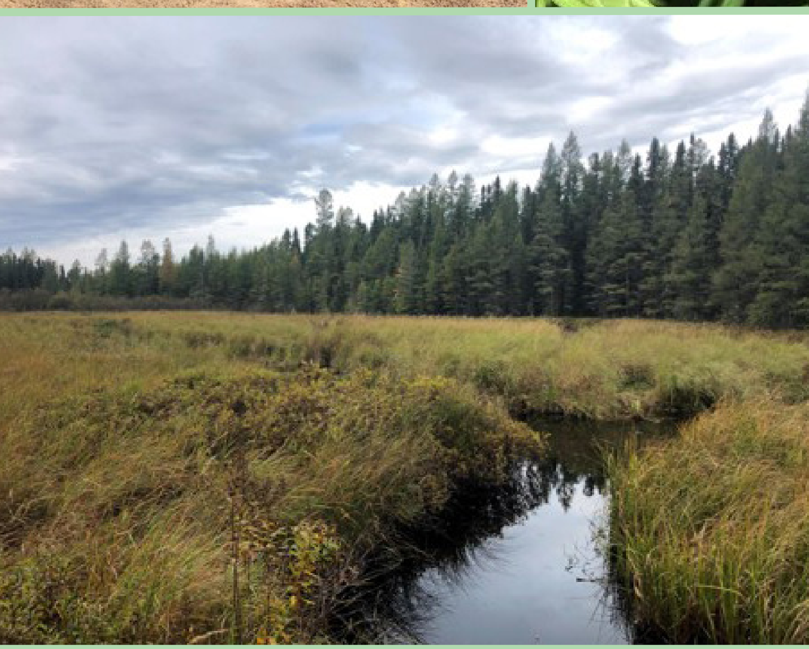
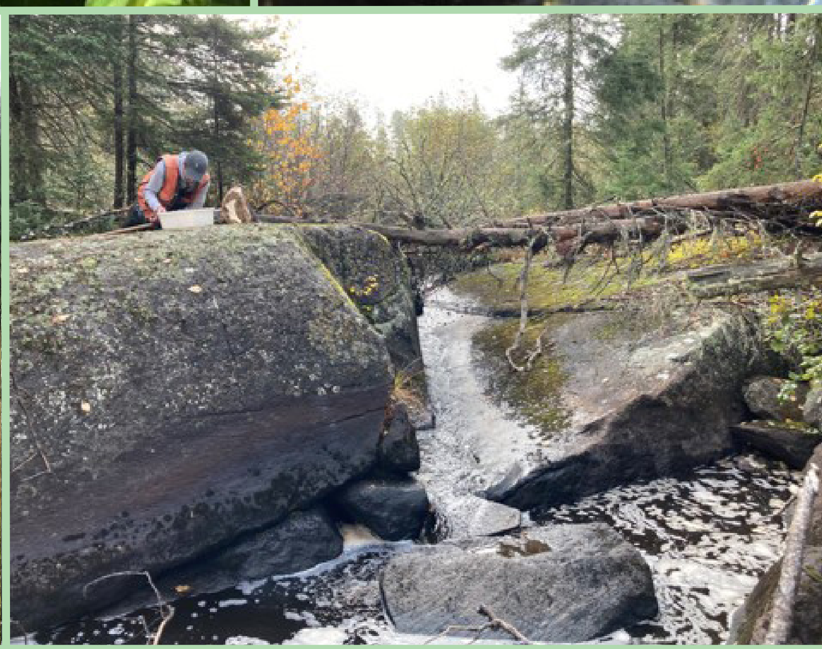
User Manual for a Beta Streamflow Duration Assessment Method for the Great Plains of the United States



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September 2022

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Disclaimers

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Section 1: Introduction and Background

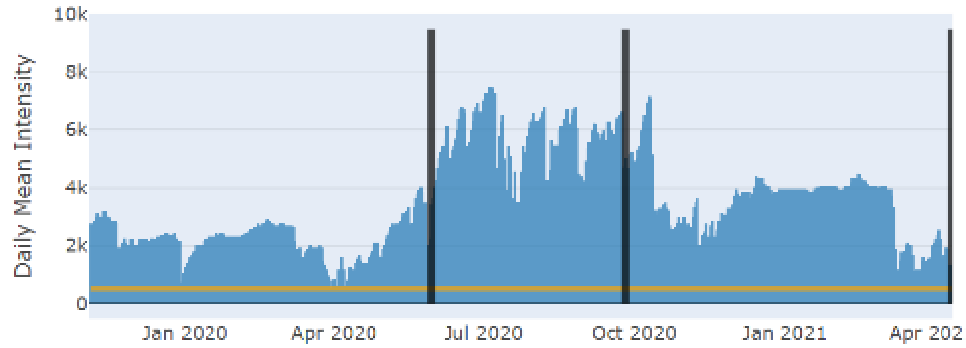
Streams exhibit a diverse range of hydrologic regimes, and the hydrologic regime strongly influences the physical, chemical, and biological characteristics of active stream channels and their adjacent riparian areas. Thus, information describing a stream's hydrologic regime is useful to support resource 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, McKay et al. 2014), they 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, there is a need for rapid, field-based methods to determine flow duration class at the reach scale (defined in Section 2) in the absence of long-term hydrologic data (Fritz et al. 2020).

This method is intended to classify stream reaches into one of three streamflow duration classes[1]:

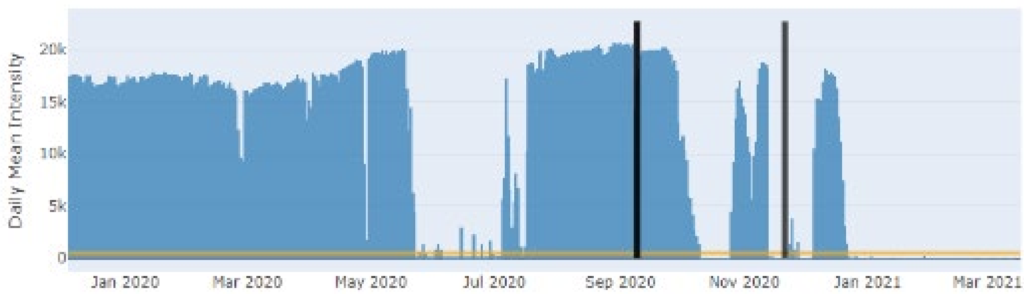
> *Ephemeral reaches* are channels that flow only in direct response to precipitation. Water typically flows only during and/or shortly after large precipitation events, the streambed is always above the water table, and stormwater runoff is the primary water source.
>
> *Intermittent reaches* are channels 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.

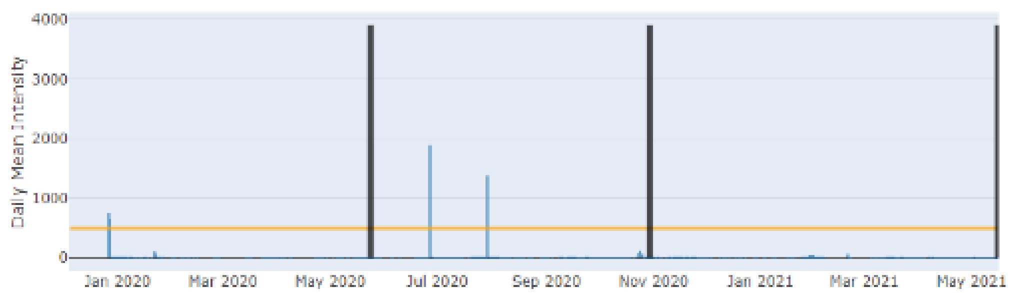
[1] The definitions used for development of this manual are consistent with the definitions used to develop the SDAM for the Pacific Northwest and the beta SDAMs for the Arid West and Western Mountains.



Perennial stream reach
Tributary to Trout Brook, Chequamegon National Forest, WI



Intermittent stream reach
Flume Canyon, Lincoln National Forest, NM



Ephemeral stream reach
Tributary to North Fork Solomon River (at Kirwin Reservoir), Kirwin National Wildlife Refuge, KS

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 on the right, including flow classification. 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. in review). 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 was downloaded and indicator data was 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 flow 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 beta Streamflow Duration Assessment Method (SDAM) that is intended to distinguish flow duration classes of stream reaches in the Northern and Southern Great Plains regions of the United States (hereafter referred to as the Great Plains, or GP) 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. The Great Plains were delineated based on the importance of snowmelt to river discharge, as their boundary approximately follows the line south of which mean annual snowfall is less than 0.7 meters (m) (2 feet (ft); Wohl et al. 2016) (Figure 2).

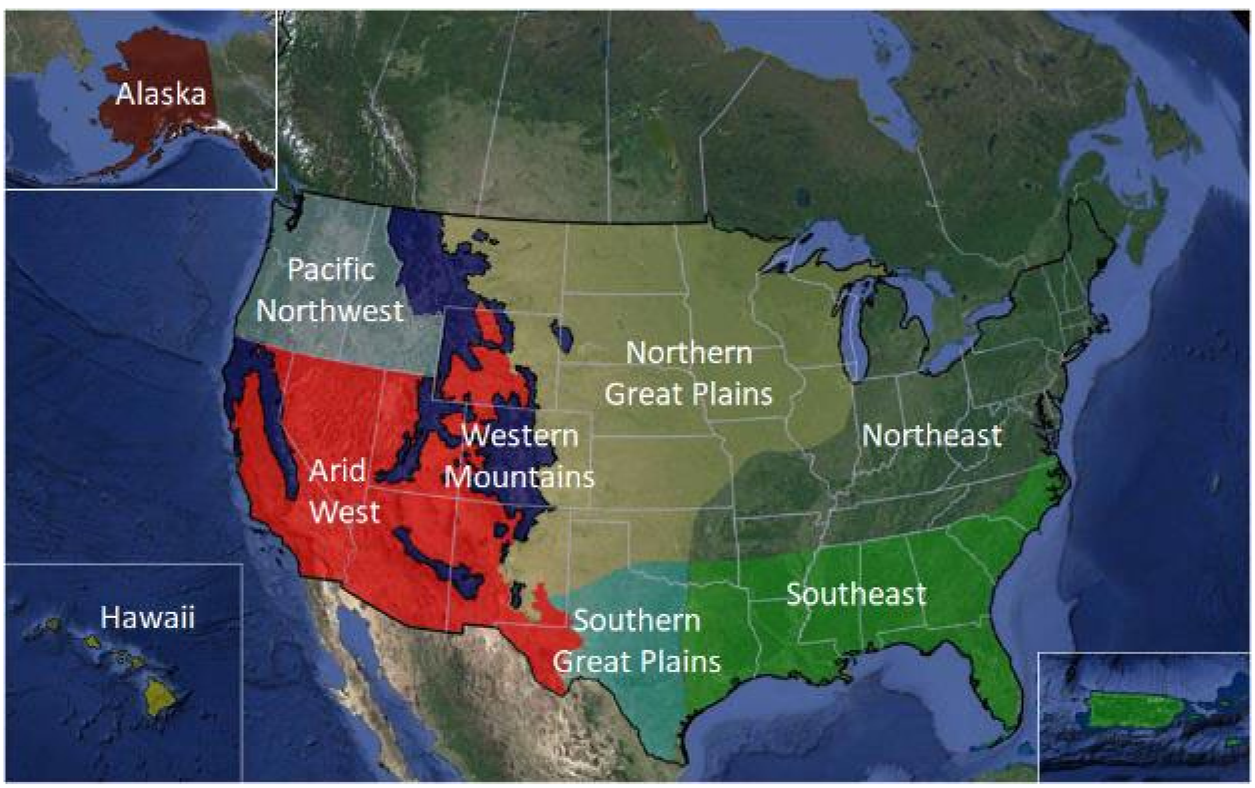


Figure 2. Map of flow duration study regions. The beta SDAM GP applies to the Northern and Southern Great Plains as shown.

