in the streambed. Figure 10 depicts common terrestrial taxa that may be found near stream channels. If you are unsure whether the invertebrates you encounter are aquatic or terrestrial, collecting a voucher specimen and identifying it in a lab setting or consulting an entomologist is recommended.

[5] https://www.macroinvertebrates.org/app/download

Figure 10. Examples of terrestrial macroinvertebrates you may find in a dry channel. Top Left: larva of soldier flies (Stratiomyidae). Top Right: garden snail (*Cornu aspersum*) (Image credits: Raphael Mazor); Middle left: Earthworm (*Lumbricus terrestris*) (Image credit: Ren Pedersen); Middle right: Woodlouse or pillbug (*Armadillidium vulgare*) (Image credit: Dann Thombs CC-BY-NC-ND); Bottom right: Common pink flat-back millipede (*Pseudopolydesmus serratus*) (Image credit: Ken Clark CC-BY); Bottom left: White-lip globe snail (*Mesodon thyroidus*, Polygyridae) (Image credit: Joe Arruda CC-BY-NC).

3.8.3.1 Benthic Macroinvertebrate Index (BMI) score

This indicator scores the total abundance and richness of all aquatic macroinvertebrates. Richness is based on family-level identification for aquatic insects and mollusks, order-level for crustaceans and mites, and class or phylum for all other aquatic macroinvertebrates. When enumerating this indicator, living material (e.g., live aquatic insect larvae or pupae) and non-living material (e.g., caddisfly cases, shed exuviae) are considered equally. Individuals of terrestrial adult stage of aquatic insects are not included.

Scoring for this indicator is as shown in Table 3. Though not required, identified taxa contributing to richness should be indicated on the field form. A guide to taxa commonly encountered during field data collection for the NE and SE SDAM effort can be found in Appendix B.

Table 3. Scoring guidance for the BMI indicator.

Score	Evidence of perennial flows	Guidance
0	Absent	No aquatic macroinvertebrates observed.
1	Weak	Total abundance is 1 to 3.
2	Moderate	Total abundance is ≥4.
3	Strong	Total abundance is ≥10 AND richness ≥3, OR Richness ≥5.

3.8.3.2 Total aquatic macroinvertebrate abundance (SE only)

This indicator scores the total abundance of aquatic macroinvertebrates in the reach, including insects and non-insects. It does not require identification of aquatic macroinvertebrates; however, counted individuals must only represent aquatic stages (or instars). Both living material (e.g., live larvae) and non-living material (e.g., caddisfly cases, shed exuviae) are considered equally during enumeration. Scoring is as shown below:

- No aquatic macroinvertebrates observed.
- Total abundance of aquatic macroinvertebrates is 1 or 2.
- Total abundance of aquatic macroinvertebrates is 3 to 40.
- Total abundance of aquatic macroinvertebrates is 41 or more.

3.8.4 Slope (NE only)

Slope has an indirect relationship with streamflow duration and can help modify the interpretation of other indicators measured as part of the SDAM. Reaches with very high slopes are often ephemeral headwaters, and lower slopes are typical of perennial mainstem reaches.

Slope is measured as the percent slope between the upper and lower extent of the assessment reach. This task requires a two-person team (Figure 11). One person stands at bankfull elevation at the downstream end of the reach, and a second person stands within eyesight at the opposite end of the reach, also at bankfull elevation. This measurement requires direct line-of-sight between the lower and upper ends of the reach. If direct line-of-sight from the bottom to top of the reach is not possible, the slope of the longest representative portion of the reach should be 'line-of-sight' evaluated. If multiple slope measurements are needed, the average slope of the assessment reach should be recorded (note, calculation of the average slope would need to be weighted by the channel distance represented by each slope measurement). Slope should be recorded to the nearest half-percent. To convert slope from degrees to percent multiple the tangent of the degrees by one hundred (i.e., tan(degrees)*100 = % slope). Some low-gradient streams may have slopes that are indistinguishable from zero using this method.

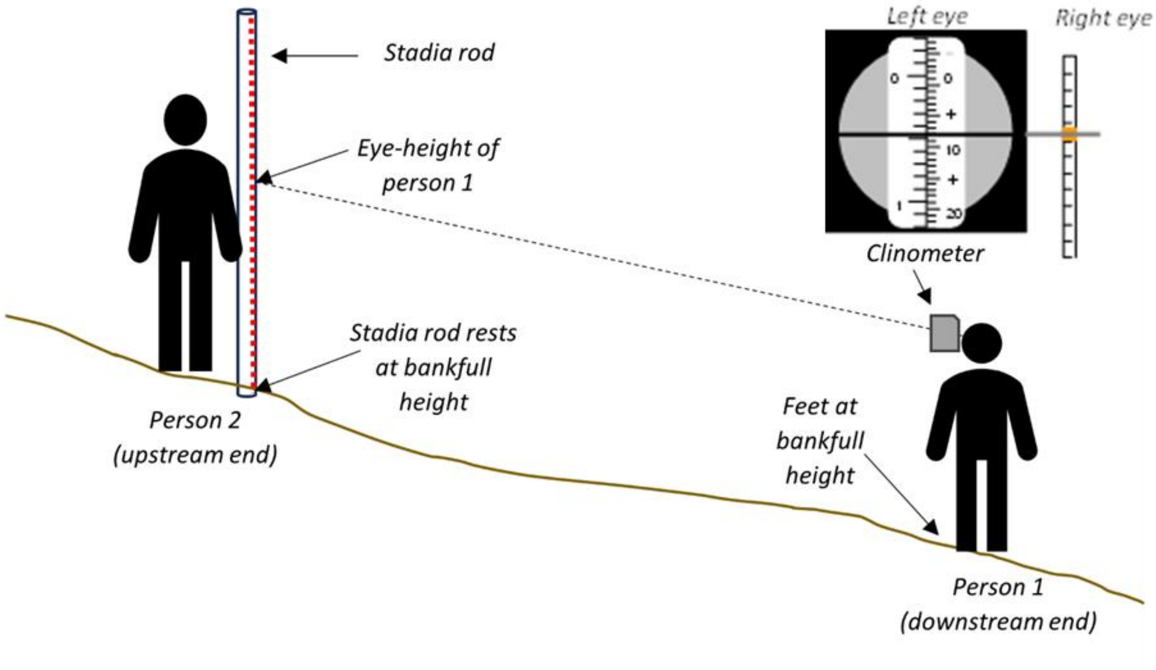


Figure 11. Schematic illustration of slope measurement using a clinometer.

3.8.5 Shading

Using a convex spherical densiometer, stream shading is estimated in terms of the percent cover of objects (e.g., vegetation, buildings, canyon walls, etc.) that have the potential to block sunlight. The procedure used in the NE and SE SDAMs uses the Strickler (1959) modification of a densiometer to correct for over-estimation of stream shading that occurs with unmodified readings. Taping off (Figure 12) the lower left and right portions of the mirror emphasizes overhead structures over foreground structures (the main source of bias in stream shading measurements).

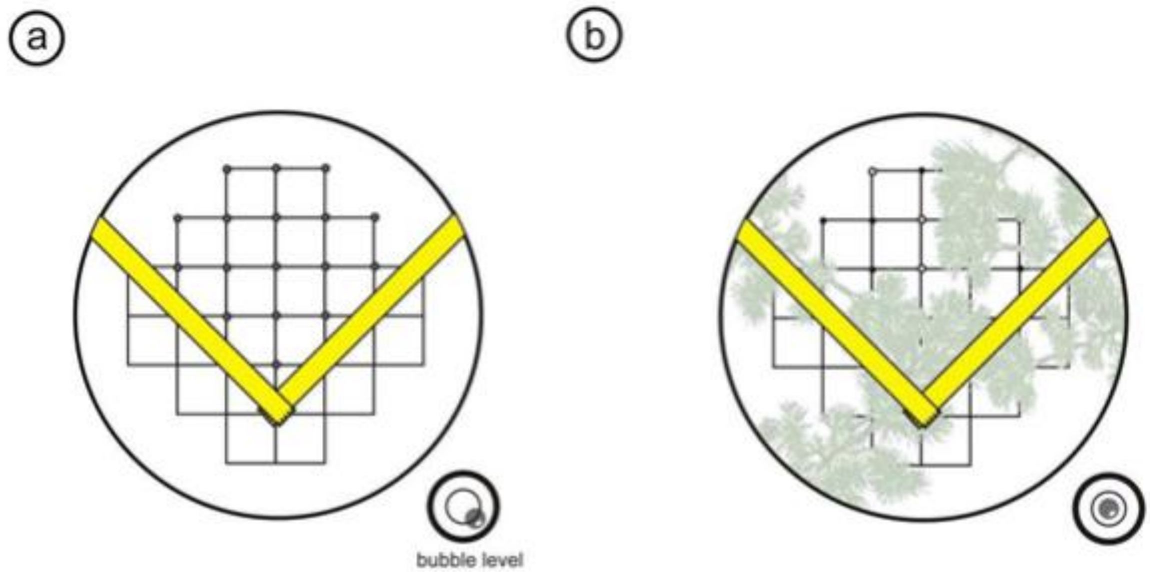


Figure 12. Representation of the mirrored surface of a convex spherical densiometer showing the position for taping the mirror and the intersection points used for the densiometer reading. The score for the hypothetical condition (b) is 9 out of 17 possible covered intersection points within the "V" formed by the two pieces of tape.

The densiometer is read by counting the number of line intersections on the mirror that are obscured by overhanging vegetation or other features that prevent sunlight from reaching the stream. If measurements are being taken when leaves of deciduous woody vegetation are not fully expressed, count all grid intersections that lie within the branches of the woody vegetation. So rather than looking at individual tree leaves, look at the "zone of influence" of vegetative cover (Nadeau et al. 2020).

All densiometer readings should be taken at 0.3 m above the water surface (or dry streambed surface) and with the bubble on the densiometer leveled. The densiometer should be held just far enough from the squatting observer's body so that his/her forehead is just barely obscured by the intersection of the two pieces of tape, when the densiometer is oriented so that the "V" of the tape is closest to the observer's face.

Take and record four readings from the center of each of three transects spanning the width of the bankfull channel: a) facing upstream, b) facing downstream, c) facing the left bank, and d) facing the right bank. Each recording should be an integer value ranging from 0 to 17. The observer should revolve around the densiometer (i.e., the densiometer pivots around a point) over the center point of the transect (as opposed to the densiometer revolving around the observer). Read and record densiometer readings at the top, middle, and bottom of the reach, for a total of 12 readings (four readings at each of three transects). The indicator is then recorded as the percent of points covered by shade-casting objects, total points covered divided by 204 and multiplied by 100.

3.8.6 Prevalence of rooted upland plants in streambed (SE only)

Few terrestrial upland plants can tolerate the conditions they would experience on the streambed of a reach with relatively long flow durations. Prolonged inundation, soil saturation, and sheer stress create an inhospitable environment for most upland plants, preventing their establishment or persistence.

Thus, the prevalence of upland plants in the streambed indicates that flows have insufficient frequency, duration, or severity to limit these species.

For this indicator, upland plants are those with FAC, FACU, and Upland (UPL) indicators or species with No Indicator (NI) on the most recent NWPL.[6] **NOTE**: while some applications of the NWPL treat FAC plants as hydrophytes, they do not count as hydrophytes for purposes of the SE SDAM. For instance, some well-known riparian species are FAC in the NWPL regions applicable to the SE, such as Eastern cottonwood (*Populus deltoides*; all applicable NWPL regions) and box elder (*Acer negundo*; all applicable NWPL regions).

The SE region encompasses parts of three different NWPL regions: Atlantic and Gulf Coastal Plain (AGCP), Eastern Mountains and Piedmont (EMP), and the Great Plains (GP) (Figure 13). Indicator status for certain species may differ between regions; therefore, it is important to consult the correct list when determining indicator status. For example, spicebush (*Lindera benzoin*), a common, widespread shrub often found growing in riparian areas, is FACW in the ACGP and GP but FAC in the EMP.