Section 1: Introduction and Background

The beta SDAM GP is based on biological, geomorphological, and regional location indicators. Biological indicators, known to respond to gradients of streamflow duration (Fritz et al. 2020), 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 indicators can also be rapidly measured and provide information about the hydrologic drivers of streamflow duration. 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. Across large regions, the interaction and interpretation of biological and geomorphic indicators may vary; therefore, the inclusion of a regional location indicator can account for such variation and allow a single method to accurately classify flow duration of reaches over a large area.

The beta method for the Great Plains

This manual describes a protocol that uses a small number of indicators to predict the streamflow duration class of stream reaches in the GP. All indicators except one are measured during a single field visit. The method is being made available as a beta version for a one-year preliminary implementation period to allow the user community to provide feedback before a final SDAM GP is produced. For more information on the development of the beta SDAM GP, please see the Great Plains Data Supplement (https://www.epa.gov/system/files/documents/2022-09/devel-eval-of-the-beta-sdam-for-the-gp.pdf). For more information on the development of SDAMs for other U.S. regions, please refer to EPA's SDAM website: https://www.epa.gov/streamflow-duration-assessment.

The beta SDAM GP assigns reaches to one of four possible classifications: *ephemeral, intermittent, perennial,* and *at least intermittent*. The latter classification occurs when an *intermittent* or *perennial* classification cannot be made with high confidence, but an *ephemeral* classification can be ruled out. The protocol uses a machine learning model known as 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. We have developed an open-access, user-friendly web application for entering indicator data and running the developed random forest model to obtain the classification for individual assessment reaches.

The beta SDAM GP is based on nine indicators listed below:

Biological indicators

- The number (richness) of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) [EPT] families.
- Percent shading.
- Number of hydrophytic plant species.
- Absence of rooted upland plants in the streambed.

Geomorphological indicators

- Bankfull channel width.
- Sinuosity.
- Floodplain and channel dimensions.
- Particle size or stream substrate sorting.

Regional location indicator

- Northern or Southern Great Plains.

Intended use and limitations

The beta SDAM GP is intended to support field classification of streamflow duration at the reach scale in streams with defined channels (having a bed and banks) in the GP regions. Use of the beta SDAM GP may inform a range of activities where information on streamflow duration is useful, including jurisdictional determinations under the Clean Water Act; however, the beta SDAM GP is not in itself a jurisdictional determination. The method is not 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 beta SDAM GP when classifying streamflow duration (Fritz et al. 2020).

Although the beta SDAM GP is 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.

Poor water quality in streams may affect biological indicators—notably, the presence of EPT taxa. For example, streams in watersheds dominated by agricultural or urban uses may have lower species richness or other evidence of impact to populations of EPT taxa (e.g., Quist and Schultz 2014, Whiles et al. 2014, Wang et al. 2007). Several studies have documented strong correlations of EPT taxa measures with high concentrations of nutrients (e.g., Wang et al. 2007, Heatherly et al. 2007) and sediment deposition has been found to be inversely related to EPA taxa richness or density (Quist and Schultz 201, Zweig and Rabeni 2001). Consequently, the beta SDAM GP may fail to identify perennial reaches as *perennial* in situations where water quality has been severely degraded by nutrients, sediment, or other stressors such that EPT taxa are reduced or eliminated.

Development of the beta SDAM GP

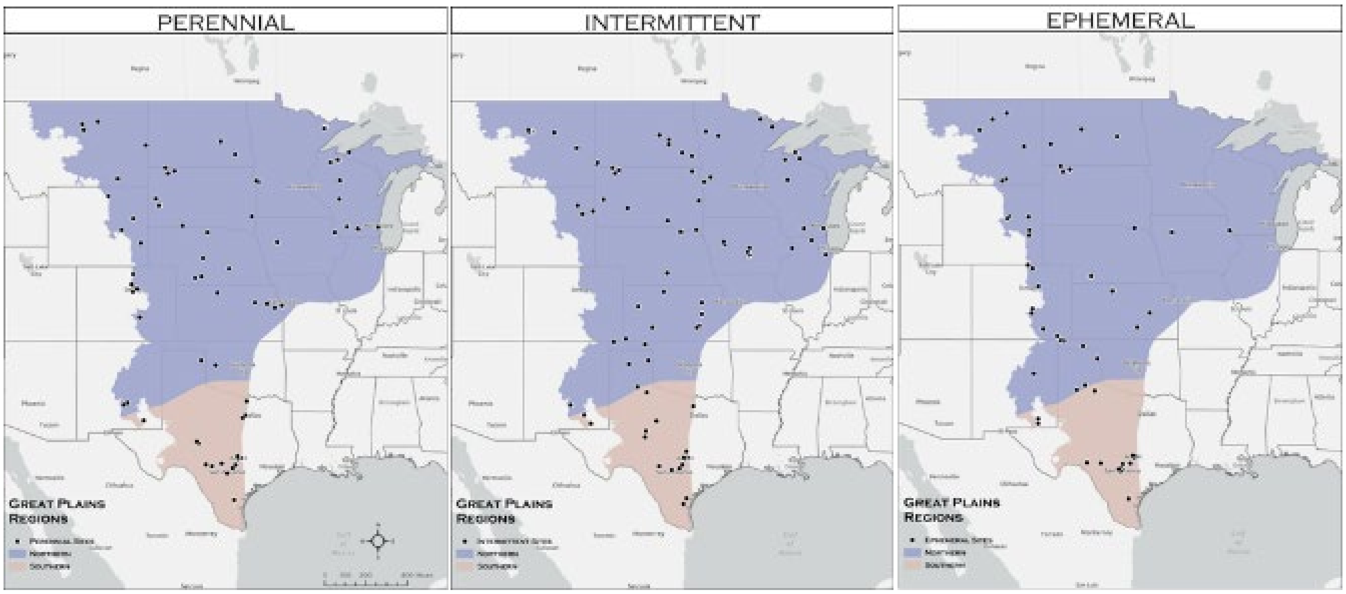


Figure 3. Locations of ephemeral, intermittent, and perennial stream reaches used to calibrate the beta SDAM GP.

This method resulted from a multi-year study conducted in 293 locations across the Great Plains following the process described in Fritz et al. (2020). Of these, data from 251 sites (or reaches) where flow class could be determined from direct hydrologic data were used to develop the beta SDAM GP (Figure 3). Of these 251 reaches, 71 were ephemeral, 100 were intermittent, and 80 were perennial. Streamflow duration class was directly determined from continuous (hourly interval) data loggers deployed at the study reaches (152) or from active USGS stream gages (29). Multiple sources of hydrologic data (e.g., inactive USGS stream gage data, published studies, consultation with local experts) were used to classify the remaining reaches (70), that did not have continuous data loggers deployed for this study. The Northern and Southern Great Plains were assessed simultaneously and analyzed both as combined and separate datasets.

Development of the beta SDAM GP followed the process steps below (Fritz et al. 2020):

- Conducted a literature review (James et al. 2022) with two goals:
    - Identified existing SDAMs, focusing on those originating in the Great Plains or developed using a similar approach (see Nadeau 2015; NMED 2011).

    - Identified (27) potential biological, hydrological, and geomorphological field indicators of streamflow duration for evaluation in the Great Plains.
- Identified candidate study reaches with known streamflow duration class, representing diverse environmental settings throughout the region.
- Collected field indicator data at study reaches.
- Evaluated 95 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 beta method for rapid and consistent application.

The final beta method correctly classified 68% of study reaches among three classes (*perennial* vs. *intermittent* vs. *ephemeral*), while 87% of study reaches were classified correctly between two classes (*ephemeral* vs. *at least intermittent*). Generally, misclassifications among intermittent and perennial reaches were more common than misclassifications among ephemeral and intermittent reaches. The ability of the beta SDAM GP 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, 2013, Nadeau et al. 2015).

How the beta SDAM GP differs from other regional SDAMs

The beta SDAM GP is the fourth method resulting from an EPA-led effort to develop SDAMs for nationwide coverage of the USA (Figure 4). The first was developed for the Pacific Northwest (PNW; Nadeau et al. 2015) and finalized in 2015 (Nadeau 2015). The second and third methods, for the Arid West (AW; Mazor et al. 2021a) and the Western Mountains (WM; Mazor et al. 2021b), were made available as beta versions for a preliminary implementation period while the EPA and its partners continue an expanded data collection effort to inform the refinement of the final SDAMs for these regions (anticipated in 2023). The four tools differ in several respects, due in part to resources and time availability to gather data, but primarily to optimize performance of the data-driven tool in each region. Differences between the four SDAMs are summarized in Table 1.

Table 1. General differences and similarities among regional SDAMs developed by the EPA.

	Great Plains (beta) (Sept 2022)	Western Mountains (beta) (Dec 2021)	Arid West (beta) (March 2021)	Pacific Northwest (Nov 2015)
Collection of data used to develop the method	Blend of instrumented and single-visit reaches, similar to the Western Mountains	Blend of single-visit reaches (where streamflow duration was already well characterized) and instrumented reaches (where continuous hydrologic data was generated to classify streamflow duration).	Single-visit reaches alone. Minimal collection of new hydrologic data.	Extensive collection of hydrologic data.
Types of indicators	Biological, geomorphological, and regional location	Biological, geomorphological, and climatic	Biological	Biological and geomorphological
Single indicators?	None	Fish	Fish Algal cover ≥10%	Fish Aquatic life stages of snakes or amphibians
Type of tool	Random forest model	Random forest model	Classification table (simplified from random forest model)	Decision tree (simplified from random forest model)
Stratification	None (strata used as indicator)	Snow-influence	None	None
Classifications	Perennial, intermittent, ephemeral, and at least intermittent.	Perennial, intermittent, ephemeral, and at least intermittent.	Perennial, intermittent, ephemeral, at least intermittent, and need more information.	Perennial, intermittent, ephemeral, and at least intermittent.
Aquatic invertebrate identification	Required at Family level for EPT only	Required at Family level	Required at Order level	Required at Family level
Hydrophytic plant identification	Required	None	Required	Required
Field time required	Up to 2 hours	Up to 2 hours	Up to 2 hours	Up to 2 hours

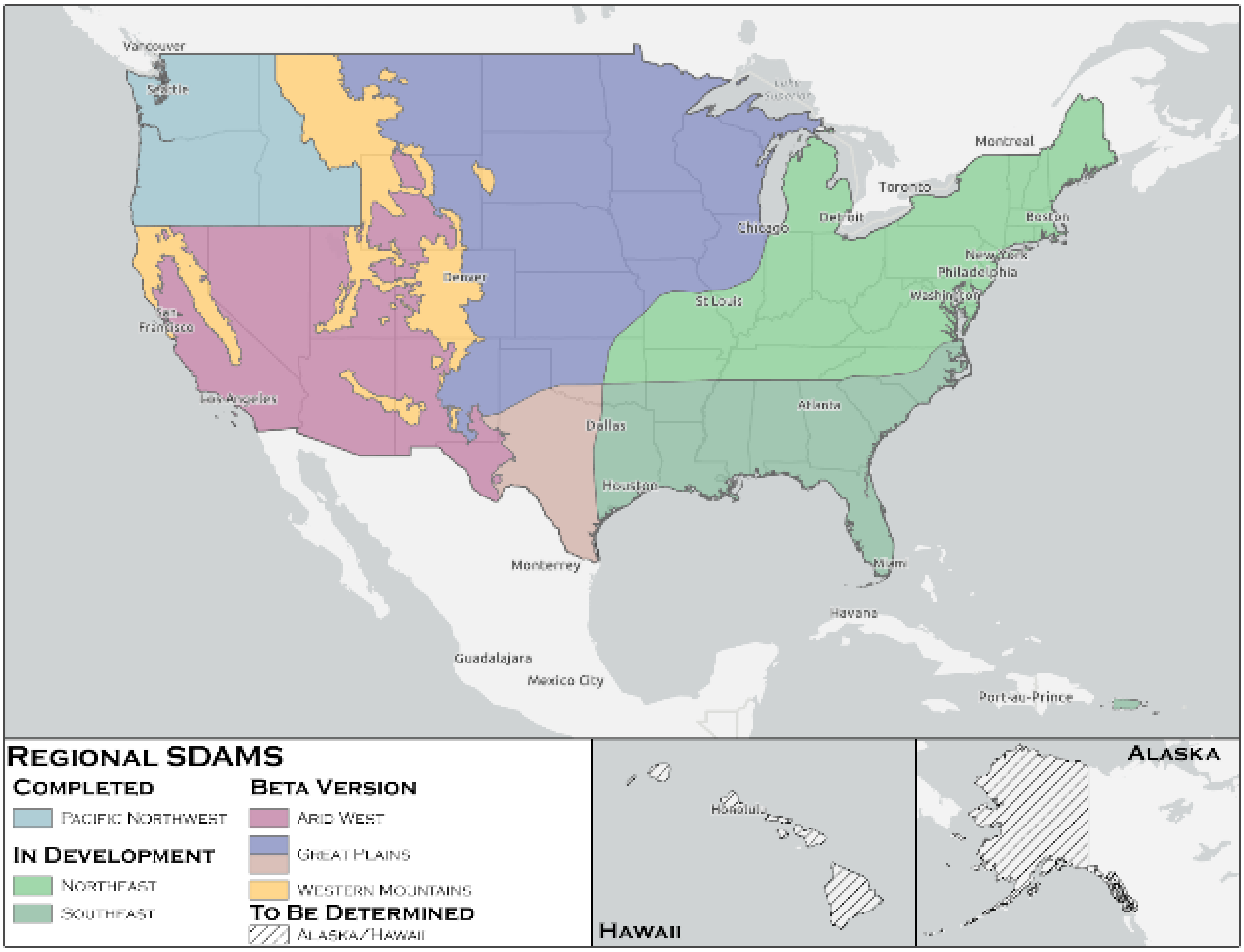


Figure 4. Status of the development of regional SDAMs at the time of this manual's publication.

Section 2: Overview of the Beta SDAM GP and the Assessment Process

Considerations for assessing streamflow duration and interpreting indicators

Clean Water Act Jurisdiction

Regulatory agencies evaluate aquatic resources based on current regulations, guidance, and policy. The beta SDAM GP does not incorporate that broad scope of analysis. Rather, the method provides information that may support timely jurisdictional decisions because it helps determine streamflow duration class.

Scales of assessment

The beta SDAM GP protocol applies to an assessment reach, the length of which scales with the mean bankfull channel width. Regardless of channel width, reaches are required to be a minimum of 40 meters and no longer than 200 meters. The minimum reach-length of 40 m is necessary to ensure that a sufficient area has been assessed to observe indicators. Quantification and observations of indicators are restricted to the bankfull channel and within one-half bankfull channel width from the top of each bank. However, ancillary information from outside the assessment reach (such as surrounding land use) is also recorded.

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 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 include:

- Longitudinal changes in stream indicators are related to increasing duration and volume of flow. As streams gain or lose streamflow, the expression of indicators changes.
- Longitudinal changes are due to channel gradient and valley width, which affect physical processes, and they may directly or indirectly affect the expression of indicators. Sharp transitions in valley gradient or width (e.g., going from a confined canyon to an alluvial fan) can be associated with changes in streamflow duration.
- The size of the stream; streams develop different channel dimensions due to differences in flow magnitude, sediment loads, landscape position, land-use history, and other factors.
- 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 events should also be noted by the user.

- Transitions in land use with different water use (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) that affect the expression of indicators.
- Stream management and manipulation, such as diversions, water importation, dam operations, and habitat modification (e.g., streambed armoring), can also influence biological, hydrological, and physical characteristics of streams.

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. This method was developed to be robust to both types of temporal variability and is 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.

Some indicators are highly responsive to temporal variability. For example, the GP is known to experience high intensity, short-lived flood events. After these scouring events, aquatic invertebrates (including EPT) may be displaced from a stream reach. In contrast, rooted hydrophytic plants, if present, will likely remain. Similarly, EPT 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 riparian corridor. For example, willows with well-established root systems are likely to survive in an intermittent reach experiencing severe drought, even when flow in a single year is insufficient to support EPT. Through the inclusion of multiple indicators having different lifespans and life-history traits, beta SDAM GP classifications reflect both recent and long-term patterns in flow duration.

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 (Carlson et al. 2019), and the beta SDAM GP may determine if these flow regimes support indicators consistent with different streamflow duration classes. Thus, the beta SDAM GP may be applied to these systems when streamflow duration information is needed.

Geomorphological indicators (specifically, bankfull channel width and sinuosity) 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 if the channel geomorphology reflects natural processes or if it reflects the effects of management activities.

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, the beta SDAM GP classified disturbed reaches with similar accuracy as undisturbed reaches.

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 invertebrates in channels that have undergone recent grading activity). Groundwater pumping, impoundments, and diversions can affect both vegetation and geomorphological indicators (e.g., Friedman et al. 1997). 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 the section on data collection. Assessors should describe disturbances in the “Notes on disturbances or difficult assessment reach conditions” section of the field form.

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 channel 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 assessment form.

Section 3: Data Collection

Order of operations in completing the beta SDAM GP assessment

The following general workflow is recommended for efficiency in the field:

In the office:

1. Conduct desktop reconnaissance.
    a. Confirm location in Northern or Southern GP with reach latitude/longitude.
    b. Optional: Perform preliminary assessment of sinuosity.
    c. Determine if placement of assessment reach will need to be adjusted to avoid changes in stream order/tributaries (and account for major disturbances, if project constraints allow).
    d. Download and have available appropriate USACE wetland plant lists.
2. Prepare sampling gear.

On-site:

3. Walk the assessment reach.
    a. Record the bankfull channel width at three locations and calculate the average to determine the assessment reach length (40 x bankfull width; minimum: 40 m, maximum: 200 m).
    b. Identify the reach boundaries.
    c. Record the coordinates of the downstream boundary of the assessment reach from the center of the channel, photograph the assessment reach, and collect densiometer readings.
    d. Continue taking photographs and collecting densiometer readings at the middle and top of the assessment reach, noting where best to assess floodplain and channel dimensions, searching for EPT taxa, and identifying hydrophytic vegetation.
    e. Start sketching the assessment reach on the field form
4. Record general reach site information on the field form (https://www.epa.gov/system/files/documents/2022-09/beta-sdam-for-the-gp-field-forms.pdf).
5. Evaluate the remaining indicators:
    a. Collect and identify EPT families.
    b. Assess channel and floodplain dimension.
    c. Assess degree of substrate sorting and/or difference of channel substrate material from surrounding uplands.
    d. Record number of hydrophytic vegetation taxa.
    e. Assess upland plants growing in the channel and their abundance.
    f. Assess channel sinuosity.
    g. Complete sketch of the assessment reach on the field form.
6. Review the field form for completeness.
7. Enter data into the web application to get a classification (https://ecosystemplanningrestoration.shinyapps.io/beta_sdam_gp/).

If more than one user is conducting the field assessment, it may be efficient for one person to collect, identify and count EPT families while the other is completing the remaining tasks in steps 3-5.

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.

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 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.

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 USEPA 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 discharge.

- USGS StreamStats: https://streamstats.usgs.gov/ss/
- USEPA WATERS GeoViewer: https://www.epa.gov/waterdata/waters-geoviewer

Assessors should consider consulting local experts and agencies to gain additional insights about reach conditions and see if additional data are available. 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 duration.

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 may be helpful for determining a plant's hydrophytic status. Nearby public land managers (such as U.S. Forest Service or the National Park Service) should be consulted to see if they have lists of common riparian plants in the vicinity of the assessment reach. Several online databases can generate regionally appropriate flora lists and/or assist with identification (Table 3). Note that there are three National Wetland Plant List (NWPL) regions that overlap with the region covered by the beta SDAM GP; consult the appropriate list for your location (see further discussion under Number of Hydrophytic Plant Species, Indicator #3)

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

Resource	Geographic coverage
NWPL Mapper Tool	United States and territories
USDA Plants Database	United States and territories
Consortium of Midwest Herbaria	Illinois, Michigan, Minnesota, and Wisconsin
Lady Bird Johnson Wildflower Center	Continental U.S. (native species only)
Kansas Wildflowers and Grasses	Kansas
Rocky Mountain Herbarium	Includes Montana, Wyoming, Colorado, and New Mexico
Minnesota Wildflowers	Minnesota

Desktop reconnaissance also helps determine if permits are required to collect aquatic invertebrates. Threatened and endangered species may be expected in the area, and stream assessment activities may require additional permits from appropriate federal and state agencies.

Optional: Perform preliminary assessment of sinuosity

A preliminary score for sinuosity may be obtained during desktop reconnassiance. Desktop measurement of this indicator using aerial imagery can be quite accurate in some settings, but unclear and difficult in others, and may not always reflect present-day conditions; therefore, field confirmation is always required.

Prepare sampling gear

The following gear is suggested for completion of the beta SDAM GP. Ensure that all equipment is functional before each assessment visit. Also ensure that all equipment has been cleaned off-site between assessment visits to prevent the spread of invasive species.

- This manual, and copies of paper field forms.
- Clipboard/pencils/permanent markers.

- Field notebook.
- Maps and aerial photographs (1:250 scale if possible).
- Global Positioning System (GPS) – used 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, reach length, flood-prone width, and valley length.
- Pocket rod or leveling rod/meter stick – for determining max bankfull depth for flood-prone width measurement.
- Kick-net or small net and tray – used to sample aquatic macroinvertebrates.
- Hand lens – to assist with macroinvertebrate and plant identification.
- Digital camera (or smartphone with camera), plus charger. Ideally, use a digital 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.
- Sand-gauge card.
- Convex spherical densiometer, taped to restrict assessment to the forward-facing 17 assessment points (see Percent Shading, Indicator #2 for information on how to prepare the densiometer).
- Aquatic macroinvertebrate field guides that focus on EPT (e.g., *Guide to Aquatic Invertebrates of the Upper Midwest*, Bouchard et al. 2004).
- Vials filled with 70% ethanol and sealable plastic bags for collection of biological specimens, with sample labels printed on waterproof paper.
- Hydrophytic plant identification guides (e.g., *Wetland and Aquatic Plants of the Northern Great Plains*, Chadde 2019).
- The U.S. Army Corps of Engineers List of wetland plants for sites to be visited – http://wetland-plants.usace.army.mil/.
- First-aid kit, sunscreen, insect repellant, and appropriate clothing.