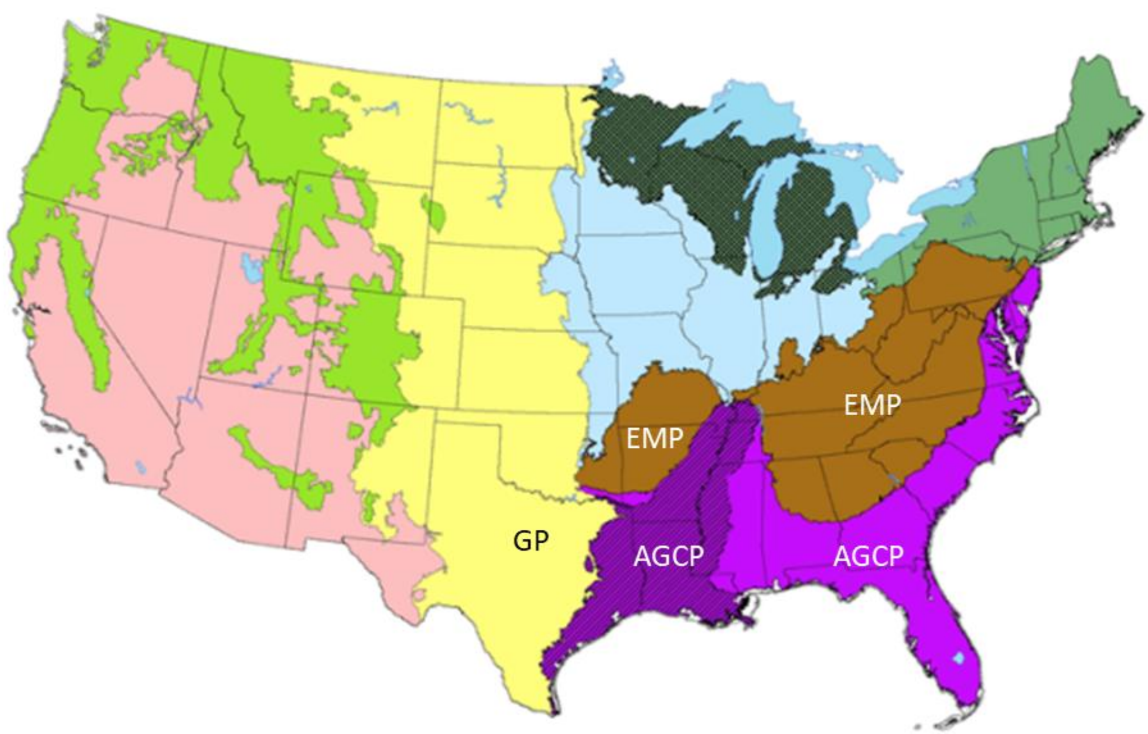


Figure 13. National Wetland Plant List (NWPL) regions that overlap with the SE SDAM region.

What if I can't confidently identify a plant?

It may be acceptable to use environmental context and cues to determine that a plant is a non-hydrophyte, even if taxonomic identifications cannot be made. If a plant is growing exclusively in the channel and is absent from adjacent uplands, that may indicate the plant is a hydrophyte and should not be considered for this indicator. Also, if a genus-level identification can be made, some genera are

[6] https://nwpl.sec.usace.army.mil/

dominated by either upland species (e.g., *Acer*) or hydrophytic species (e.g., *Ludwigia*). Post-sampling confirmation based on photos or collected specimens is strongly recommended. Photos can also be used when consulting plant identification applications that use image recognition (e.g., Seek, iNaturalist).

When assessing this indicator, the focus should be on plants rooted on the entire streambed, including the thalweg. Upland plants growing on any part of the bank or on upland islands within the OHWM should not be considered. A user will indicate the prevalence of upland plants growing in the streambed along the entire reach and identify them on the field form. This indicator is scored as shown in Table 4. Note that a ***lower*** score indicates ***greater*** prevalence of rooted upland plants in the streambed.

Score the indicator using the guidance in Table 4; photos that demonstrate the scoring guidance are shown in Figure 14.

This indicator is derived from the North Carolina Methodology for Identification of Intermittent and Perennial Streams (NCDWQ 2010). As with other indicators derived from the North Carolina Methodology, “moderate” scores (i.e., 2) are intended as an approximate midpoint between the extremes of “poor” and “strong”.

Table 4. Scoring guidance for the Prevalence of Rooted Upland Plants in the Streambed indicator.

Score	Evidence of perennial flows	Guidance
0	Absent	Rooted upland plants are prevalent within the streambed (greater than 75%).
1	Weak	Rooted upland plants are consistently dispersed throughout the streambed (20 – 75%).
2	Moderate	Few rooted upland plants are present within the streambed (less than 20%).
3	Strong	Rooted upland plants are absent within the streambed.

Figure 14. Examples illustrating scoring levels for the Prevalence of Rooted Upland Plants in the Streambed indicator. White arrows identify the streambed locations with rooted upland plant species in the photos. (0) Lowbush blueberry (*Vaccinium angustifolium*; FACU) is prevalent in the channel; (1) Common dittany (*Cunila origanoides*; NI) is widely dispersed throughout the streambed; (2) A few wood nettle individuals (*Laportea canandensis*; FAC) are found in the streambed; and (3) The only rooted plants in the streambed are hydrophytes (*Justicia americana*, water willow; OBL).

3.8.7 Particle size of stream substrate (SE only)

Well-developed channels that have eroded through the soil profile often have substrate materials dominated by larger sediment sizes, such as coarse sand, gravel, and cobble, relative to finer textured floodplain sediments and adjacent soils. Similar sediment sizes in the stream bed and the adjacent streamside area may indicate that stream forming processes have not been consistent enough to cut into the soil profile typical of an intermittent or perennial stream. For instance, the bed of intermittent or perennial streams is often comprised of coarser sediment relative to the bank area or floodplain due to consistent stream-forming flows that have transported finer particles downstream as the channel has eroded downward.

Evaluate whether the distribution of sediment size in the stream substrate is relatively coarser than the adjacent floodplain or streamside area to determine if downcutting has penetrated through the soil profile.

Score the indicator using the guidance in Table 5; photos that demonstrate the scoring guidance are shown in Figure 15.

This indicator is derived from the North Carolina Methodology for Identification of Intermittent and Perennial Streams (NCDWQ 2010). As with other indicators derived from the North Carolina Methodology, “moderate” scores (i.e., 2) are intended as an approximate midpoint between the extremes of “poor” and “strong”. Half scores (i.e., 0.5, 1.5, and 2.5), mid-way between the scores shown in Table 5 are appropriate to allow the assessor the flexibility to characterize this indicator more continuously.

Table 5. Scoring guidance for Particle Size of Stream Substrate indicator.

Score	Evidence of perennial flows	Guidance
0	Absent	The channel is poorly developed, very little to no coarse sediment is present. There is no difference between particle size in the stream substrate and adjacent land.
1	Weak	The channel is poorly developed through the soil profile. Some coarse sediment is present in the streambed but is discontinuous. Particle size differs little between the stream substrate and adjacent land.
2	Moderate	There is a well-developed channel, but it is not deeply incised through the soil profile. Some coarse sediment is present in the streambed in a continuous layer. Particle size differs somewhat between the stream substrate and adjacent land.
3	Strong	The channel is well-developed through the soil profile with relatively coarse streambed sediments compared to the riparian zone soils: coarse sand, gravel, or cobbles in the piedmont; cobbles or boulders in the Mountains; and medium or coarse sand in the coastal plain. Particle size differs greatly between the stream substrate and adjacent land.

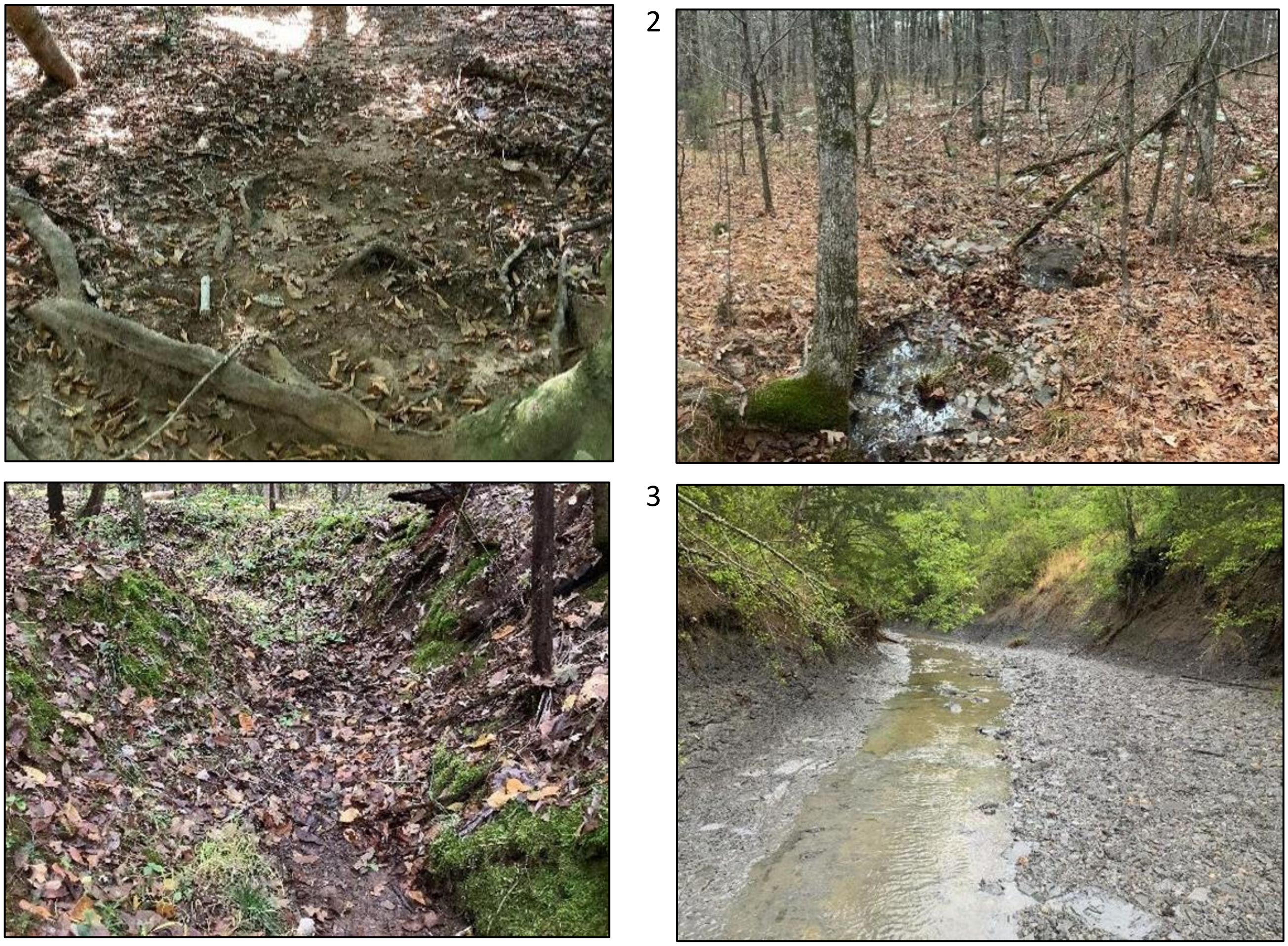


Figure 15. Examples illustrating scoring levels for the Particle Size of Stream Substrate indicator. (0) Channel is poorly developed, with little or no sediments coarser than adjacent land present; (1) Channel is still not well developed, but some discontinuous areas of sediments coarser than adjacent land can be found under the leaves; (2) Channel is well developed, but not deeply incised through the soil profile and there is a more continuous layer of coarser sediment compared to adjacent area; (3) Channel is well developed through soil profile with coarser sediments than surrounding riparian areas throughout.

3.8.8 Prevalence of fibrous roots in streambed (SE only)

Fibrous roots are non-woody, small diameter (<0.2.5 mm) roots that grow shallowly and can often form dense masses in the first few inches of the soil (Figure 16). These roots are generally easy to tear and function in water and nutrient uptake. The presence of fibrous roots reflects the incursion of upland plants into the streambed, where the presence of water and high-energy flows might typically limit their growth. The roots of hydrophytes and riparian trees are adapted to water flow and are more robust (i.e., harder to tear) and should not be considered when evaluating this indicator.

When assessing this indicator, the focus should be on fibrous roots in the streambed, including the thalweg. Roots growing in any part of the bank or on upland islands within the OHWM should not be considered. A user will indicate the prevalence of fibrous roots growing in the streambed along the entire reach and identify them on the field form. This indicator is scored as shown in Table 6. Note that a **lower** score indicates **greater** prevalence of fibrous roots in the streambed.

This indicator is derived from the North Carolina Methodology for Identification of Intermittent and Perennial Streams (NCDWQ 2010). As with other indicators derived from the North Carolina Methodology, “moderate” scores (i.e., 2) are intended as an approximate midpoint between the extremes of “poor” and “strong”. Half scores (i.e., 0.5, 1.5, and 2.5), mid-way between the scores shown in Table 6, are appropriate to allow the assessor the flexibility to characterize this indicator more continuously.