Timing of sampling

Ideally, beta SDAM GP application should occur during the growing season when many aquatic macroinvertebrates are most active, and most macroinvertebrates and hydrophytes are 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 GP, where the presence of snow and channel ice during the colder months may also be a factor. However, most of the indicators included in the method persist well beyond a single growing season (e.g., hydrophytic vegetation) or are not dependent on it (e.g., geomorphological indicators), reducing the sensitivity of the method 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 invertebrates and other biological indicators to recover (Grimm and Fisher 1989; Hax and Golladay 1998; Fritz and Dodds 2004). In general, aquatic invertebrate 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. Field evaluations should not be completed within one week of significant rainfall that results in surface runoff. 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 beta SDAM GP data. The Antecedent Precipitation Tool (APT; U.S. Army Corps of Engineers 2020a) can also be helpful for evaluating recent precipitation conditions at a site relative to the 30 year average - https://www.epa.gov/wotus/antecedent-precipitation-tool-apt.

Assessment reach size, selection, and placement

An assessment reach should have a length equal to ***40 bankfull channel-widths,*** with a minimum of 40 m (to ensure that sufficient area is assessed to observe indicators) and a maximum length of 200 m. Bankfull channel width is averaged from measurements at three locations (e.g., at the downstream end, at 15 m, and at 30 m upstream from the downstream end). Width measurements are made at bankfull elevation, perpendicular to the thalweg (i.e., the point within the channel with the greatest portion of flow). In single-thread systems, the channel-width is the same as the bankfull width. In multi-thread systems, the width is measured for the entire active channel, based on the outer limits of the OHWM. Reach length is measured along the thalweg. If access constraints require a shorter assessment reach than needed, the actual assessed reach-length should be noted on the field form, along with an explanation for why a shortened reach was necessary.

Assessors should look for indicators of bankfull elevation when measuring bankfull channel width. These indicators include:

- The presence of a floodplain at the elevation of initial flooding.
- The elevation associated with the *highest* depositional features.
- An obvious slope break that differentiates the channel from a relatively flat floodplain terrace higher than the channel.
- A transition from exposed sediments to terrestrial vegetation.
- Moss growth on rocks along the banks.
- Evidence of recent flooding.
- Presence of drift material caught on overhanging vegetation.
- Transition from flood- and scour-tolerant vegetation to that which is relatively intolerant.

Certain indicators 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), 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 should be avoided. In the field, it may often be possible to determine the bankfull stage on only one bank of the stream. However, 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.

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 up- or downstream.

Note that bankfull channel width is also an indicator of streamflow duration, as described below under Bankfull Channel Width, Indicator #5 and is used to assess the floodplain and channel dimensions indicator (i.e., entrenchment ratio; Indicator #6). Associated measurements needed for entrenchment ratio may be collected when bankfull channel width is measured.

Walking the assessment reach

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 investigation may 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 where information is needed. 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).

Once the walk is complete, the assessor can document the areas along the stream channel where various sources (e.g., stormflow, tributaries, or groundwater) or sinks (alluvial fans, abrupt changes in bed slope, etc.) of water 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. Regardless of whether the assessment reach is shifted, shortened, or multiple reaches are assessed, an assessment reach should not be less than 40 m in length to ensure that indicators are measured appropriately. Assessments based on reaches shorter than 40 m may not detect indicators that would be recorded by assessments with the recommended size and may thus provide inaccurate classifications.

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 up- or down-stream 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 the hydrology, multiple assessment reaches may be required (e.g., one above and one below the feature).

Photo-documentation

Photographs can provide strong evidence to support conclusions resulting from a beta SDAM GP application, 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:

- Hydrophytic plant identifications, showing diagnostic features and extent within the reach.

- EPT and evidence of EPT (e.g., caddisfly casings), if practical.
- Extent of upland rooted plants in channel.
- Sinuosity or lack thereof.
- Particle size and/or stream substrate sorting.
- Floodplain and channel dimensions.
- Disturbed or unusual conditions that may affect the measurement or interpretation of indicators.

Conducting assessments and completing the field form

General reach information

After walking the reach and determining the appropriate boundaries for the assessment area, enter 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 of the downstream end of the reach from the center of the channel. These can be used to determine if the reach is in the Northern or Southern GP.

Weather conditions

Note current weather conditions. If known, note precipitation within the previous week on the datasheet, and consider delaying sampling, if possible. If rescheduling is not possible, note whether the streambed is recently scoured, and if turbidity is likely to affect the measurement of indicators.

Surrounding land use

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 and reach length

Record the bankfull channel width values (to nearest 0.1 m) that were measured at three locations (Figure 5). Widths should be measured perpendicular to the thalweg. In braided systems, widths should span all channels within the OHWM. Taking measurements at 0, 15, and 30 m above the downstream end of the reach or approximately one-third of the expected reach length is recommended. Calculate the average width.

Record the reach length (m), which should be 40 times the average bankfull channel width, but no less than 40 m and no more than 200 m, and measured along the thalweg (i.e., along the deepest points within the channel) with a tape measure. In multi-thread systems, measure reach-length along the thalweg of the deepest channel. If circumstances require a shorter reach length, enter the assessed reach's actual length. Justification for an assessment reach length shorter than 40 m should be provided in "Describe reach boundaries."

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

Describe reach boundaries

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 check 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.

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 limit the growth of hydrophytes and/or 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: As the San Marcos River progresses through the city of San Marcos in Texas, its banks have been hardened and the natural riparian vegetation has been removed (though there is still aquatic vegetation apparent in the channel itself). The removal of in-stream and riparian zone habitat and addition of urban non-point source discharges may also impact aquatic invertebrate communities, especially those more sensitive to water quality disturbances (e.g., many EPT taxa). Right: Keenan Creek in Wisconsin has been straightened and channelized, affecting naturally occurring stream pattern (e.g., sinuosity), and profile (e.g., entrenchment). Image credits: James Treacy.

Observed hydrology

Surface flow

Visually estimate or use the 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 is 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.

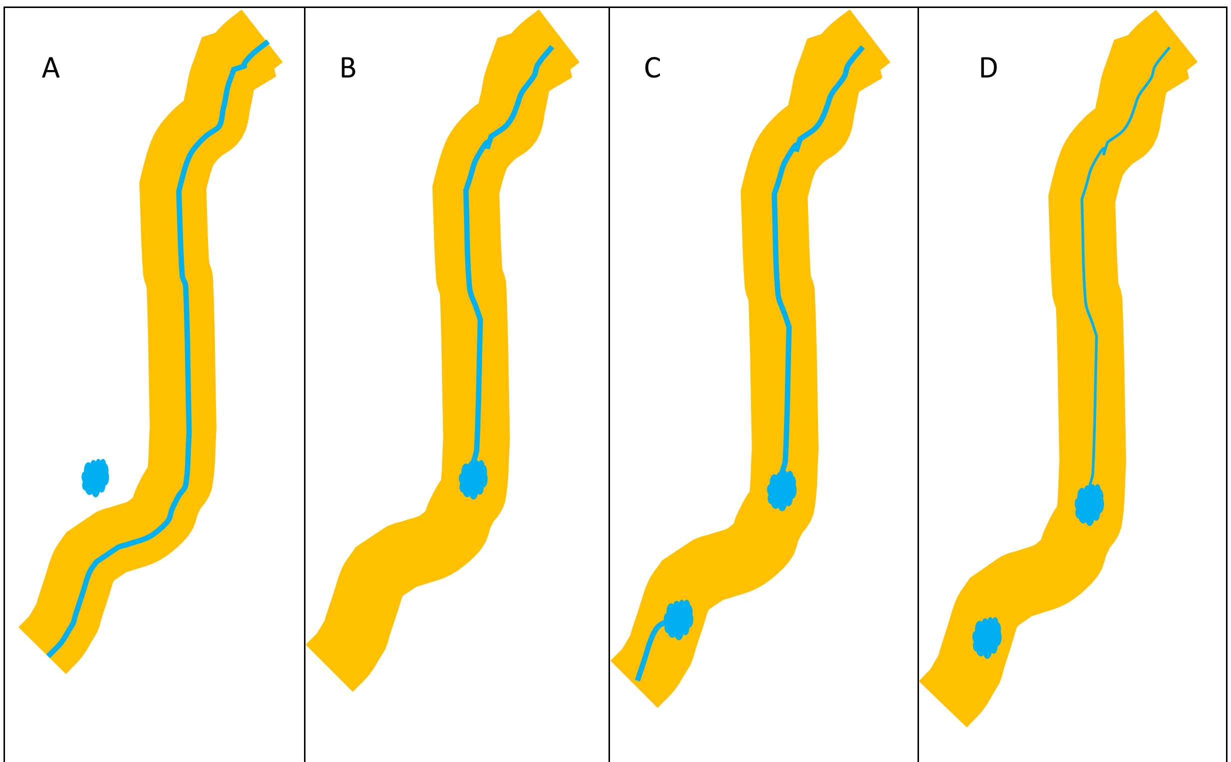
- Shallow subsurface water can be heard moving in the channel, particularly in steep channels with coarse substrates.

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 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.



A	B	C	D
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.

Assessment reach sketch

On the data sheet, sketch the assessment reach, 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.

How to measure indicators of streamflow duration

Assessments are based on the measurement of nine indicators of streamflow duration:

Biological indicators

- EPT family richness
- Percent shading
- Number of hydrophytic plant species
- Absence of rooted upland plants in the streambed

Geomorphological indicators

- Bankfull channel width
- Sinuosity
- Floodplain and channel dimensions
- Particle size or stream substrate sorting

Regional location indicator

- Northern or Southern Great Plains

EPT family richness, percent shading, number of hydrophytic plant species, sinuosity, floodplain and channel dimensions, and particle size/stream substrate sorting are positive indicators of streamflow duration. That is, a greater abundance or strength of these indicators is generally associated with longer duration flows (e.g., Dodds et al. 2004, Burk and Kennedy 2013, Billi et al. 2018). For example, higher EPT taxa abundance or stronger sinuosity are both associated with perennial reaches. The relationship between streamflow duration and bankfull channel width is less straightforward. In general, wider channels and more sinuous channels are more likely to be perennial and positioned lower in the watershed than narrower and less sinuous non-perennial channels. Wetter portions of the Great Plains will also have more riparian vegetation (Borchert 1950) and cohesive bank material (Hecker et al. 2019) that is conducive for meandering channel pattern than drier portions which are expected to have less sinuous channels. The regional location indicator considers large scale differences in climate and other geographic factors across the Great Plains that affects flow duration (Hammond et al. 2021).

However, a wide range of streamflow duration occurs in a variety of climatic settings and in both narrow and wide channels. The regional location indicators affect the way other indicators are interpreted, and they were included in the method because they greatly improve the overall accuracy of resulting classifications. Rooted upland plants are a negative indicator of streamflow duration. Greater abundance or expression of rooted upland plants in the assessment reach is associated with shorter flow duration classes. To be consistent with the other indicators in terms of its relationship to evidence of perennial flow, the scoring for the rooted upland plants indicator is reversed by characterizing its rarity or absence.

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. Within each indicator description, common ways that disturbances can interfere with indicator measurement are described.

1. EPT family richness

Mayflies, stoneflies, and caddisflies are aquatic insects that require the presence of water (and in many cases flowing water) for their growth and development for at least part of their life cycle. Mayflies, stoneflies, and caddisflies (called "EPT" taxa, after their orders: Ephemeroptera, Plecoptera, and Trichoptera) are widespread aquatic insects that are often found in perennial and intermittent streams but are not typically found in ephemeral streams or are represented by fewer taxa (e.g., King et al. 2015, Stagliano 2005). For this indicator, the number of EPT families (not individuals), up to 5 or more, should be enumerated. Living material (e.g., live larvae or pupae), and non-living material (e.g., caddisfly cases, shed exuviae) are equally considered for this indicator. Images highlighting diagnostic features are in the call-out box, and photos of EPT families commonly found in the GP are provided in Appendix B.

A series of photos (if feasible) should be taken of any taxa in question to allow further identification to be made off-site, if necessary. If the identification is uncertain, then describe any distinguishing features that were observed in the notes. Alternatively, specimens may be preserved in 70% ethanol and identities confirmed in a lab setting with an appropriate taxonomic key or identification guide (e.g., Merritt et al. 2019) or by consultation with an entomologist.

Identification of mayflies, stoneflies, and caddisflies

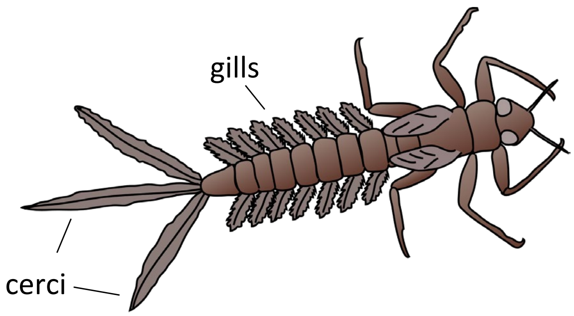


Image by [Dieter Tracey]

Mayflies (Ephemeroptera)
Mayfly nymphs may be readily identified by the presence of plate- or feather-like gills along sides or top of the abdomen. They typically have three cerci ("tails"), although in some species, they appear to have two. They have only one claw at the end of each foot, in contrast to stoneflies (which have two). They lack a pupal phase, but their exuviae may be abundant on streamside vegetation and emergent boulders at certain times of the year.

Stoneflies (Plecoptera)
Stonefly nymphs have gills along the thorax, and two claws at the end of each leg. They have two cerci, whereas mayflies usually have three. Like mayflies, stoneflies lack a pupal stage and instead metamorphose directly into winged adults, and their exuviae can be found alongside dry or flowing streams.

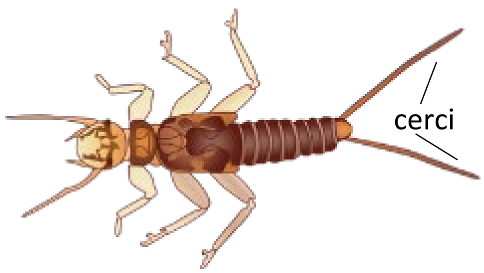


Image by [Tracey Saxby]

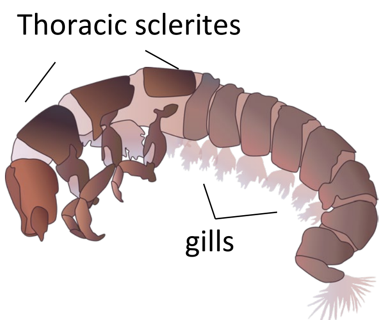


Image by [Tracey Saxby]

Caddisflies (Trichoptera)
Caddisfly larvae typically have a C-shaped body ending in two hooks. Thread-like gills may be found along the underside of the abdomen, and three pairs of legs under the thorax (setting them apart from some fly larvae, that may otherwise look similar). The top of thorax may be partly or fully hardened ("sclerotized"). Caddisfly larvae and pupae are aquatic, and they are often found with cases made of sand, pebbles, twigs, leaves, or small snail shells. Most larvae are free roaming, but a few families build larval retreats in fixed locations under cobbles and boulders. One family (Rhyacophilidae) lacks a case or larval retreat, although it builds pupal cases out of pebbles and fine-grained sand. Caddis larval and pupal cases are often the most easily observed sign of aquatic invertebrates in a dry stream.

EPT are assessed within the defined reach. A kick-net or D-frame net and a hand lens are used to, respectively, collect and identify specimens. Assessors begin sampling at the most downstream point in the assessment reach and proceed to sample the upstream direction. The net is placed perpendicular against the streambed while the substrate is disturbed upstream of the net for a minimum of one minute. Jab the net under banks, overhanging terrestrial and aquatic vegetation, leaf packs, and in log jams or other woody material. Samples should be collected from **at least six** distinct locations representing the different habitats occurring in the reach. Empty contents of the net into a white tray with fresh water for determining the number of EPT families present. Many EPT can appear cryptic and/or the same until seen against a contrasting color background, and some can be pea-sized or smaller.

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 specimen identification time), **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 (pick up rocks and loose gravel).

Dry channels: Focus the search on areas serving as refuge such as any remaining pools or areas of moist substrate for living macroinvertebrates, and under cobbles and other larger bed materials for caddisfly casings (Figure 8). Exuviae of emergent mayflies or stoneflies may be observed on dry cobbles or stream-side vegetation (Figure 8). In summary, sampling methodology consistent with the Xerces Society's recommendations on using aquatic macroinvertebrates as indicators of streamflow duration (Mazzacano and Black 2008), as developed for the SDAM PNW (Nadeau 2015) is recommended.

If a reach contains both dry and wet areas, focus on searching the wet habitats, as these are the most likely places to encounter EPT. However, do not ignore dry areas.


Figure 8. Examples of evidence of EPT 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.

2. Percent shading

Data used to develop the beta SDAM GP indicated that perennial and intermittent reaches generally had higher levels of shading than ephemeral streams. This outcome suggests that riparian corridors along streams with longer flow durations have a greater ability to support woody vegetation (e.g., gallery forests) in the Great Plains. Using a convex spherical densiometer, stream shading is estimated in terms of percent cover of objects (vegetation, buildings, etc.) that block sunlight. The method described uses the Strickler (1959) modification of a densiometer to correct for over-estimation of stream shading that occurs with unmodified readings. Taping off (Figure 9) the lower left and right portions of the mirror emphasizes overhead structures over foreground structures (the main source of bias in stream shading measurements).

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. Consider the “zone of influence” of vegetative cover expected during the growing season (Nadeau et al. 2018).

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 (integer values ranging 0 to 17) from the center of the channel at upstream, middle, and downstream locations in the reach: a) facing upstream, b) facing downstream, c) facing the left bank, d) facing the right bank. The observer and the densiometer should revolve together over the center point of the transect to keep the “V” oriented as above.

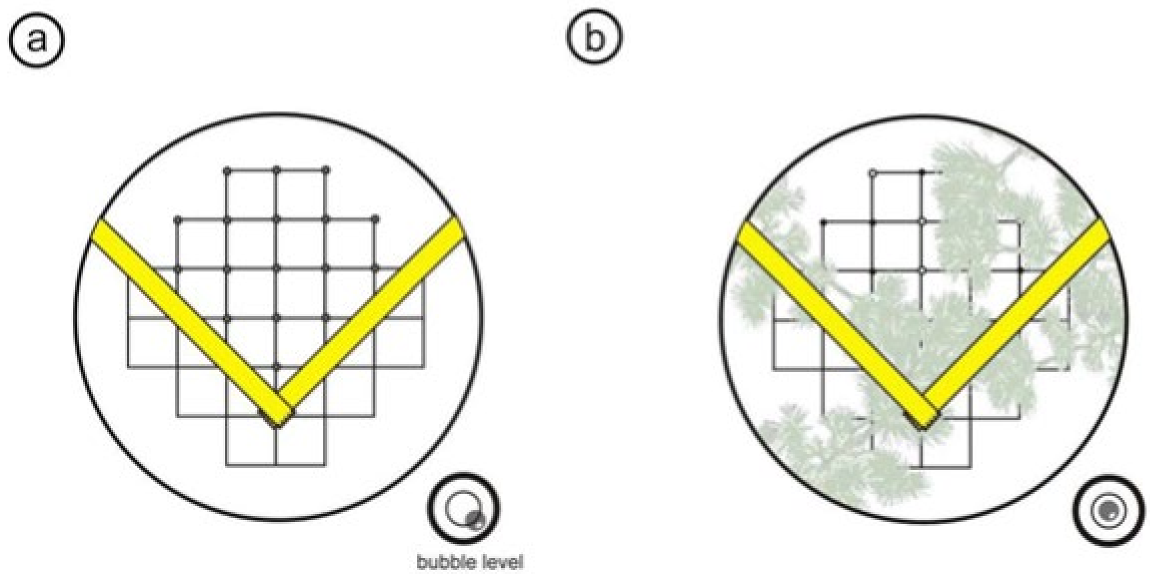


Figure 9. Representation of the mirrored surface of a convex spherical densiometer showing the position for taping the mirror and the intersection points used for the densiometer reading. The score for the hypothetical condition (b) is 9 out of 17 possible covered intersection points within the “V” formed by the two pieces of tape (figure from Ode et al. 2016).

3. Number of hydrophytic plant species

For the beta SDAM GP, hydrophytes are defined as those with a Facultative Wetland (FACW) or Obligate (OBL) wetland indicator status in the National Wetland Plant List[2] (NWPL, USACE 2020b). The GP region encompasses all or parts of three different NWPL regions: the Great Plains, Midwest (MW), and Northcentral Northeast (NCNE) (Figure 10). Indicator status for certain species may differ between regions; therefore, it is important to consult the correct list when determining indicator status. For example, stinging nettle (*Urtica dioica*), a common, widespread herb often found growing in riparian zones, is FACW in the MW but FAC in the GP and NCNE.

[2] https://cwbi-app.sec.usace.army.mil/nwpl_static/v34/home/home.html

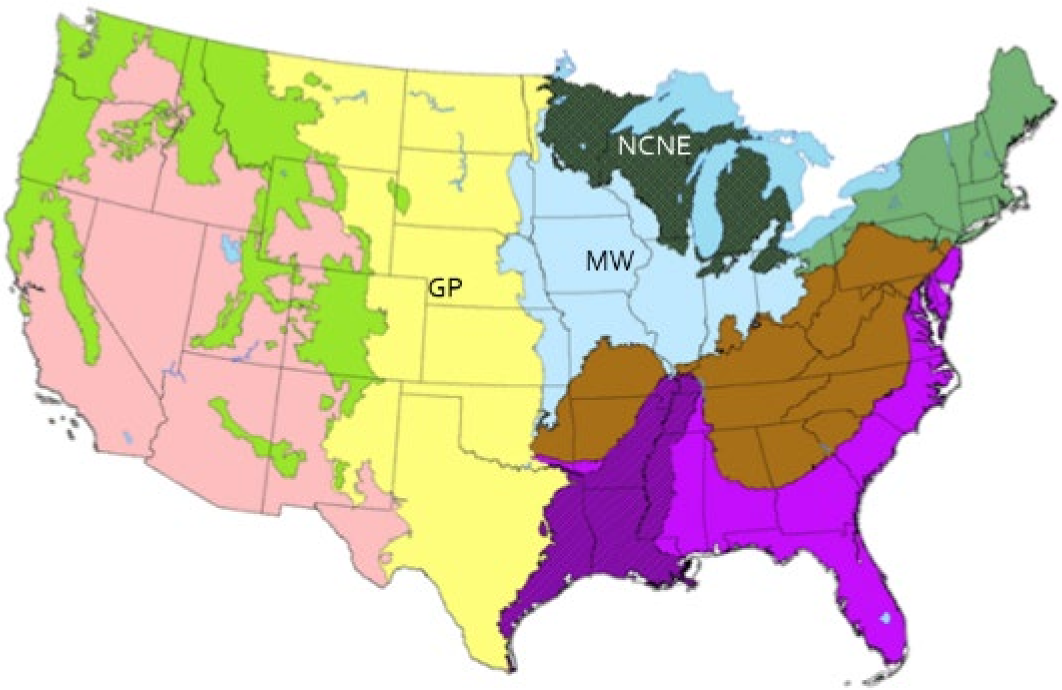


Figure 10. National Wetland Plant List (NWPL) regions that overlap with the beta SDAM GP region.