Table 6. Scoring guidance for the Fibrous Roots in Streambed indicator.

Score	Evidence of perennial flows	Guidance
0	Absent	A strong network of fibrous roots is persistent in the stream thalweg and surrounding area.
1	Weak	A discontinuous network of fibrous roots is present in the stream thalweg and surrounding area.
2	Moderate	Very few fibrous roots are present anywhere in the streambed.
3	Strong	No fibrous roots are present.

Figure 16. Example of fibrous roots (left) vs. woody roots (right).

3.8.9 Drainage Area

Drainage area is rapidly calculated using one of two existing web tools, USGS StreamStats or The National Map Viewer. For drainage areas less than 1 square mile, round to the nearest 0.001 square miles. For this indicator, it is important to have accurate location coordinates, see instructions in Section 3.7.1 General reach information. The National Map Viewer is used only when a StreamStats calculation cannot be made due to regional unavailability or a restricted boundary, or when the channel is not mapped by the National Hydrography Dataset (NHD). States in which StreamStats is currently not available at the time of publication include, but are not limited to: Florida, Louisiana, Michigan, and Texas. See instructions below on how to calculate drainage area using StreamStats and The National Map Viewer.

Instructions to calculate drainage area using StreamStats[7]:

1. Refer to field notes and sketches made during the reach assessment that identify features such as roads, confluences, and topographic relief (see Conducting assessments and completing the field form section). This will help confirm the reach location when calculating drainage area.
2. Go to https://streamstats.usgs.gov/ss/.
3. In the Search for a place box, enter latitude and longitude (longitude should be a negative value) coordinates in decimal degrees separated by a comma and space, press enter, and select the appropriate state that pops up on the left-hand panel.
4. Click the Delineate button in blue on the left-hand panel; the Delineate button will then turn red. On the map, the red circle represents the assessment reach. Click on a blue water pixel within the circle, and the basin will be delineated.
    a. Before selecting the blue pixel, observe geographical features on the web map and compare with field notes for coordinate selection.
        i. On StreamStats different base maps are available for viewing imagery. If the coordinate location does not fall directly on one of the blue water pixels, but the coordinate location can be traced perpendicular to a pixel, then using that pixel is acceptable. This should be given careful consideration because selecting a pixel on a larger, downstream segment or parallel segment draining an adjacent catchment would likely produce an inaccurate drainage area. Not all channels observed in the field may be represented as blue pixels in StreamStats or as blue lines on The National Map layer. In this case, it is best to refer to field observations of surrounding features and compare with the web map. If the coordinate point does not correspond to a pixel on StreamStats, The National Map Viewer should be used.
        ii. Conditions that complicate drainage area calculations include locations near tributary junctions where three potentially different stream channels (upstream mainstem, tributary, and mainstem) connect at a single point, and where the coordinate location is between two parallel stream channels. In both cases, use field notes, assessment reach sketches, and features on base map layers like roads and topographic relief to select the appropriate pixel for the assessment reach.
    b. If the red circle does not touch a water pixel or does not border one, then clicking on the red circle may produce an inaccurate delineation (this is especially true with changes in elevation). In this case, use The National Map Viewer instead.

[7] As of May 2025

5. The Basin will be delineated in yellow (Figure 17). Click Continue on the left-hand panel. Scroll down to Basin Characteristics and check DRNAREA and then click Continue at the bottom. If the DRNAREA is not an option (as has been observed in Oklahoma, for example), use CONTDA (contributing drainage area), if neither DRNAREA nor CONTDA are available, use The National Map Viewer instead.
6. Select Open Report to see the area measurement. If the area measurement is less than 1 sq. mile, round to the nearest 0.001 sq. mile as your input into the web application.

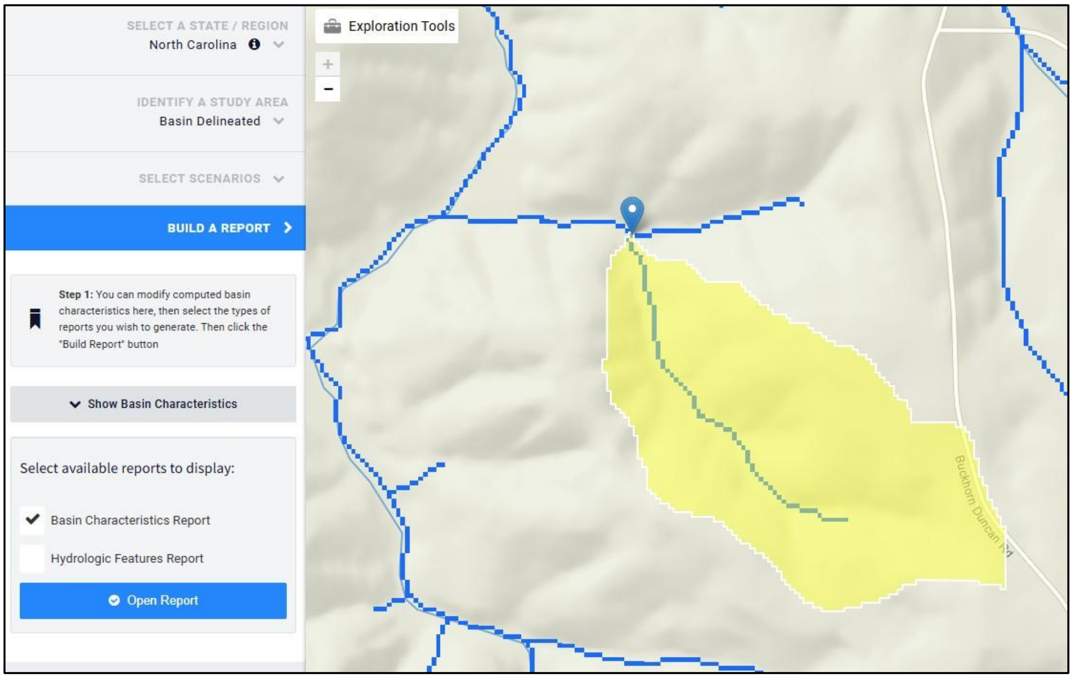


Figure 17. Calculating drainage area using StreamStats.

Instructions to calculate drainage area using The National Map Viewer[8]:

1. Go to https://apps.nationalmap.gov/viewer/.
2. On the green toolbar along the right, click on the top button, Basemap. Select USGS National Map, additional base maps are also available and may be useful for finding the location on the map. Not all channels observed in the field may be represented as blue lines on the USGS National Map. In this case, it is best to refer to field observations of surrounding features and compare with the base maps.
3. Click on the next button down, Layers. Scroll down the Layers menu and click on: NHD Plus High-Resolution Dataset, Watershed Boundary Dataset, and 3DEP Elevation – Auto Contours to make them visible. The fine pink lines represent catchment boundaries for NHD Plus.
4. In the white search bar on the upper left, enter the latitude coordinate, a comma and space, and then the longitude coordinate (which should be a negative value). Coordinates should be in decimal degrees. Press enter and a black circle will appear on the map.

[8] As of May 2025

5. Zoom out (using either "-" button on the left or mouse scroll wheel) to see the surrounding topographic contour lines to delineate the basin.
6. On the toolbar, select the button with a ruler, the Measurement tool. Click the Area button.
7. Start at the black circle and begin to draw a polygon by left clicking and moving the cursor along the desired boundary. A measurement box will appear on the lower left.
8. Where possible, trace the Hydrologic Unit boundary; otherwise, use the contour lines for the delineation. Single left click at each corner or wherever the boundary is not a straight line. Concave curvature (contour lines bending away) represents the valley containing the channels whereas convex curvature (bending toward) represents the ridge. Continue around the entire watershed perimeter, double click to complete the polygon.
9. In the Measurement tool box select Square Miles in the unit dropdown menu. If the area is less than 1 square mile, change the units to Hectares and then convert hectares to square miles (multiply by 0.00386). Round the area to the nearest 0.001 sq. mile as your input into the web application (Figure 18).

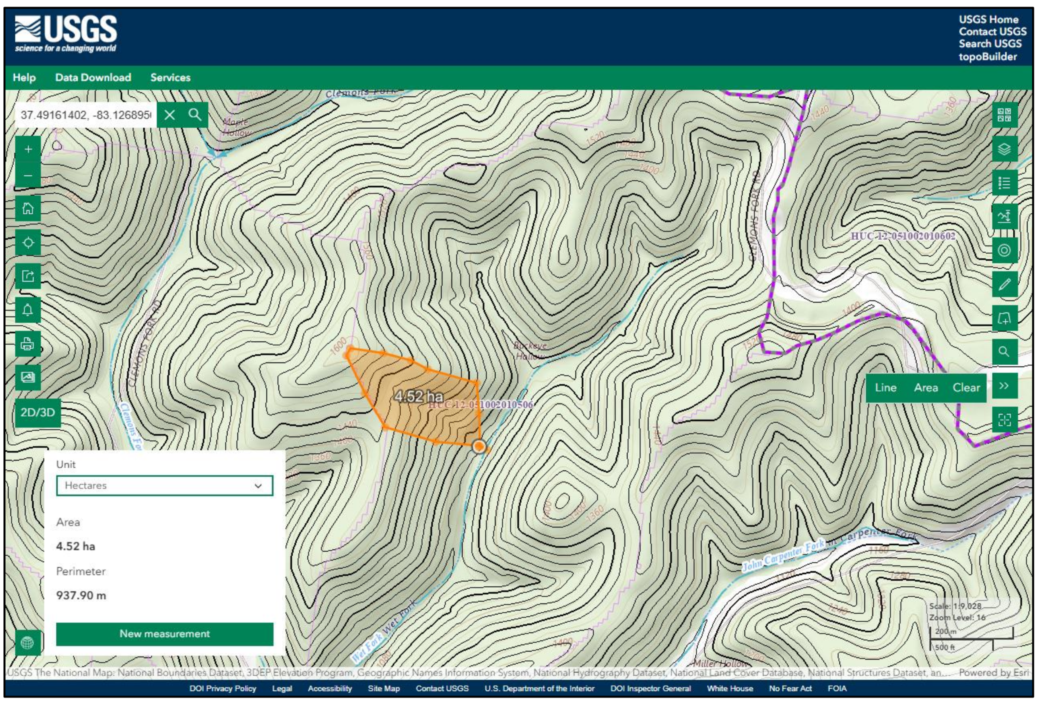


Figure 18. Calculating drainage area using The National Map Viewer. Converting hectares to square miles and rounding results in 0.017 square miles (4.52 * 0.00386 = 0.01745, rounds to 0.017).

3.8.10 Elevation

This indicator uses elevation data from the Amazon Web Services (AWS) terrain tiles dataset.[9] The SDAM web application will retrieve this value based on coordinates entered or a selected location on the map when selecting the appropriate regional SDAM (see Section 4 Data Interpretation and Using the Web Application). Therefore, it is important to have accurate location coordinates for the

[9] https://registry.opendata.aws/terrain-tiles/.

downstream end of the reach, see instructions in Section 3.7.1 General reach information. Note, if the coordinates used in StreamStats or The National Map Viewer to delineate the drainage area are different than those collected in the field, use the coordinates from StreamStats or the The National Map Viewer in the SDAM web application to retrieve the elevation.

To obtain the elevation without using coordinates or the map to determine the appropriate regional SDAM in the web application, enter coordinates where prompted in the indicators section of the web application.

3.8.11 Average Monthly Precipitation for May, June, and July (SE only)

This indicator is calculated using the 30-year average precipitation from the PRISM (Parameter-elevation Regression on Independent Slopes Model) Climate Group statistical mapping system from May, June, and July.[10] The average monthly precipitation will be automatically calculated by the web application based on the coordinates entered or point on the map selected. Note, if the coordinates used in StreamStats or The National Map Viewer to delineate the drainage area are different than those collected in the field, use the coordinates from StreamStats or The National Map Viewer in the SDAM web application.

To obtain the average monthly precipitation without using coordinates or the map to determine the appropriate regional SDAM in the web application, enter coordinates where prompted in the indicators section of the web application.

3.9 Additional notes and photographs

After assessing and recording all the indicators described above, provide any additional notes about the assessment including whether any fish were present in the reach (except mosquito fish, *Gambusia* spp.); include photographs in the photo log.

[10] See https://prism.oregonstate.edu/normals/

Section 4: Data Interpretation and Using the Web Application

The NE and SE SDAMs rely on random forest models to make classifications; therefore, the EPA has developed a free, open-access web application that runs the model for each assessment reach and is used to obtain a flow classification. This application allows assessors to input data from assessments, including ordinal scores and non-ordinal information like number of aquatic macroinvertebrates. In addition, users have the option to produce a PDF report, which may be included as documentation of SDAM results. No data entered into the web application are stored or submitted to the EPA or other agencies.

The web application walks users through three steps in analyzing data from an SDAM. First, the user selects the desired regional SDAM (either by entering coordinates, clicking on a map, or selecting from a drop-down list). The coordinates field of the web application uses decimal degrees format of the World Geodetic System 1984 (WGS84) datum. Then the user enters field data on each indicator required for the selected SDAM. At this point, the user can run the model and obtain the resulting classification. The third step, report production, is optional. Users may enter additional information about the assessment (such as date of the site visit, notes, and photos of indicators) and produce a PDF report. A link at the top of the web application provides Supporting Materials including User Manuals, Field Forms, Training Videos and more.

4.1 Outcomes of NE and SE SDAM classification

As described in Section 1.1 The SDAM for the Northeast and Southeast, application of the SDAM can result in one of six possible classifications:

- Ephemeral
- Intermittent
- Perennial
- At least intermittent
- Less than perennial
- Needs more information

The first three streamflow duration classifications correspond to the three classes of streams used to calibrate the NE and SE SDAMs. These outcomes occur when the pattern of observed indicators closely matches patterns in the calibration data, and thus a classification can be assigned with high confidence. Single indicators of flow duration (see Nadeau 2015) were tested for the NE and SE SDAMs, but data analysis did not suggest that their use would improve classification accuracy.

In some cases, the pattern of indicators is associated with multiple classes, and the NE and SE SDAM models cannot assign a single classification with high confidence. However, the models may be able to rule out an ephemeral classification with high confidence or a perennial classification with high confidence. In the former case, the outcome is at least intermittent, meaning that there is a high likelihood that the stream is either perennial or intermittent, but not ephemeral. In the latter case, the outcome is less than perennial, meaning that there is a high likelihood that the stream is either intermittent or ephemeral, but not perennial. In both cases, the two classes (i.e., perennial vs. intermittent and intermittent vs. ephemeral) cannot be distinguished with confidence. In some instances, this information may be sufficient for management decisions, although additional assessment may be warranted. Two outcomes, at least intermittent and less than perennial, were rare in the NE and SE SDAM development data sets: less than 4% of the time for both classifications. The needs more information outcome is possible and generally occurs when no classification can be made with confidence, but this did not occur in the development data sets for either the NE or SE regions.

4.2 Applications of the NE and SE SDAMs outside the intended area

The NE and SE SDAMs are intended only for application to these regions as shown in Figure 2. The online web application allows the user to apply the protocol to reaches outside of these regions; however, classifications resulting from these applications are for informational purposes only. For example, it may be helpful to assess reaches with more than one regional SDAM near regional boundaries. The online web application allows the users to apply indicator data collected from reaches outside the NE or SE regions to generate NE or SE model classifications. Reports generated from such applications will identify the SDAM region in which the assessed reach was located.

4.3 What to do when a more specific classification is needed

If the application of the NE or SE SDAM results in needs more information, it means that no classification can be made with confidence. If an assessment's outcome is ambiguous about the specific flow duration class (i.e., less than perennial or at least intermittent), it may help to examine other lines of evidence or conduct additional assessments, as described below in approximate order of increasing effort.

<u>When a more specific classification is needed:</u>

- Review historical aerial imagery
- Conduct additional assessments at the same reach
- Conduct assessment at similar nearby reaches
- Conduct reach revisits during regionally appropriate wet or dry seasons
- Collect hydrologic data

4.3.1 Review historical aerial imagery

<u>Considerations for aerial imagery</u>

- Accurate dates of images
- Changes in reach or watershed conditions since image was taken
- Seasonal and recent climatic conditions for each image

In much of the NE and SE, forest cover obscuring the channel often prevents the use of sequences of aerial imagery to provide information about streamflow duration. In settings where forest cover is absent or less dense, as well as in certain areas along the western margins of the NE and SE regions (e.g., Texas and Oklahoma), the use of Google Earth's time slider and USGS Earth Explorer offer a convenient method of reviewing historical imagery (however, dates indicated by Google Earth time slider may be approximate or not accurate). If surface water is observed in all interpretable images across multiple years (especially during dry seasons), this may provide evidence that the reach is likely perennial. If surface water is never observed, even when other nearby intermittent streams show water, the consistent absence of surface water may provide evidence that the reach is likely ephemeral (particularly if images are captured during the wet season or after major storm events). If surface water is present in some images and dry in others, the stream may be intermittent. The evidence for perennial flow is strong if the images with surface water occur in the dry season, and do not coincide with recent storm events. It is also important that users consider whether conditions as reflected by historical imagery are congruent with current conditions. For example, due to groundwater withdrawals, a stream that once flowed perennially may now have ephemeral flow; therefore, images from 15-20+ years in the past might not be indicative of current flow conditions.

Any time that discrete observations of flow or no flow are used to inform a determination of flow duration class, such observations should be evaluated in the context of relatively normal climatic conditions. Doing so ensures that flow duration class is not determined based on observations of flow or no flow during abnormally wet or abnormally dry periods. The Antecedent Precipitation Tool (U.S. Army Corps of Engineers 2023) is a useful tool to determine if climate conditions are ‘normal’ for a locale (see Section 3.4 Timing of sampling). However, aerial images may not have high enough temporal resolution to confidently classify streams as ephemeral or perennial without additional data. See examples in Figure 19.

Perennial reach: Tackett Creek, Claiborne County, TN

4/2008: Flowing | 4/2013: Flowing | 11/2020: Flowing

Intermittent reach: Wild Hog Creek, Joseph Williams Tallgrass Prairie Preserve, Pawhuska, OK

10/2011: Dry | 4/2013: Flowing | 7/2022: Isolated Pools

Ephemeral reach: Tributary to Brushy Creek, near Riesel, TX

12/2009: Isolated Pools | 12/2012: Dry | 5/2021: Isolated Pools

Figure 19. Examples of using aerial imagery to support streamflow duration classification. Images were taken from Google Earth using the time slider.

4.3.2 Conduct additional assessments at the same reach

Some indicators may be difficult to detect or interpret due to short-term disturbances, floods, severe drought, or other conditions that affect the sampling event's validity. A repeat application of the SDAM, even a few weeks later when effects from the disturbance have abated, may be sufficient to provide a determination. Similarly, conducting an additional evaluation during a different season may improve the ability to identify vegetation and collect aquatic macroinvertebrates, leading to a more conclusive assessment.

4.3.3 Conduct assessments at nearby reaches

Indicators may provide more conclusive results at reaches upstream from the assessment reach or downstream from the assessment reach, and if those locations represent similar conditions may be useful for interpreting ambiguous results. For example, there should be no significant discharges, diversions, or confluences between the new and original assessment locations, and they should have similar geomorphology. See Section 3.5 Assessment reach considerations for additional information.

4.3.4 Conduct reach revisits during regionally appropriate wet and dry seasons

A single, well-timed assessment may provide sufficient hydrologic evidence about streamflow duration. As with observations from aerial imagery, any time onsite observations of flow or absence of flow are used to inform a determination of flow duration class, such observations should be evaluated in the context of normal climatic conditions. Doing so ensures that flow duration class is not determined based on hydrologic observations of flow that occurred during abnormally wet or abnormally dry periods. The previously mentioned APT can provide this information.

4.3.5 Collect hydrologic data

Properly deployed loggers, stream gauges, or wildlife cameras can provide direct evidence about streamflow duration at ambiguous assessment reaches. It may be possible to distinguish intermittent from ephemeral streams in just a single season with these tools, assuming typical precipitation.

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Appendix A. Glossary of Terms

Term	Definition
Abdomen	The terminal section of an arthropod body.
Active channel	A portion of the valley bottom that can be distinguished based on the three primary criteria of (i) channels defined by erosional and depositional forms created by river processes, (ii) the upper elevation limit at which water is contained within a channel, and (iii) portions of a channel without mature woody vegetation. Braided systems have multiple threads and channel bars that are all part of the active channel.
Alluvial	Refers to natural, channelized runoff from terrestrial terrain, and the material borne or deposited by such runoff.
Assessment reach	The length of reach, ranging from 40 m to 200 m, where SDAM indicators are measured.
Aquatic macroinvertebrates	Invertebrate organisms that require aquatic environments for parts or all of their life cycle and are visible without the use of a microscope (i.e., > 0.5 mm body length). Includes bottom dwelling or benthic macroinvertebrates.
Bank	The side of an active channel, typically associated with a steeper side gradient than the adjacent streambed, floodplain, or valley bottom.
Bankfull elevation	The elevation associated with a shift in the hydraulic geometry of the channel and the transition point between the channel and the floodplain. In unconstrained settings, this is the height of the water in the channel just when it begins to flow onto the floodplain.
Bankfull width	Width of the stream channel at bankfull elevation.
Braided system	A stream with a wide, relatively horizontal channel bed over which during low flows, water forms an interlacing pattern of splitting into numerous small conveyances that coalesce a short distance downstream. Same as multi-threaded system.
Canal	An artificial or formerly natural waterway used to convey water between locations, possibly in both directions. Same as ditch.
Catchment	An area of land, bounded by a drainage divide, which drains to a channel or waterbody. Synonymous with watershed.
Channel	A feature in fluvial systems consisting of a streambed and its opposing banks which confines and conveys surface water flow. A braided system consists of multiple channels, which may include inactive or abandoned channels.
Confinement	The degree to which levees, terraces, hillsides, or canyon walls prevent the lateral migration of a fluvial channel.
Culvert	A drain or covered channel that crosses under a road, pathway, or railway.
Ditch	An artificial or formerly natural waterway used to convey water between locations, possibly in both directions. Same as canal.

Dorsal	Upper surface of abdomen, or back when viewed from above.
Ephemeral	Channels that flow only in direct response to precipitation. Water typically flows at the surface only during and/or shortly after large precipitation events, the streambed is always above the water table, and stormwater runoff is the primary water source.
Exuviae	The shed exoskeletons of arthropods typically left behind when an aquatic larva or nymph becomes a winged adult. Singular: exuvium.
FAC	Facultative plants. They are equally likely to occur in wetlands and non-wetlands.
FACU	Facultative upland plants. They usually occur in non-wetlands but are occasionally found in wetlands.
FACW	Facultative wetland plants. They usually occur in wetlands but may occur in non-wetlands.
Fibrous Roots	Non-woody, small diameter (<0.10 in) roots that often form dense masses in the first few inches of the soil. They are often easily torn and are not adapted to flowing conditions.
Floodplain	The bench or broad flat area of a fluvial channel that corresponds to the height of bankfull flow. It is a relatively flat depositional area that is periodically flooded (as evidenced by deposits of fine sediment, wrack lines, vertical zonation of plant communities, etc.).
Flood-prone width	Width of floodplain at the flood-prone elevation (2x maximum bankfull depth)
Groundwater	Water that is underground in soil, pores, or crevices in rocks.
Head	The anterior-most section of an arthropod body, where mouthparts, eyes, and other sensory organs are located. The head is typically (but not always) distinct from the rest of the body.
Hydrophyte	Plants that are adapted to inundated conditions found in wetlands and riparian areas.
Hyporheic	The saturated zone under a river or stream, including the substrate and water-filled spaces between the particles.
Indicator	For the NE and SE SDAMs, indicators are rapid, generally field-based measurements that are used to predict streamflow duration class.
Instar	A phase between two periods of molting in arthropods (i.e., insects).
Intermittent	Channels that contain sustained flowing surface water for only part of the year, typically during the wet season, where the streambed may be below the water table and/or where the snowmelt from surrounding uplands provides sustained flow. The flow may vary greatly with stormwater runoff.
Larva	An immature stage of an insect or other invertebrates. Several insects have aquatic larval stages, such as mayflies, stoneflies, and caddisflies. Immature salamanders are sometimes also described as larvae. Plural: larvae.