Hydrophytic plant species that exhibit an odd or unusual distribution pattern in the assessment reach should not be considered among the number of hydrophytic plant species present. Examples of odd or unusual distribution patterns are described below; all Figures are from the Arid West and are strictly for illustrative purposes.

- Isolated individuals, or small patches covering only a small portion of the total assessment area (e.g., < 2%) and only found in one location (as opposed to plants sparsely distributed throughout the reach). Local conditions may support the growth of hydrophytes in otherwise unsuitable conditions. In more arid regions, this can occur at road crossings, where road runoff increases water availability to vegetation (Figure 11).
- Long-lived species exclusively represented by seedlings or plants less than one-year old. A large flood may promote the growth of hydrophytes in streams that are normally too dry to sustain them (Figure 12).
- Old specimens clearly in decline. This scenario may be a sign of major long-term reductions in water availability due to changes in water use practices or to extreme and/or persistent drought (Figure 13).

These species may be recorded on the field form, along with notes explaining the unusual distribution patterns observed, but should not be among the number of hydrophyte species entered for this beta SDAM GP indicator.

Figure 11. Local conditions that support growth of hydrophytes. In Ridgecrest, CA, a culvert at an ephemeral stream crossing disrupts the movement of water, sustaining the growth of hydrophytes in the immediate vicinity. Photo credit: Cara Clark.

Figure 12. Long-lived species only represented by young specimens. Red alders (Alnus rubra), while abundant at Mission Creek in the Mojave Desert, were only observed as seedlings. Photo credit: Raphael Mazor.

Figure 13. Water-stressed riparian trees near Oro Grande on the Mojave River. Reproduced from Lines (1999).

Identify up to five hydrophytic plant species growing within the channel or up to one half-channel width from the channel of the assessment reach that do not have unusual or odd distribution patterns. Hydrophytes growing at greater distances from the channel may be supported by local water sources not related to streamflow in the assessment reach. In general, a focus on the most dominant species in the reach is efficient; focusing on species where confidence in identification is highest is acceptable. Take photos of each plant species, focusing on diagnostic features and photos that illustrate the abundance and environmental context where the species grows.

If the site is devoid of vegetation, check the box marked “No vegetation within reach.”

Common questions about identifying hydrophytes

Are FACW and OBL plants equally important?
Yes. For this method, OBL and FACW plants are equally important indicators of streamflow duration.

Do Facultative (FAC) or Facultative Upland (FACU) status plants count?
No. Although some applications of the NWPL treat FAC or FACU plants as hydrophytes, they do not count towards this indicator for the beta SDAM GP. For instance, some important, high-profile riparian species are FAC in some or all of the NWPL regions applicable to the Great

Plains, such as American sycamore (*Platanus occidentalis*; GP NWPL region), Eastern cottonwood (*Populus deltoides*; all applicable NWPL regions), green ash (*Fraxinus pennsylvanica*; GP NWPL region), and box elder (*Acer negundo*; all applicable NWPL regions). This exclusion in no way lessens the ecological importance or conservation value of these plants, but rather indicates their relative tolerance for drier conditions than FACW or OBL species.

What if a species is not included in the NWPL?
If a plant is not included in the NWPL, assume that it is not a hydrophyte unless environmental context strongly indicates otherwise. (See "What if I can't confidently identify a dominant plant?" below.)

Is genus-level identification okay?
It depends on the genus. Consult the NWPL. Some genera contain high levels of diversity (e.g., *Carex*), while others are dominated by wetland species (e.g., *Ludwigia*). For instance, across the GP, nearly all willow (*Salix*) species are hydrophytes (though there are a few exceptions), so genus-level identifications of willows are usually acceptable. Post-sampling confirmation based on photos or collected specimens is recommended.

What if I can't confidently identify a dominant plant?
It may be acceptable to use environmental context and cues to determine that a plant is a hydrophyte, even if taxonomic identifications cannot be made. Examples include submerged or emergent macrophytes, or plants observed to grow exclusively in saturated soil and absent from adjacent uplands (Figure 14). Post-sampling confirmation based on photos or collected specimens is strongly recommended. Photo documentation should convey this context. Photo confirmation is particularly important if the only hydrophyte observed in an assessment cannot be identified on-site. Photos can also be used when consulting plant identification applications that use image recognition (e.g, Seek, iNaturalist).

Figure 14. Examples of plants determined to be hydrophytes based on context. Left: An emergent macrophyte growing within the channel. Right: Sedges and cattails growing exclusively in the streamside zone absent from adjacent uplands.

What if a hydrophytic plant species covers <2% of the assessment area (channel width plus ½ channel width on both sides of the channel x reach length) and is represented only by seedlings and/or dead/dying individuals?

Do not consider the species among the number of hydrophyte plant species present in the reach. The species with such distributions can be photographed and noted for additional information on the reach.

4. Absence of rooted upland plants in streambed

Upland plant species are usually unable to establish in streams having longer streamflow duration, as prolonged soil saturation provides less than ideal growth conditions for these species. Surface flow can limit plant establishment by displacing seeds or otherwise preventing germination and growth. Therefore, reaches where rooted upland plants cover much of the streambed may indicate ephemeral or intermittent flow. For the beta SDAM GP, upland plants are those with FAC, FACU and Upland (UPL) indicators on the most recent NWPL or species with No Indicator (NI).

When assessing this indicator, the focus should be on plants rooted in the streambed; plants growing on any part of the bank should not be considered (Figure 15). Evaluate the entire length of the reach for this indicator and choose the score from Table 3 that best characterizes the predominant condition in the reach. Intermediary scoring (i.e., 0.5, 1.5, 2.5) of the ordinal scores shown in Table 3 are appropriate to allow the accessor flexibility to characterize this indicator more continuously. Note that a higher score is given for the absence of rooted upland plants in the streambed.

Table 3. Scoring guidance for the Absence of Rooted Upland Plants indicator

Score	Evidence of perennial flows	Guidance
0	Poor	Rooted upland plants are prevalent within the streambed/thalweg.
1	Weak	Rooted upland plants are consistently dispersed throughout the streambed/thalweg.
2	Moderate	Few rooted upland plants are present within the streambed/thalweg.
3	Strong	Rooted upland plants are absent within the streambed/thalweg.

*Figure 15. Example of an ephemeral stream with rooted upland vegetation growing in the channel. Where vegetation is growing within the streambed of Safe Dolan Creek in Texas, it is dominated by Texas sotol (*Dasylirion texanum*) and Ashe juniper (Juniperus ashei), both of which have no indicator (NI) on the National Wetland Plant List for the Great Plains region.*

5. 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. While this reversed pattern is more common in a region like the Arid West, it may also occur within the Great Plains, particularly near its boundary with the Arid West (parts of New Mexico, Texas, and Wyoming). 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 the assessment reach size, selection, and placement section. In multi-threaded channels, the width of the entire active channel is measured for this indicator, based on the outer limits of the OHWM. Wohl et al. (2016) described 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.

6. Sinuosity

Sinuosity is a measure of the curviness of a stream channel and is measured as the ratio of the stream length to valley length (Figure 16). When the two lengths are equal, the ratio is 1, and sinuosity is considered low; that is, the stream flows in a straight channel from the top to the bottom of the reach. In contrast, when the stream channel follows a meandering path, the stream length will be greater than the valley length, and the ratio will be greater than 1; a higher ratio reflects a more meandering path.

Sinuosity is caused by hydraulic processes that deposit sediment on one side of a reach while eroding it from another. It is typically highest in sand- and gravel-bed stream-reaches, and lowest in confined stream-reaches within canyons. Local features resistant to erosion (such as bedrock outcrops or logjams) may increase sinuosity as well. Although it has no direct relationship with streamflow duration (that is, it is neither a driver of, nor a response to, streamflow duration), perennial reaches more frequently exhibit the conditions necessary to produce meanders than ephemeral streams (Billi et al. 2018). As such, it is an effective indicator of streamflow duration in the Great Plains.

Sinuosity may be assessed in a number of ways in both the field and from a desktop usingGIS or interpretation of aerial imagery. For the beta SDAM GP, field measurement is preferred, and whenever desktop estimates are used, field confirmation is required.

In the field, sinuosity may be visually estimated, or measured using a surveyor's level. Although the length of the assessment reach may too short to properly characterize sinuosity for certain stream reaches, the beta SDAM GP is calibrated for estimates made at reaches ranging from 40 to 200 m in length (i.e., 40 times the bankfull channel width

To score this indicator, compare the measured sinuosity value to the guidance in Table 4 and Figure 16. In multi-threaded systems, the sinuosity measurement should be based on the dominant (i.e., lowest elevation) channel, and not the entire active channel (Figure 17). In modified channels, score the sinuosity observed, not what would be expected in a natural system.

Table 4. Scoring guidance for the Sinuosity indicator.

Score	Evidence of perennial flows	Guidance
0	Poor	Ratio of valley length: Stream length < 1.05. Stream is completely straight with no bends
1	Weak	Ratio between 1.05 and 1.2. Stream has very few bends, and mostly straight section.
2	Moderate	Ratio between 1.2 and 1.4. Stream has good sinuosity with some straight sections.
3	Strong	Ratio > 1.4. Stream has numerous, closely spaced bends with few straight sections.

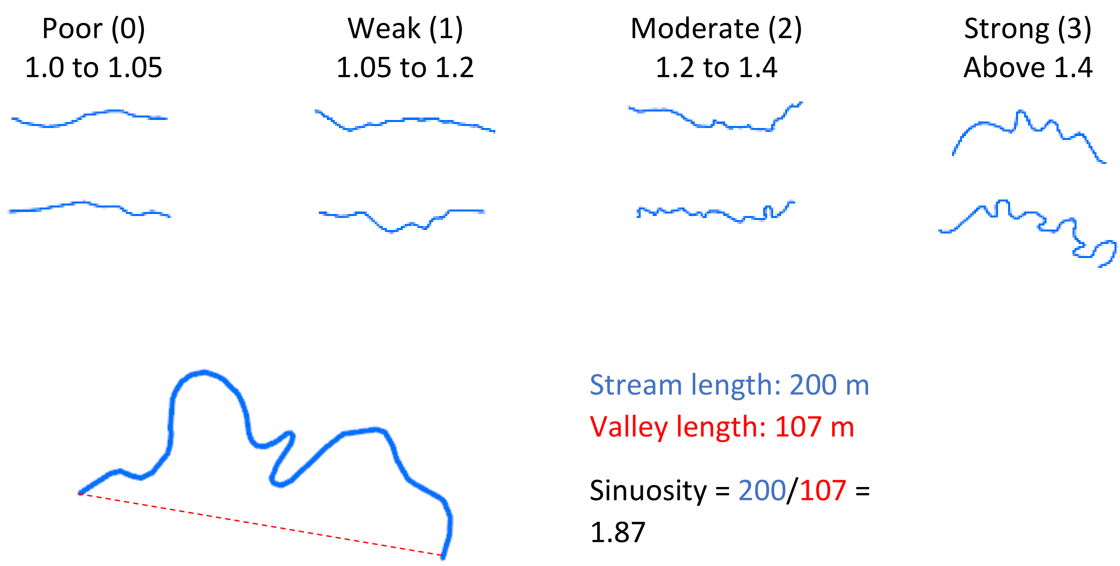


Figure 16. Scoring guidance for the Sinuosity indicator. Values in parentheses are sinuosity scores and ranges are for ratios of stream length to valley length. Shown (top) are two example stream channels for each range of stream length to valley length and (bottom) an example that identifies the stream length, valley length, and ratio calculation.