Low-flow channel	In braided systems, the main channel with the lowest thalweg elevation. In intermittent or ephemeral reaches, the low-flow channel typically retains flow longer than other channels.
Multi-threaded system	A stream with a wide, relatively horizontal channel bed over which during low flows, water forms an interlacing pattern of splitting into numerous small conveyances that coalesce a short distance downstream. Same as braided system.
NI	Plants that have no assigned wetland indicator (e.g., FACW, FACU) in a specific National Wetland Plant List region.
OBL	Obligate wetland plants. They almost always occur in wetlands.
Ordinary high-water mark (OHWM)	The line on the shore established by the fluctuations of water and indicated by physical characteristics, such as a clear natural line impressed on the bank, shelving, changes in the character of the soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas. See 33 CFR 328.3. An OHWM is required to establish lateral extent of U.S. Army Corps of Engineers jurisdiction in non-tidal streams. See 33 CFR 328.4.
Perennial	Channels that contain flowing surface water continuously during a year of normal rainfall, often with the streambed located below the water table for most of the year. Groundwater typically supplies the baseflow for perennial reaches, but the baseflow may also be supplemented by stormwater runoff and/or snowmelt.
Pool	A depression in a channel where water velocity is slow and suspended particles tend to deposit. Pools typically retain surface water longer than other portions of intermittent or ephemeral streams.
Proleg	Leg-like extensions on the abdomen (never the thorax) of some insect larvae. Typically, prolegs are unsegmented.
Pupa	An immature stage of insect orders with complete metamorphosis, occurring between the larval and adult stage. Pupal stages are typically immobile.
Reach	A length of stream that generally has consistent geomorphological and biological characteristics.
Riffle	A shallow portion of a channel where water velocity and turbulence are high, typically with coarse substrate (cobble and gravels). Riffles typically dry out earlier than other portions of intermittent or ephemeral streams, and harbor higher abundance and diversity of aquatic macroinvertebrates.
Riparian	A transitional area between the channel and adjacent upland ecosystems.
Rooted upland plants	Plants rooted in the streambed that have wetland indicator statuses of FAC, FACU, UPL, and NI.

Runoff	Surface flow of water caused by precipitation or irrigation over saturated or impervious surfaces.
Sclerotized	Hardened, as in the tough plates covering various body parts in some arthropods.
Scour	Concentrated erosive action of flowing water in streams that removes and carries material away from the bed or banks. Algal and invertebrate abundance is typically depressed after scouring events.
Secondary channel	A subsidiary channel that branches from the main channel and trend parallel or subparallel to the main channel before rejoining it downstream.
Streambed	The bottom of a stream channel between the banks over which water and sediment are transported during periods of flow.
Thalweg	The line along the deepest flow path within the channel.
Thorax	The middle section of an arthropod body where legs and wing pads (if present) are attached.
Tributary	A stream that conveys water and sediment to a larger waterbody downstream.
UPL	Upland plants. They almost always occur in non-wetlands.
Uplands	Any portion of a drainage basin outside the river corridor.
Valley width	The portion of the valley within which the fluvial channel is able to migrate without cutting into hill slopes, terraces, or artificial structures.
Ventral	Underside of abdomen, or belly when viewed from below.
Watershed	An area of land, bounded by a drainage divide, which drains to a channel or waterbody. Synonymous with catchment.

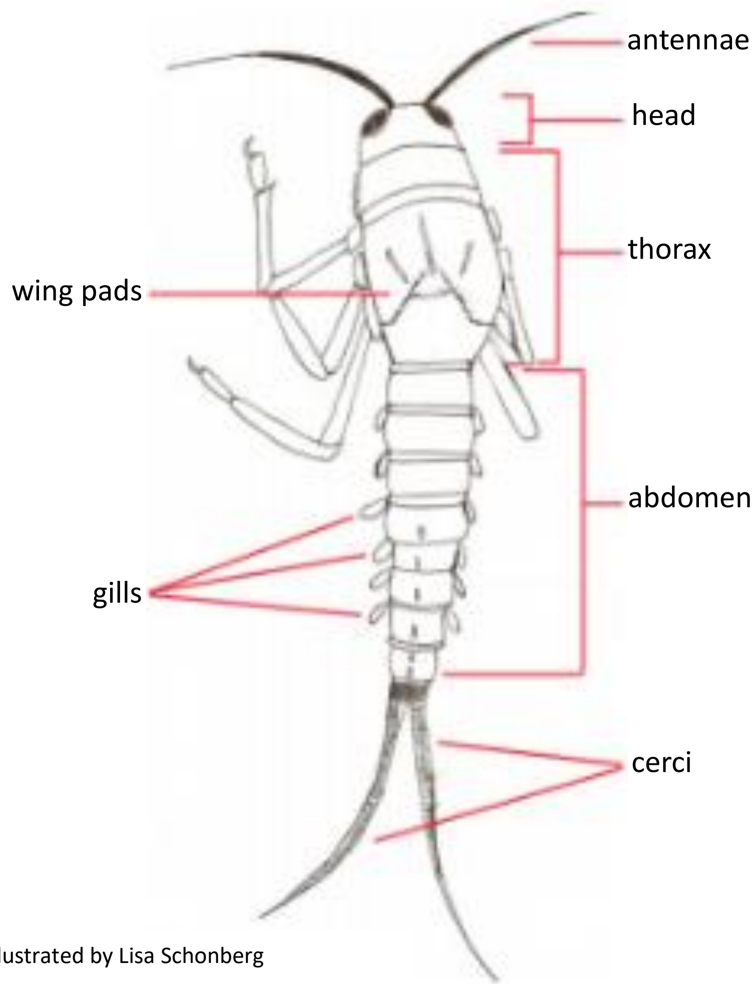
Appendix B. Guide to Aquatic Invertebrate Orders and Families in the Eastern United States

To determine richness for the BMI indicator, assessors must distinguish aquatic insects and mollusks to the family level, crustaceans and mites to the order level, and all other non-insects to the class or phylum level. For convenience, we provide a guide to common taxa encountered during field data collection at SDAM study sites for the NE and SE.

All photographs are from the Macroinvertebrates.org website, an online reference for identification of aquatic insects of eastern North America, unless otherwise noted.

General insect anatomy

Dorsal view of a mayfly (Ephemeroptera) nymph

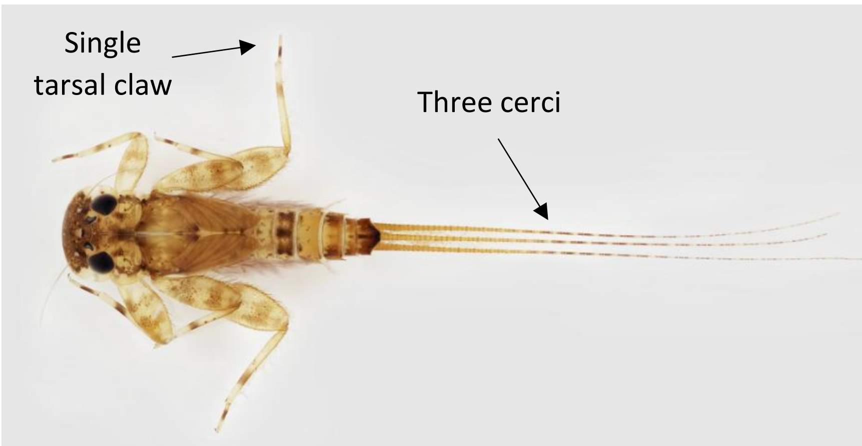


Illustrated by Lisa Schonberg

Insect Orders and Families

Ephemeroptera (mayflies)

Mayfly larvae have abdominal gills and generally three cerci (tails), though some species have two. A single tarsal claw is present, and wing pads are usually visible. Adult mayflies are short-lived and terrestrial but may be found in large breeding swarms near waterbodies. Identification to family level is needed for richness.



Heptageniidae (flat-headed mayflies). Heptageniid mayflies often have a flattened appearance, and cling to the undersides of cobbles in fast-flowing water. Heptageniid mayflies were among the most common and abundant taxa encountered during data collection.

Baetidae (small minnow mayflies). This family has a streamlined appearance and swimming motion similar to a minnow. This specimen is *Baetis.* In some species of *Baetis*, only two cerci are evident. Baetid mayflies were the second most encountered mayfly during NE and SE data collection. Image credit: California Department of Fish and Wildlife (CADFW).

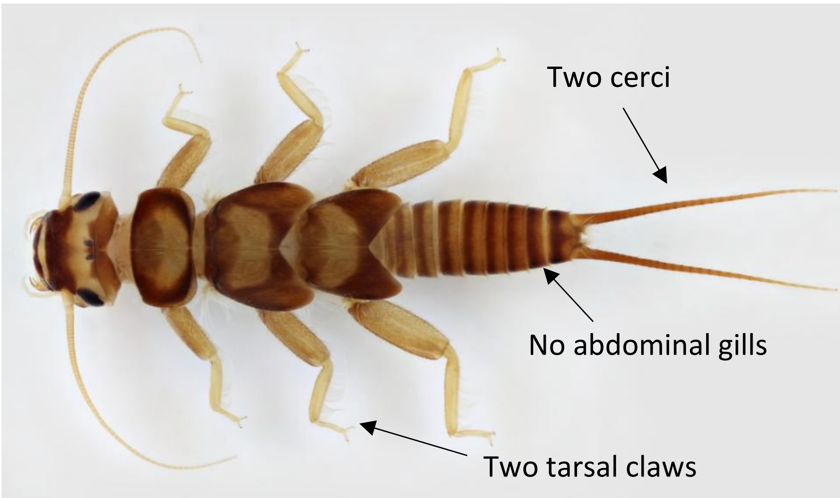
Leptophlebiidae (prong-gilled mayflies). This family of mayflies prefers gravel-bottomed streams and is often found in woody debris or among roots protruding from the bank. They are flat bodied and tend to cling to substrate. Their gills often have long forked prongs, giving this family its common name. Image credit: James Treacy.

Ephemerellidae (spiny crawler mayflies). This family tends to be found in riffles and at the margins of flowing water and swim with a 'floppy' motion. Gills have a 'spine' type shape and are absent from abdominal segment two (just below wing pads).

Ameletidae (comb-mouthed minnow mayflies). Often found in cold, fast-flowing mountain streams. Similar streamlined shape to Baetidae, but antennae are much shorter. Family represented by one genus, *Ameletus*.

Plecoptera (stoneflies)

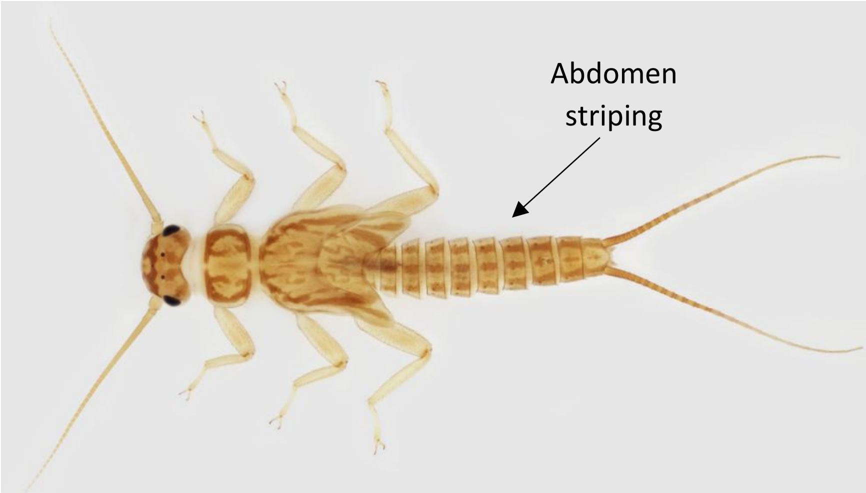
Stonefly larvae usually have tuft-like gills on the thorax (and sometimes also on the first few abdominal segments), two (not one) tarsal claws at the end of each leg, and always have two (never three) cerci, making them easily distinguishable from mayflies. Wing pads are usually visible. There is no pupal stage. All stonefly larvae are aquatic, and adults are terrestrial.



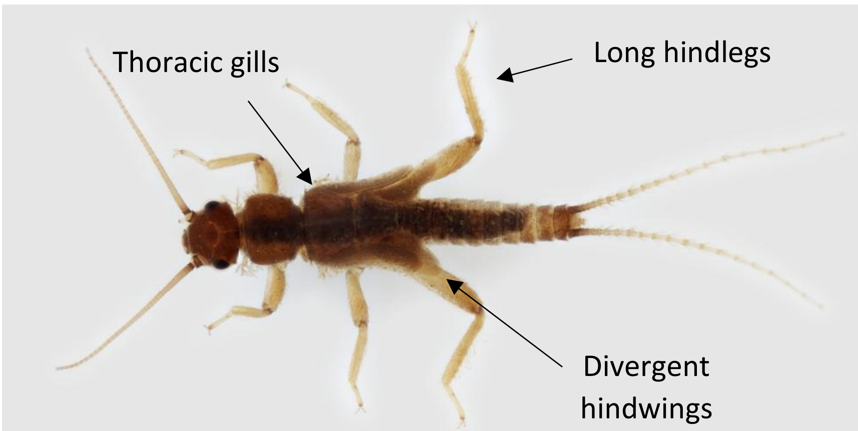
Perlidae (common stoneflies). The Perlidae family is large and conspicuous, often with ornate patterns on the head and thorax. This family has gills on the thorax (not abdomen). Perlids were the most common and abundant stoneflies identified during NE and SE data collection outside winter and early spring.

Capniidae (small winter stoneflies). Members of this family have long, slender bodies with no thoracic or abdominal gills. Capniids were the most common and abundant stonefly collected during winter and early spring surveys.

Leuctridae (rolled winged stoneflies). Members of this family are very similar in appearance to Capniid stoneflies; no thoracic or abdominal gills are present.



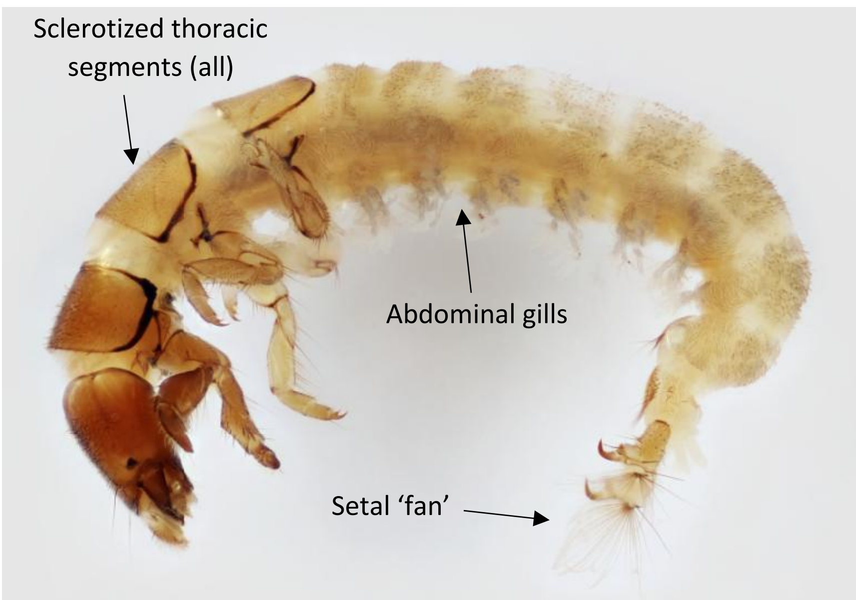
Perlodidae (stripetails). Members of this family have a patterned head and thorax and often longitudinal black-and-yellow striping on the abdomen. However, unlike the Perlids, no abdominal or thoracic gills are present.



Nemouridae (nemourid stoneflies). This family is relatively small; it is distinguished from other stonefly families by hindwings that diverge conspicuously from the boxy axis, and long hindlegs that can extend to the tip of the abdomen.

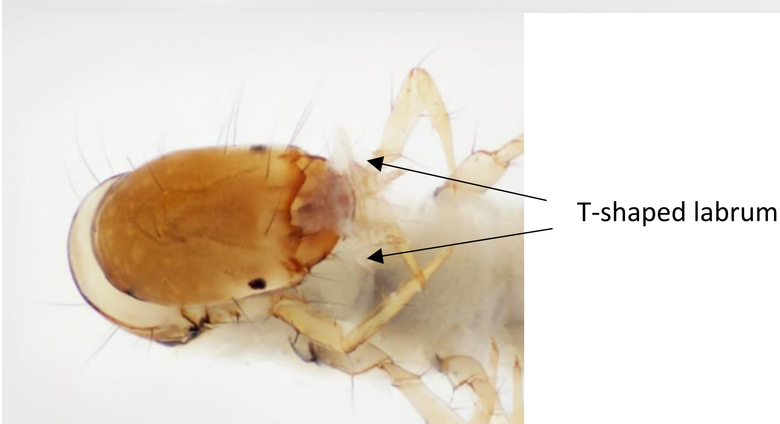
Trichoptera (caddisflies)

Caddisflies are closely related to moths and butterflies. Unlike mayflies and stoneflies, they have a pupal stage and undergo complete metamorphosis. Many taxa build conspicuous cases or retreats that may persist in dry streams. Some have filamentous gills on the ventral side (underside) of the abdomen (as opposed to the plate-like gills on the dorsal side (back) of the abdomen, as seen with mayflies). Their abdomen ends in two anal prolegs, each with a sclerotized hook, rather than long tail-like cerci. No wing pads are visible, but the thorax is usually dark and hardened (i.e., sclerotized) on the top, with the abdomen being completely membranous. Caddisfly larvae are generally C-shaped. All larvae and pupal stages are aquatic, and all adults are terrestrial.



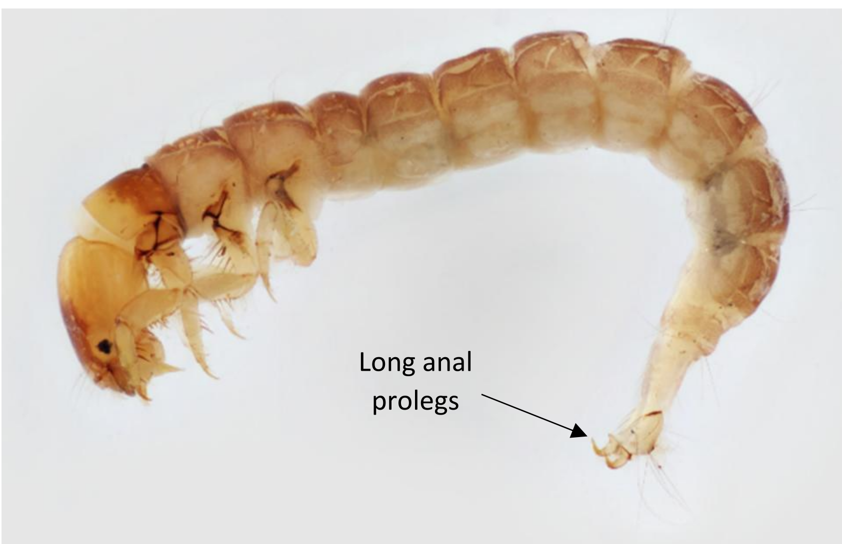
Hydropsychidae (net-spinner caddisflies). This group lives within nets made out of silk, pebbles, and other materials. All thoracic segments are sclerotized and a setal 'fan' is present on the prolegs. Hydropsychids were the most common caddisfly (and one of the most common families overall) collected during NE and SE field sampling.

Limnephilidae (northern case-makers). Limnephilids are a large group of roaming caddisflies that build cases out of diverse materials, such as pebbles, sand, leaf segments, and twigs.



Philopotamidae (finger-net caddisflies). Like hydropsychid caddisflies, members of this family build a net retreat but are often found roaming free. It is distinguished from other families of caddisflies by its T-shaped labrum (extendable mouthpart).

Lepidostomatidae (scaly mouth caddisflies). Members of this group are most commonly found in mountainous regions in small streams or the edges of large rivers. Cases are of various materials and shapes, though a four-sided case constructed of square pieces of leaves is most commonly found. The lepidostomatids are the only trichopteran family with very small antennae situated directly next to the eyes.



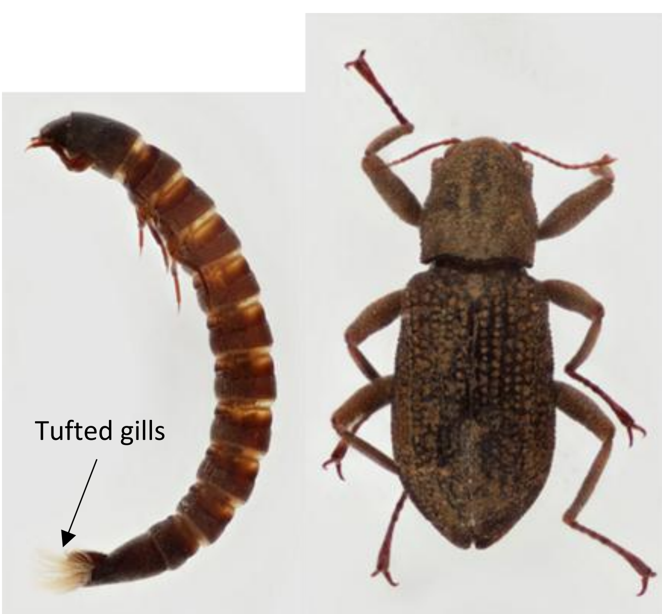
Polycentropodidae (trumpet-net, tube maker caddisflies). Members of this family do not utilize a case; instead, they construct a tubular silken net. Only the first thoracic segment is sclerotized; the anal prolegs are long and freely moveable.

Rhyacophilidae (free-roaming caddisflies). This family is usually found wandering freely on the undersides of boulders and cobbles, actively hunting for prey. Notice the long anal prolegs, which have large, sclerotized claws. Members of this family often have well defined segments, giving them a beaded appearance. Some species have a striking blue-green coloration, which may fade when preserved in alcohol. Image credit: CADFW.

Coleoptera (beetles)

The order Coleoptera can include both aquatic larvae and adults, unlike most of the insect orders covered in this Appendix. All adult beetles have hardened forewings known as elytra, though no wingpads are visible on larvae. Larvae have diverse morphology, typically with eyespots present but compound eyes absent, legs with four to five segments, and no lateral gills on the abdomen or thorax (if gills are present, they are often at the tip of abdomen). Beetle larvae can also look superficially like caddisfly larvae; however, their bodies usually show a greater degree of sclerotization (including the abdomen), and they usually have prominent chewing and/or piercing mouthparts.

Dytiscidae (diving beetles). Larvae have less sclerotization than other beetles, but generally have some hardening of the abdomen (in contrast to caddisflies). Dytiscidae was the most common and abundant beetle family collected during NE and SE field sampling.



Elmidae (riffle beetles). Elmid beetle larvae have a completely sclerotized body and tufted gills at the tip of the abdomen. Adult elmids are typically very small (1 to 8 mm). They frequently have rows of indentations along the elytra, relatively long legs ending in proportionally long claws, and thread-like antennae.

Psephenidae (water pennies). The larvae of this family are fully aquatic; however, adults are terrestrial and rarely observed as they are relatively short lived. Larvae are round and flat, often found clinging like suction cups to cobbles in fast-flowing streams; their legs are only visible from the ventral side. Their unusual shape makes them unmistakable for any other aquatic insect larvae.

Gyrinidae (whirligig beetles). The larvae of this family have lateral, abdominal gills, unlike most of the larvae of aquatic Coleopteran families. Larvae also have four hooks on the last abdominal segment. Adults have compound eyes on the dorsal and ventral surface, giving them a four-eyed appearance. Adult beetles often zip around in swirling motions along the surface of the water, giving them their common name.

Hydrophilidae (water scavenger beetles). The larvae of some genera are easily recognized by lateral filaments along the abdomen (not gills; *Berosus* (left), though most taxa do not have these filaments (e.g., *Tropisternus*, below)

Odonata (dragonflies and damselflies)

Dragonflies and damselflies have large, predatory aquatic larvae. They have a conspicuous labial mask held under the head (see below), which extends to capture prey nearby. Larvae of dragonflies tend to have stout, robust bodies (round or elongated) and abdomens that end with 5 stiff points. In contrast, larvae of damselflies have abdomens that end in three paddle-like gills. Both have wing pads that are evident in mature specimens and neither have external gills along the length of their abdomens, unlike mayflies and caddisflies.

Labial mask

Gomphidae (clubtail dragonflies). This family is distinguished by its short, four-segmented antennae, the third of which is much larger than all the other segments (the final segment may be very small). The labial mask is relatively flat.

Cordulegastridae (spiketail dragonflies). This family has hairy abdomens that taper at the midpoint. The labral mask has spoon-like palps that cover the face on the ventral side.

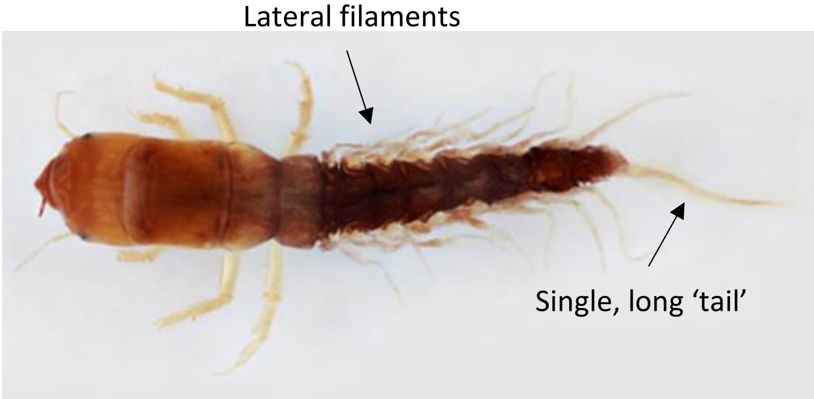
Calopterygidae (broad-winged damselflies; left): Calopterygidae can be distinguished from other damselflies by the long first antennal segment (indicated with an arrow).