Figure 17. Sinuosity measurements in a multi-threaded system. The stream length (dashed blue line) is measured in the dominant (i.e., lowest elevation) channel. Valley length is represented by the solid red line.

7. Floodplain and channel dimensions

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 18). Bankfull is the height on the streambanks during moderate high-water events when water begins to overflow onto the floodplain. 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. Further discussion of identifying bankfull and measuring bankfull width can be found in the assessment reach size, selection, and placement section.

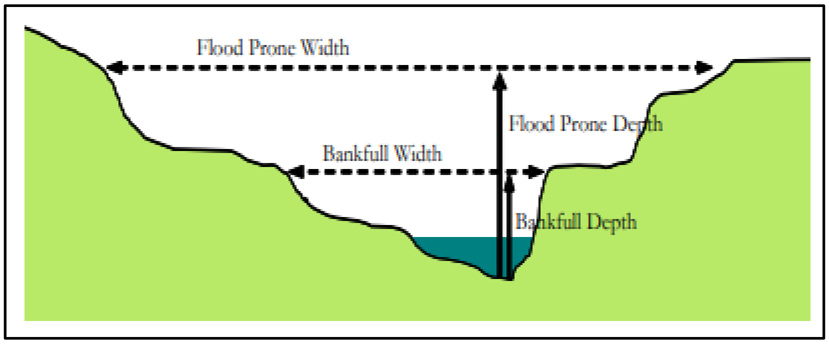


Figure 18. Measurement of entrenchment is based on the ratio of the flood-prone width to the bankfull width.

After determining bankfull width at a representative location (e.g., one of the locations where bankfull width was measured to determine reach length), the floodplain and channel dimension indicator can be visually scored or measured following:

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. Divide the flood-prone width by the bankfull width to estimate the entrenchment ratio.
5. If necessary, conduct this assessment at multiple locations to determine the entrenchment ratio typical of the reach.

Score the indicator using Table 5.

Table 5. Scoring guidance for Floodplain and Channel Dimensions indicator.

Score	Evidence of perennial flows	Guidance
0.0	Poor	Ratio of flood-prone width to bankfull width < 1.2. Stream is incised, with a noticeably confined channel. Floodplain is narrow or absent, and typically disconnected from the channel.
1.5	Moderate	Ratio between 1.2 and 2.5. Stream is moderately confined. Floodplain is present but may only be active during larger floods.
3.0	Strong	Ratio > 2.5. Stream is minimally confined, with a wide, active floodplain.

8. Particle size or stream substrate sorting

Well-developed streams 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 floodplain sediments and adjacent soils. Similar sediment sizes in the stream bed and the adjacent stream side 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. The bed in ephemeral channels is typically soil, having the same or similar soil texture as areas adjacent to the channel, and often having differentiated soil horizons.

This indicator can be evaluated in two ways:

1) In channel versus outside channel: Determine if the sediment texture on the bed of the channel is similar to sediment texture adjacent to the channel (e.g., on banks or adjacent floodplain). If this is the case, then there is evidence that erosive forces have not been active enough to down cut the channel and support an intermittent or perennial system. Stormflow runoff resulting from human development can form incised ephemeral or intermittent channels; however, these channels often still have little to no coarse substrates.
2) Substrate sorting: Look at the particle size distribution on the channel bed. For lower gradient channels dominated by sand substrate, the user may need to identify sorting across coarse versus fine sand.

Regardless of the approach used to assess channel sediments (e.g., pebble count, sand-gauge reference card), evaluate an area adjacent to but not in the channel for comparison purposes. Avoid adjacent areas with dense vegetation and recent soil disturbance.

Score the indicator using the guidance in Table 6; photos that demonstrate the scoring guidance are shown in Figure 19. Intermediary scoring (i.e., 0.75, 2.25) of the ordinal scores shown in Table 6 are appropriate to allow the accessor flexibility to characterize this indicator more continuously.

Table 6. Scoring guidance for Particle Size/Streambed Sorting indicator.

Score	Evidence of perennial flows	Guidance
0.0	Poor	Particle sizes in the channel are similar or comparable to particle sizes in areas close to but not in the channel. Substrate sorting is not readily observed in the channel.
1.5	Moderate	Particle sizes in the channel are moderately similar to particle sizes in areas close to but not in the channel. Various sized substrates are present in the channel and are represented by a higher ratio of larger particles (gravel/cobble).
3.0	Strong	Particle sizes in the channel are noticeably different from particle sizes in areas close to but not in the channel. There is a clear distribution of various sized substrates in the channel with finer particles accumulating in the pools, and larger particles accumulating in the riffles/runs.

Figure 19. Different levels of particle size/stream substrate sorting.Top photo: Dry channel in Texas where the in channel particle size of material is similar to surrounding uplands (score of 0); Middle photo: This Montana stream shows signs of increased sorting in the middle of the channel, with slightly larger particles than surrounding uplands (score of 1.5); Bottom photo: Particle sizes in this North Dakota channel located are much larger compared to surrounding uplands and a high level of sorting can be seen in the riffle in the middle of the photo (score of 3).

9. Northern or Southern Great Plains

Whether a reach is within the Northern or Southern Great Plains (Figure 2) is an indicator of flow duration (Figure 2). The following states lie only in the Northern GP: CO, IA, IL, KS, MN, MO, MT, ND, NE, SD, WI, and WY. NM, OK, and TX lie in both the Northern and Southern GP regions. The web application identifies the correct region for the assessment reach, as well as determines if a site is in an adjacent region (e.g., the Arid West) not covered by the beta SDAM GP.

Additional notes and photographs

After assessing and recording all the indicators described above, provide any additional notes about the assessment, and include photographs in the photo log.

Section 4: Data Interpretation and using the web application

Because the beta SDAM GP relies on a random forest model to make classifications, we have developed a free, open-access web application (https://ecosystemplanningrestoration.shinyapps.io/beta_sdam_gp/) that allows assessors to input data from assessments and obtain a classification. In addition, users have the option to produce a PDF report in a standardized format, which may then be included in any documentation that requires incorporation of SDAM results.

The web application provides three tabs. The first tab provides background information about the method. The second tab is where users can enter geographic coordinates or select the region (Northern or Southern Great Plains) as well as enter field data needed to obtain a classification and additional information (such as assessment date) and photographs needed to produce a standard report. The third tab provides links to additional resources. Classifications may be obtained without producing a report. No data submitted to the web application is stored or submitted to the EPA or other agencies.

Outcomes of beta SDAM GP classification

Application of the beta SDAM GP can result in one of four possible classifications:

- Ephemeral
- Intermittent
- Perennial
- At least intermittent

The first three streamflow duration classifications correspond to the three classes of streams used to calibrate the beta SDAM GP (i.e., perennial, intermittent, or ephemeral streams). 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.

In some cases, the pattern of indicators is associated with multiple classes, and the beta SDAM GP model cannot assign a single classification with high confidence. However, the beta SDAM GP model may be able to rule out an ephemeral classification with high confidence. In this case, the outcome is *at least intermittent*, meaning that there is a high likelihood that the stream is either perennial or intermittent. In this circumstance, however, the two classes cannot be distinguished with confidence. In some cases, this information may be sufficient for management decisions, although additional assessment may be warranted. The *at least intermittent* outcome was rare in the beta SDAM GP development data set.

Applications of the Beta SDAM GP outside the intended area

The beta SDAM GP is intended only for application to the GP regions shown in Figure 2. The online web application allows the user to apply the protocol to reaches outside the GP; however, classifications resulting from these applications are for informational purposes only.

For example, it may be helpful to assess reaches near regional boundaries. Reports generated from such applications are accompanied by warnings.

What to do if more information about streamflow duration is desired?

The beta SDAM GP will always result in one of the four classifications described above. There may be cases when additional information is desired. For example, conditions at the time of assessment may have complicated the measurement of some indicators. It may help to examine other lines of evidence or conduct additional evaluations.

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 beta SDAM GP, 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 aquatic invertebrates, leading to more conclusive assessments.

Conduct evaluations at nearby reaches

Indicators may provide more conclusive results at reaches up- or downstream from the assessment reach, as long as those locations represent similar conditions. 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 the assessment reach size, selection, and placement section for guidance.

Review historical aerial imagery

In many parts of the Great Plains, sequences of aerial imagery can provide information about streamflow duration. Google Earth's time slider and USGS Earth Explorer offer a convenient method of reviewing historical imagery, particularly for areas where trees do not obscure channels (however, Google Earth time slider may not have accurate image dates). 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 APT (U.S. Army Corps of Engineers 2020a) is a useful tool to determine if climate conditions are 'normal' for a locale (see timing of sampling section). 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 20.

Perennial reach: South Loup River at Arnold, NE


7/2006: Flowing


5/2012: Flowing


4/2017: Flowing

Intermittent reach: Tributary to North Fork Grand River, Dakota Prairie Grasslands, SD


9/1997: Pools only


12/2003: Pools only


10/2014: Discontinuous flow

Ephemeral reach: Tributary to East Carrizo Creek, Pike and San Isabel National Forests, CO


6/2005: Dry


10/2011: Dry


10/2016: Dry

Figure 20. Examples of using aerial imagery to support streamflow duration classification. Images were taken from Google Earth using the time slider.

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.

Collect additional 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 beta SDAM GP indicators are measured.
Bank	The side of an active channel, typically associated with a steeper side gradient than the adjacent channel bed, 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 system downstream. Same as multi-threaded system.
Benthic macroinvertebrates	Invertebrate organisms found at the bottom of waterbodies and visible without the use of a microscope (i.e., > 0.5 mm body length).
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.
Cerci	The tail-like filaments at the posterior end of some arthropods' abdomens. Singular: cerucs.
Channel	A feature in fluvial systems consisting of a bed and its opposing banks which confines and conveys surface water flow. A braided system consists of multiple channels, including 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.

Entrenchment ratio	Ratio of the flood-prone area width to the bankfull channel width, used as part of scoring the Floodplain and Channel Dimensions indicator.
Ephemeral	Ephemeral streams are 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.
EPT	Ephemeroptera, Plecoptera, Trichoptera
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.
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 area	Width of floodplain at the flood-prone elevation (2x maximum bankfull depth)
Groundwater	Water found 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	A measurement of environmental conditions. For the beta SDAM GP, indicators are rapid, generally field-based measurements that predict streamflow duration class.
Intermittent	Intermittent reaches are 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 low-flow channel is the main channel with the lowest thalweg elevation. In intermittent or ephemeral reaches, the low-flow channel typically retains flow longer than other channels.
Macrophyte	Aquatic plants.
Metamorphosis	The process of transforming from one life stage to another. The term may apply to the transformation from larval to adult insects, as well as to amphibians (e.g., the transformation from tadpoles to adult frogs). Newly transformed frogs are sometimes called metamorphs. Insects with incomplete metamorphosis (e.g., mayflies and stoneflies) transition directly from larval to adult stages, whereas insects with complete metamorphosis (e.g., caddisflies) go through a pupal stage.
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 system 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.
Nymph	An immature stage of an insect. The term only applies to insect orders that lack complete metamorphosis (i.e., groups that lack a pupal stage and transform directly from larva to adult). Mayflies and stoneflies are examples of aquatic insects that have larvae known as nymphs.
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 USACE jurisdiction in non-tidal streams. See 33 CFR 328.4.
Perennial	Perennial reaches are 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. Caddisflies are an example of an aquatic insect order with a pupal stage. Plural: pupae.
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 is 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 invertebrates.
Riparian	A transitional area between the channel and adjacent terrestrial 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.
SAV	Submerged aquatic vegetation. This class is treated the same as OBL in current versions of the National Wetland Plant List.
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.
Sinuosity	Ratio of stream length (measured at the thalweg) to valley length.
Streambed	The bottom of a stream channel between the banks that is inundated during baseflow conditions.
Thalweg	The line along the deepest flowpath 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	The under surface of the abdomen; 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 Commonly Found EPT

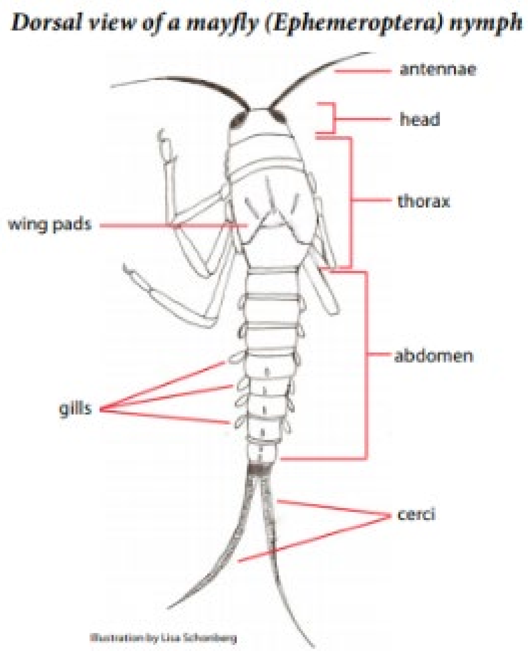
Assessors need to identify different EPT taxa in the field. This appendix will help assessors recognize common EPT taxa and how to distinguish EPT from other aquatic macroinvertebrates.