Coenagrionidae (narrow-winged damselflies; right)

Megaloptera (dobsonflies, alderflies)

Megaloptera have long-lived aquatic larvae and terrestrial adults. Larvae can be quite large and imposing. The order is distinguished by the presence of lateral filaments on the abdomen. Mouthparts have large pinchers, and each leg is tipped with small two-parted pinchers.

Corydalidae (dobsonflies). Also called hellgrammites. Large and centipede-like. Lack C-shaped bodies of caddisflies and have lateral filaments instead of gills along the abdomen. Image credit: CADFW.



Sialidae (alderflies). Usually much smaller than dobsonflies. Also distinguished from Corydalidae by the abdomen ending in a single ‘tail’, rather than in two prolegs.

Diptera (true flies)

Dipterans are a diverse group of insects, of which some have an aquatic larval and/or pupal stage. Aquatic dipteran larvae are soft-bodied and legless (although they may have prolegs). Some families have conspicuous head capsules (e.g., Simuliidae, Chironomidae).

Chironomidae (non-biting midges). Chironomidae are among the most numerous and widespread aquatic invertebrates in waterbodies. Some species have hemoglobin pigments to help them extract oxygen from hypoxic water, giving them a blood-red appearance. They have a distinct head capsule, a c-shaped body, and prolegs on the thorax and abdomen (no segmented legs like caddisflies). **This family was the most common and abundant of all taxa collected during field sampling to develop the NE and SE SDAMs, for all sampling periods.**

Dixidae (meniscus midges). Similar to Chironomids but have addition of flat lobes fringed with hair on the last abdominal segment.

Simuliidae (black flies). The base of the abdomen in this family is swollen, giving them a “bowling pin” appearance. Have two labral fans they use to filter particles from the stream.

Tipulidae (crane flies). Larvae of this family are sometimes the largest aquatic insects encountered in a stream (aside from dobsonflies). They are legless, appear to be headless (the head is withdrawn into the body), and sometimes have conspicuous anal papillae at the end of the abdomen.

Culicidae (mosquitos). Mosquito larvae hang at the water surface and breath air through a tube at the tip of the abdomen. When disturbed, they "wriggle" and swim away from the surface. Image credit: MO Department of Conservation.

Hemiptera (true bugs)

Hemipterans have partially hardened, partially membranous forewings (hemelytra), unlike beetles, and piercing mouthparts. They do not undergo complete metamorphosis, and juvenile stages generally resemble adults. While aquatic families of this order are included as taxa in the BMI score, they are not found along the bottom of the streambed ('benthic'). Instead, they are usually found striding, skating, or rowing across the water surface.

Veliidae (small water striders). They have stouter bodies and shorter legs than water striders in family Gerridae (see below). Most common and abundant hemipteran family collected during NE and SE SDAM field sampling.

Gerridae (large water striders or skaters).

Corixidae (water boatmen). These insects have oar-like front-legs, which they use to paddle through the water.

Mollusk Families (mussels, clams, and snails)

The freshwater mussels are represented by the families *Margaritiferidae* and *Unionidae*. The **Unionidae** are much better represented in the East. Both families include many endangered and protected species and should not be disturbed or collected during assessments. Freshwater mussels are distinguished by their large size, with individuals often reaching several inches in length. Different shell sizes and shapes of *Elliptio complanata* (Eastern elliptio) are shown, this is a common Unionid species found in most of the Eastern coastal states. Image credit: M. Marchand.

Corbiculidae (Asian clam). Asian clams are introduced non-native species that have become widespread in many areas of the U.S. In contrast to mussels, freshwater clams have a more symmetrical shape and a sturdier shell. They rarely reach more than an inch in diameter. Image credit: John Joseph Giacinto.

Physidae (bladder snails). Physidae are among the most common snails in streams. They are left-handed, meaning that the opening is on the left side if the spire is pointed away from you, and typically have fewer, wider whorls than other snails.

Planorbidae (ramshorn snails). Ramshorn snails have a flattened, disc-like appearance, and lack a conspicuous spire that many other snails have.

Crustacean Orders (crayfish, amphipods, and isopods)

Decapoda (crayfish). Crayfish are familiar occupants of streams; however, many species are vulnerable or critically imperiled, particularly in the southeastern states where diversity is highest. For this reason, they should not be collected during assessments. Image credit: NC Wildlife Resources Commission.

Amphipoda (amphipods, also known as scuds or side-swimmers). Amphipods resemble shrimp in form and are usually compressed laterally. They do not have a carapace (the hard covering of the thorax common in other crustacea), and most or all thoracic segments are distinct and bear leglike appendages. Image credit: Scott Bauer.

Isopoda (isopods). Unlike amphipods, isopods are usually flattened dorsoventrally (top to bottom). Isopods are many-segmented, with head, thorax, and abdomen not immediately distinct, and have seven pairs of legs. Some looks similar to terrestrial isopods, like pillbugs (aka roly-poly or wood louse)

Other: Annelida, Acariformes, and Turbellaria (worms, leeches, water mites, and flatworms)

Phylum Annelida, Class Oligochaeta.
Segmented worms. Aquatic species are often red or reddish in color due to a hemoglobin-type substance that enables them to live in oxygen-depleted water. Image credit: NW Nature.

Phylum Annelida, Class Hirudinea.
Leeches. This image depicts a species in the *Macrobdella* genus, which is common in freshwater habitats of North America. Image credit: Gabrielle Dunham CC-BY-NC.

Superorder Acariformes (Phylum Arachnida). Group that includes aquatic mites. Biological sampling will generally find adults, as most larvae are attached to host plants or animals. This image depicts a member of the *Hydrachna* genus. Image credit: Water Mites of North America Project.

Class Turbellaria (Phylum Platyhelminthes). Flatworm group that is not exclusively comprised of parasitic species. A common group found in freshwater habitats are the Planarians, which include members of the *Girardia* genus depicted here. Image credit: Alex Parry CC-BY-NC.

Appendix C. Field Forms

Appendix C1: Combined field form for the NE and SE SDAMs

Northeast and Southeast SDAMs

General site information

<table>
<tr><td colspan="2">Project name or number:</td><td>Region ☐ Northeast
☐ Southeast</td></tr>
<tr><td>Site code or identifier:</td><td colspan="2">Assessor(s):</td></tr>
<tr><td colspan="2">Waterway name:</td><td>Visit date:</td></tr>
<tr><td>Current precipitation:
□ None
□ Rain □ Snow/Ice
□ Light
□ Moderate
□ Heavy
Notes:</td><td>Recent weather: (e.g., precipitation in prior week):</td><td>Coordinates at downstream end (decimal degrees), Device:

Lat (N):

Long (E):

Datum:</td></tr>
<tr><td colspan="2">Surrounding land-use within 100 m (check one or two):
□ Urban/industrial/residential
□ Agricultural (farmland, crops, vineyards, pasture)
□ Developed open space (e.g., golf course)
□ Forested
□ Other natural
□ Other: ___________________________________</td><td>Describe reach boundaries:</td></tr>
<tr><td>Mean bankfull channel width (nearest 0.1 m): _________
(Indicator 1)

______ _______ _______</td><td>Reach length (m):
40x width
min 40 m
max 200 m</td><td>Site photographs:
Enter photo ID.

Top down: _________ Mid down: __________

Mid up: ___________ Bottom up: __________</td></tr>
<tr><td colspan="3">Disturbed or difficult conditions (check all that apply):
□ None
□ Recent flood or debris flow
□ Stream modifications (e.g., channelization)
□ Diversions
□ Discharges
□ Drought
□ Vegetation removal/limitations
□ Other (explain in notes)
Notes on disturbances or difficult site conditions:</td></tr>
<tr><td colspan="3">Observed hydrology:

______ % of reach with surface flow

______ % of reach with sub-surface or surface flow

______ # of isolated pools

Comments on observed hydrology:</td></tr>
</table>

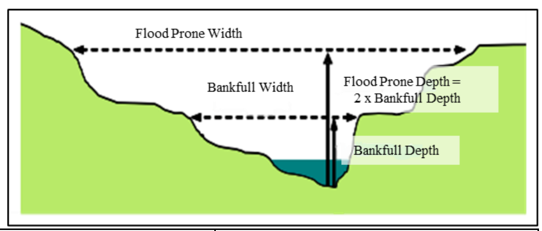
Site sketch:

1. Mean bankfull channel width (m) (NE and SE) (nearest 0.1 m, copy from first page of field form)

Notes about mean bankfull channel width:

2. Entrenchment ratio (NE only)

Measure at relatively straight section of reach avoiding pools and bends in the stream. Max entrenchment ratio value is 2.5. Entrenchment ratio of Locations 1+2+3 / 3 = Average entrenchment ratio.



		Bankfull width (m)	Flood-prone width (m)	Entrenchment Ratio (Flood-prone /Bankful)	Check if Flood-prone width is >2.5x bankfull width
Average entrenchment ratio: _______	Location 1				
	Location 2				
	Location 3				
Notes:					

Aquatic macroinvertebrate indicators

Collect aquatic macroinvertebrates from at least 6 locations in the assessment reach, searching all suitable habitats on the streambed (including dry habitats, if present).

3. BMI Score (NE and SE)

____ **(0-3)**	0 (Absent) No aquatic macroinvertebrates observed. 1 (Weak) Total abundance is 1 to 3. 2 (Moderate) Total abundance ≥4 3 (Strong) Total abundance ≥10 and richness ≥3 OR Total abundance < 10 and richness ≥5 *Note: Richness is based on family-level identification for aquatic insects and mollusks, order-level for crustaceans and mites, and class or phylum for all other aquatic macroinvertebrates.*
Taxa/Notes:	

4. Total aquatic macroinvertebrate abundance (SE only)

Mark the appropriate box for the total number of aquatic macroinvertebrates observed.

- ☐ No aquatic macroinvertebrates observed.
- ☐ Total abundance is 1 or 2.
- ☐ Total abundance is 3 to 40.
- ☐ Total abundance is 41 or more.

Notes on total aquatic macroinvertebrate abundance:

5. Slope (NE only)

Using a clinometer or other device, record the slope at bankfull as a percent, up to the nearest half-percent. If multiple sights are needed to cover the entire reach, record each and calculate a weighted average to get slope:

1)________% slope _________% of reach
2)________% slope _________% of reach
3)________% slope _________% of reach
4)________% slope _________% of reach

Notes about slope:

6. Shading (NE and SE)

At the center of three transects, use a modified convex spherical densiometer (see section 3.8.5 of the NE and SE SDAM) to record the number of points covered by trees, canyon walls, buildings, or other structures that provide shade (up to 17 points per location). Calculate percent shading as the percentage of points covered by such structures (total points covered divided by 204).

Percent shading: ____________

	Downstream transect	*Middle transect*	*Upstream transect*	
Facing upstream	/17	/17	/17	
Facing right bank	/17	/17	/17	Total number of points covered:
Facing downstream	/17	/17	/17	____ / 204 * 100%
Facing left bank	/17	/17	/17	

Notes on shading:

7. Prevalence of rooted upland plants in streambed (SE only)

____ (0-3)	Evaluate the prevalence of rooted upland plants (i.e., plants rated as FAC, FACU, UPL, or not listed in the regionally appropriate National Wetland Plant List) in the streambed. 0 (Poor) Rooted upland plants are *prevalent* within the streambed/thalweg (>75%). 1 (Weak) Rooted upland plants are *consistently dispersed* throughout the streambed/thalweg (20-75%). 2 (Moderate) There are *a few* rooted upland plants present within the streambed/thalweg (<20%). 3 (Strong) Rooted upland plants are *absent* from the streambed/thalweg.

Upland Species	**Notes**	**Photo ID**

Notes on rooted upland plants:

8. Particle size of stream substrate (SE only)

____ (0-3) *Half scores (0.5, 1.5, 2.5) are allowed.*	Compare substrate on the channel bed to the banks and adjacent floodplain. 0 (Absent) The channel is poorly developed, very little to no coarse sediment is present. There is no difference between particle size in the stream substrate and adjacent land. 1 (Weak) The channel is poorly developed through the soil profile. Some coarse sediment is present in the streambed but is discontinuous. Particle size differs little between the stream substrate and adjacent land. 2 (Moderate) There is a well-developed channel, but it is not deeply incised through the soil profile. Some coarse sediment is present in the streambed in a continuous layer. Particle size differs somewhat between the stream substrate and adjacent land. 3 (Strong) The channel is well-developed through the soil profile with relatively coarse streambed sediments compared to the riparian zone soils: coarse sand, gravel, or cobbles in the piedmont; cobbles or boulders in the mountains, and medium or coarse sand in the coastal plain. Particle size differs greatly between the stream substrate and adjacent land.
Notes about particle size of stream substrate:	

9. Prevalence of fibrous roots in the streambed (SE only)

____ (0-3) *Half scores (0.5, 1.5, 2.5) are allowed.*	Evaluate the extent of fibrous roots in the streambed. 0 (Absent) A strong network of fibrous roots is persistent in the stream thalweg and surrounding area. 1 (Weak) A discontinuous network of fibrous roots is present in the stream thalweg and surrounding area. 2 (Moderate) Very few fibrous roots are present anywhere in the streambed. 3 (Strong) No fibrous roots are present.
Notes about fibrous roots:	

10. Drainage area (NE and SE) (in square miles, if < 1 round to the nearest 0.001)

Notes about Drainage, including method/tool(s) used to calculate:

11. Elevation (NE and SE) (m)

12. Average monthly precipitation for May, June, July (SE only) (mm)

Photo log

Indicate if any other photographs taken during the assessment:

Photo ID	Description

Additional notes about the assessment including observations of fish (other than mosquitofish, *Gambusia* sp.):

Model classification:

☐ Ephemeral

☐ At least intermittent

☐ Intermittent

☐ Less than perennial

☐ Perennial

☐ Needs more information

Appendix C2: Field form for the NE SDAM

Northeast Streamflow Duration Assessment Method

General site information

Project name or number:

Site code or identifier:

Assessor(s):

Waterway name:

Visit date:

Current precipitation:
□ None
□ Rain □ Snow/Ice
□ Light
□ Moderate
□ Heavy
Notes:

Recent weather: (e.g., precipitation in prior week):

Coordinates at downstream end (decimal degrees), Device:

Lat (N):

Long (E):

Datum:

Surrounding land-use within 100 m (check one or two):
□ Urban/industrial/residential
□ Agricultural (farmland, crops, vineyards, pasture)
□ Developed open space (e.g., golf course)
□ Forested
□ Other natural
□ Other: ____________________________________

Describe reach boundaries:

Mean bankfull channel width (nearest 0.1 m): _________
(Indicator 1)

______ _______ _______

Reach length (m):
40x width
min 40 m
max 200 m

Site photographs:
Enter photo ID.

Top down: _________ Mid down: __________

Mid up: ___________ Bottom up: __________

Disturbed or difficult conditions (check all that apply):
□ None
□ Recent flood or debris flow
□ Stream modifications (e.g., channelization)
□ Diversions
□ Discharges
□ Drought
□ Vegetation removal/limitations
□ Other (explain in notes)

Notes on disturbances or difficult site conditions:

Observed hydrology:

______ % of reach with surface flow

______ % of reach with sub-surface or surface flow

______ # of isolated pools

Comments on observed hydrology:

Site sketch:

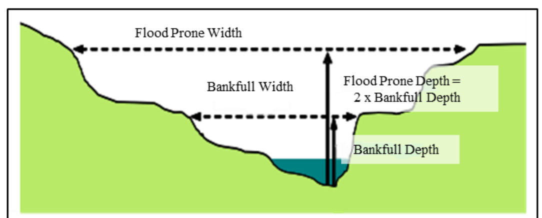
---

1. Mean bankfull channel width (m) (nearest 0.1 m, copy from first page of field form)

Notes about mean bankfull channel width:

2. Entrenchment ratio

Measure at relatively straight section of reach avoiding pools and bends in the stream. Max entrenchment ratio value is 2.5. Entrenchment ratio of Locations 1+2+3 / 3 = Average entrenchment ratio.



		Bankfull width (m)	Flood-prone width (m)	Entrenchment Ratio (Flood-prone /Bankful)	Check if Flood-prone width is >2.5x bankfull width
Average entrenchment ratio:_______	Location 1				
	Location 2				
	Location 3				
Notes:					

3. Aquatic macroinvertebrates: BMI Score

Collect aquatic macroinvertebrates from at least 6 locations in the assessment reach, searching all suitable habitats on the streambed (including dry habitats, if present).

____ **(0-3)**	0 (Absent) No aquatic macroinvertebrates observed. 1 (Weak) Total abundance is 1 to 3. 2 (Moderate) Total abundance ≥4 3 (Strong) Total abundance ≥10 and richness ≥3 OR Total abundance < 10 and richness ≥5 *Note: Richness is based on family-level identification for aquatic insects and mollusks, order-level for crustaceans and mites, and class or phylum for all other aquatic macroinvertebrates.*
Taxa/Notes:	

4. Slope

Using a clinometer or other device, record the slope at bankfull as a percent, up to the nearest half-percent. If multiple sights are needed to cover the entire reach, record each and calculate a weighted average to get slope:

1)________% slope _________% of reach
2)________% slope _________% of reach
3)________% slope _________% of reach
4)________% slope _________% of reach

Notes about slope:

5. Shading

At the center of three transects, use a modified convex spherical densiometer (see Section 2.8.5 of the NE and SE SDAM) to record the number of points covered by trees, canyon walls, buildings, or other structures that provide shade (up to 17 points per location). Calculate percent shading as the percentage of points covered by such structures (total points covered divided by 204).

Percent shading: _____	*Downstream transect*	*Middle transect*	*Upstream transect*	
Facing upstream	/17	/17	/17	
Facing right bank	/17	/17	/17	Total number of points covered:
Facing downstream	/17	/17	/17	____ / 204 * 100%
Facing left bank	/17	/17	/17	

Notes on shading:

6. Drainage area (in square miles, if < 1 round to the nearest 0.001)

Notes about Drainage are including method/tool(s) used to calculate:

7. Elevation (m)

Photo log

Indicate if any other photographs taken during the assessment:

Photo ID	Description

Additional notes about the assessment including observations of fish (other than mosquitofish, *Gambusia* sp.):

Model classification:

☐ Ephemeral

☐ At least intermittent

☐ Intermittent

☐ Less than perennial

☐ Perennial

☐ Needs more information

Appendix C3: Field form for the SE SDAM

Southeast Streamflow Duration Assessment Method

General site information

<table>
<tr><td colspan="4">Project name or number:</td></tr>
<tr><td colspan="2">Site code or identifier:</td><td colspan="2">Assessor(s):</td></tr>
<tr><td colspan="3">Waterway name:</td><td>Visit date:</td></tr>
<tr><td>Current precipitation:
□ None
□ Rain □ Snow/Ice
□ Light
□ Moderate
□ Heavy
Notes:</td><td colspan="2">Recent weather: (e.g., precipitation in prior week):</td><td>Coordinates at downstream end (decimal degrees), Device:
Lat (N):
Long (E):
Datum:</td></tr>
<tr><td colspan="2">Surrounding land-use within 100 m (check one or two):
□ Urban/industrial/residential
□ Agricultural (farmland, crops, vineyards, pasture)
□ Developed open space (e.g., golf course)
□ Forested
□ Other natural
□ Other: ___________________________________</td><td colspan="2">Describe reach boundaries:</td></tr>
<tr><td>Mean bankfull channel width (nearest 0.1 m): _________
(Indicator 1)
______ _______ _______</td><td>Reach length (m):
40x width
min 40 m
max 200 m</td><td colspan="2">Site photographs:
Enter photo ID.
Top down: _________ Mid down: __________
Mid up: ___________ Bottom up: __________</td></tr>
<tr><td colspan="4">Disturbed or difficult conditions (check all that apply):
□ None
□ Recent flood or debris flow
□ Stream modifications (e.g., channelization)
□ Diversions
□ Discharges
□ Drought
□ Vegetation removal/limitations
□ Other (explain in notes)
Notes on disturbances or difficult site conditions:</td></tr>
<tr><td colspan="2">Observed hydrology:
______ % of reach with surface flow
______ % of reach with sub-surface or surface flow
______ # of isolated pools</td><td colspan="2">Comments on observed hydrology:</td></tr>
</table>

Site sketch:

---

1. Mean bankfull channel width (m) (nearest 0.1 m, copy from first page of field form)

	Notes about mean bankfull channel width:

Aquatic macroinvertebrate indicators

Collect aquatic macroinvertebrates from at least 6 locations in the assessment reach, searching all suitable habitats on the streambed (including dry habitats, if present).

2. BMI Score

____ (0-3)	0 (Absent) No aquatic macroinvertebrates observed. 1 (Weak) Total abundance is 1 to 3. 2 (Moderate) Total abundance ≥4 3 (Strong) Total abundance ≥10 and richness ≥3 OR Total abundance < 10 and richness ≥5 *Note: Richness is based on family-level identification for aquatic insects and mollusks, order-level for crustaceans and mites, and class or phylum for all other aquatic macroinvertebrates.*
Taxa/Notes:	

3. Total aquatic macroinvertebrate abundance

Mark the appropriate box for the total number of aquatic macroinvertebrates observed.

☐ No aquatic macroinvertebrates observed.

☐ Total abundance is 1 or 2.

☐ Total abundance is 3 to 40.

☐ Total abundance is 41 or more.

Notes on total aquatic macroinvertebrate abundance:

4. Shading

At the center of three transects, use a modified convex spherical densiometer (see Section 3.8.5 of the NE and SE SDAM) to record the number of points covered by trees, canyon walls, buildings, or other structures that provide shade (up to 17 points per location). Calculate percent shading as the percentage of points covered by such structures (total points covered divided by 204).

Percent shading: ________	*Downstream transect*	*Middle transect*	*Upstream transect*	
Facing upstream	/17	/17	/17	
Facing right bank	/17	/17	/17	Total number of points covered:
Facing downstream	/17	/17	/17	____ / 204 * 100%
Facing left bank	/17	/17	/17	

Notes on shading:

5. Prevalence of rooted upland plants in streambed

____ **(0-3)**	Evaluate the prevalence of rooted upland plants (i.e., plants rated as FAC, FACU, UPL, or not listed in the regionally appropriate National Wetland Plant List) in the streambed. 0 (Poor) Rooted upland plants are *prevalent* within the streambed/thalweg (>75%). 1 (Weak) Rooted upland plants are *consistently dispersed* throughout the streambed/thalweg (20-75%). 2 (Moderate) There are *a few* rooted upland plants present within the streambed/thalweg (<20%). 3 (Strong) Rooted upland plants are *absent* from the streambed/thalweg.

Upland Species	**Notes**	**Photo ID**

Notes on rooted upland plants:

6. Particle size of stream substrate

____ **(0-3)** *Half scores (0.5, 1.5, 2.5) are allowed.*	Compare substrate on the channel bed to the banks and adjacent floodplain. 0 (Absent) The channel is poorly developed, very little to no coarse sediment is present. There is no difference between particle size in the stream substrate and adjacent land. 1 (Weak) The channel is poorly developed through the soil profile. Some coarse sediment is present in the streambed but is discontinuous. Particle size differs little between the stream substrate and adjacent land. 2 (Moderate) There is a well-developed channel, but it is not deeply incised through the soil profile. Some coarse sediment is present in the streambed in a continuous layer. Particle size differs somewhat between the stream substrate and adjacent land. 3 (Strong) The channel is well-developed through the soil profile with relatively coarse streambed sediments compared to the riparian zone soils: coarse sand, gravel, or cobbles in the piedmont; cobbles or boulders in the mountains, and medium or coarse sand in the coastal plain. Particle size differs greatly between the stream substrate and adjacent land.
Notes about particle size of stream substrate:	

7. Prevalence of fibrous roots in the streambed

____ **(0-3)** *Half scores (0.5, 1.5, 2.5) are allowed.*	Evaluate the extent of fibrous roots in the streambed. 0 (Absent) A strong network of fibrous roots is persistent in the stream thalweg and surrounding area. 1 (Weak) A discontinuous network of fibrous roots is present in the stream thalweg and surrounding area. 2 (Moderate) Very few fibrous roots are present anywhere in the streambed. 3 (Strong) No fibrous roots are present.
Notes about fibrous roots:	

8. Drainage area (in square miles, if < 1 round to the nearest 0.001)

	Notes about Drainage, including method/tool(s) used to calculate:

9. Elevation (m)

10. Average monthly precipitation for May, June, July (SE only) (mm)

Photo log

Indicate if any other photographs taken during the assessment:

Photo ID	Description

Additional notes about the assessment including observations of fish (other than mosquitofish, *Gambusia* sp.):

Model classification:

☐ Ephemeral

☐ At least intermittent

☐ Intermittent

☐ Less than perennial

☐ Perennial

☐ Needs more information