Credits are indicated under each photograph:

- CADFW: Digital Reference Collection of California Benthic Macroinvertebrates, maintained by the Aquatic Bioassessment Lab of the California Department of Fish and Wildlife.
- Macroinvertebrates.org: Macroinvertebrates.org website, an online reference for identification of aquatic insects of eastern North America.
- NAAMDRC: North America Macroinvertebrate Digital Reference Collection (https://sciencebase.usgs.gov/naamdrc/), maintained by the U.S. Geological Survey (Walters et al. 2017).

Another potentially useful reference is the digital key to the aquatic insects of North Dakota, at https://www.waterbugkey.vcsu.edu/index.htm.

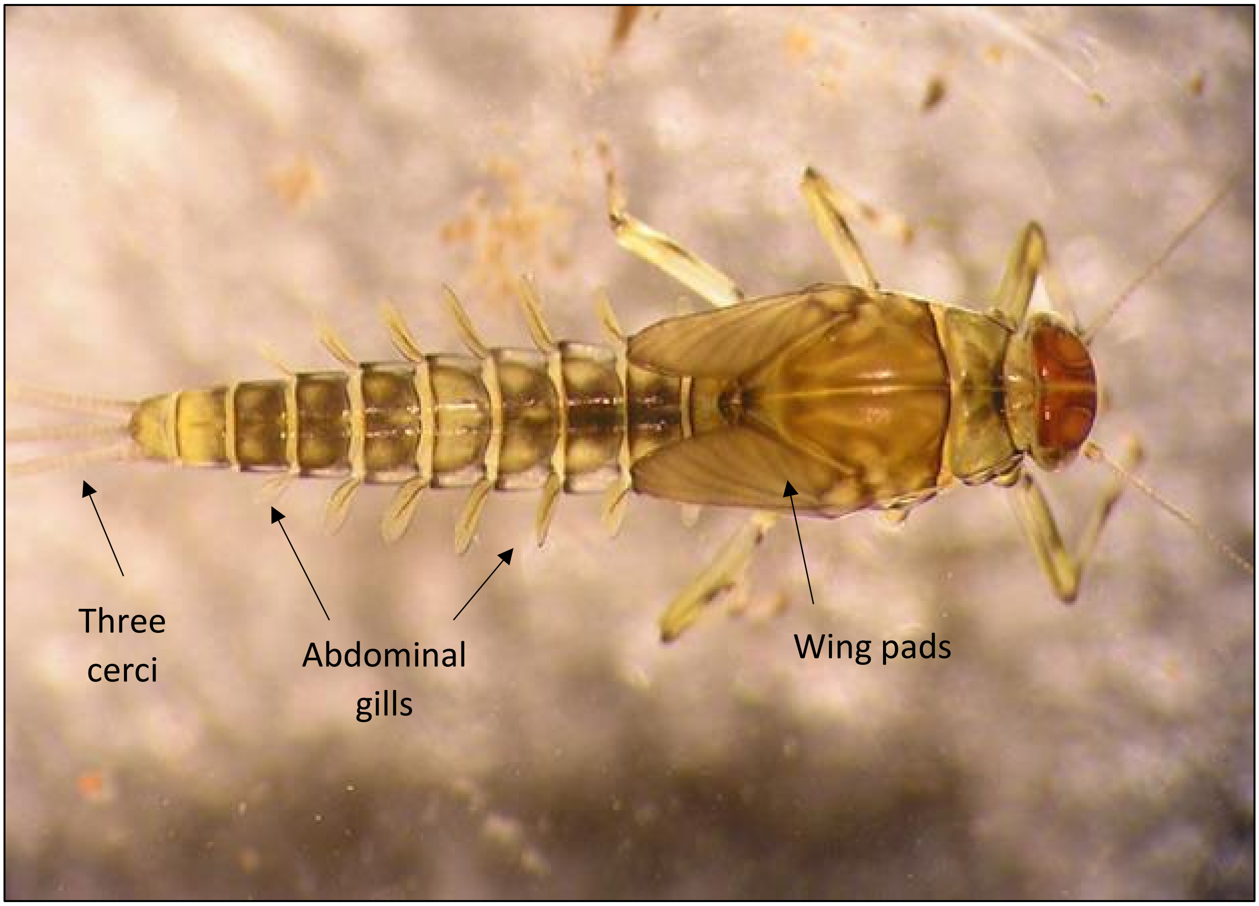
General insect anatomy



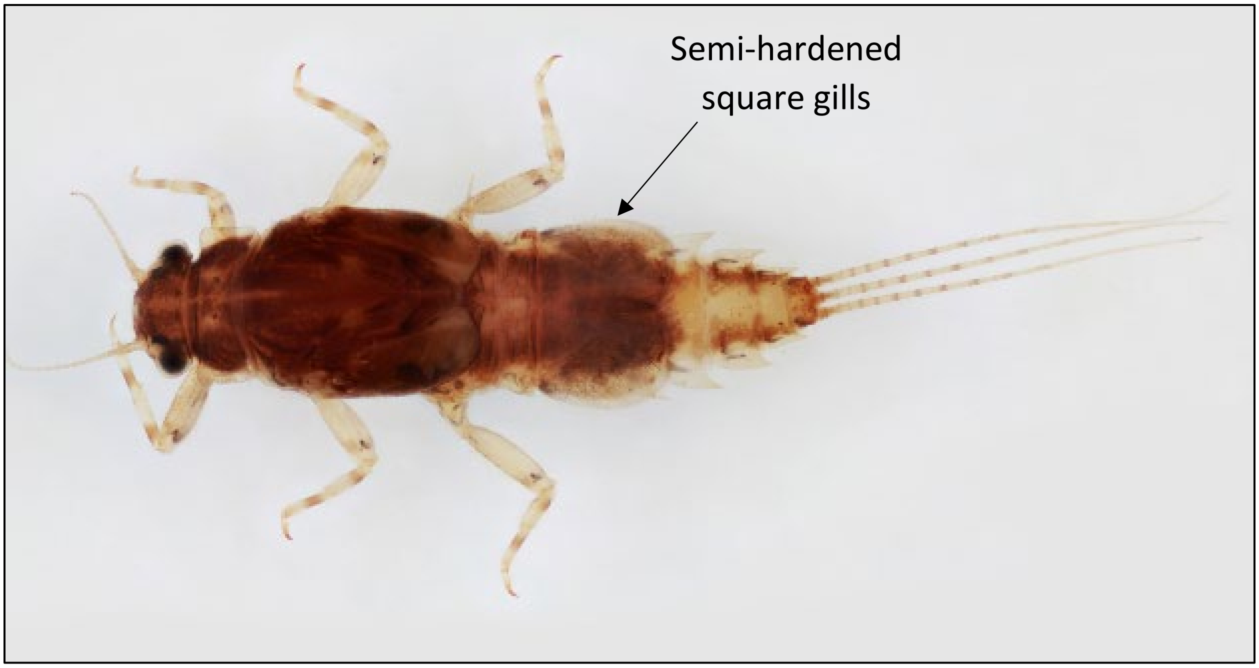
Familiarity with basic terms of insect anatomy can help distinguish EPT from other aquatic macroinvertebrates (from Mazzacano and Blackburn 2015).

Ephemeroptera (mayflies) larvae

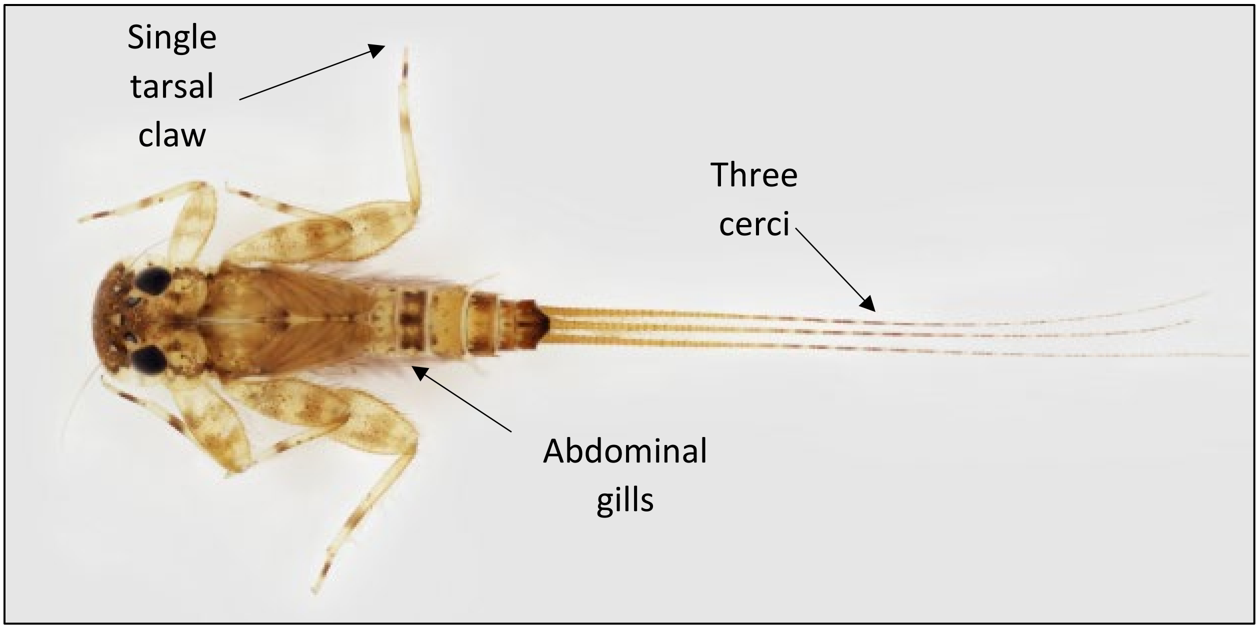
Mayflies have abdominal gills and generally have three cerci (tails), though a few species may have two cerci. Wing pads are usually visible. All adult mayflies are short-lived and terrestrial but may be found in large breeding swarms near waterbodies.



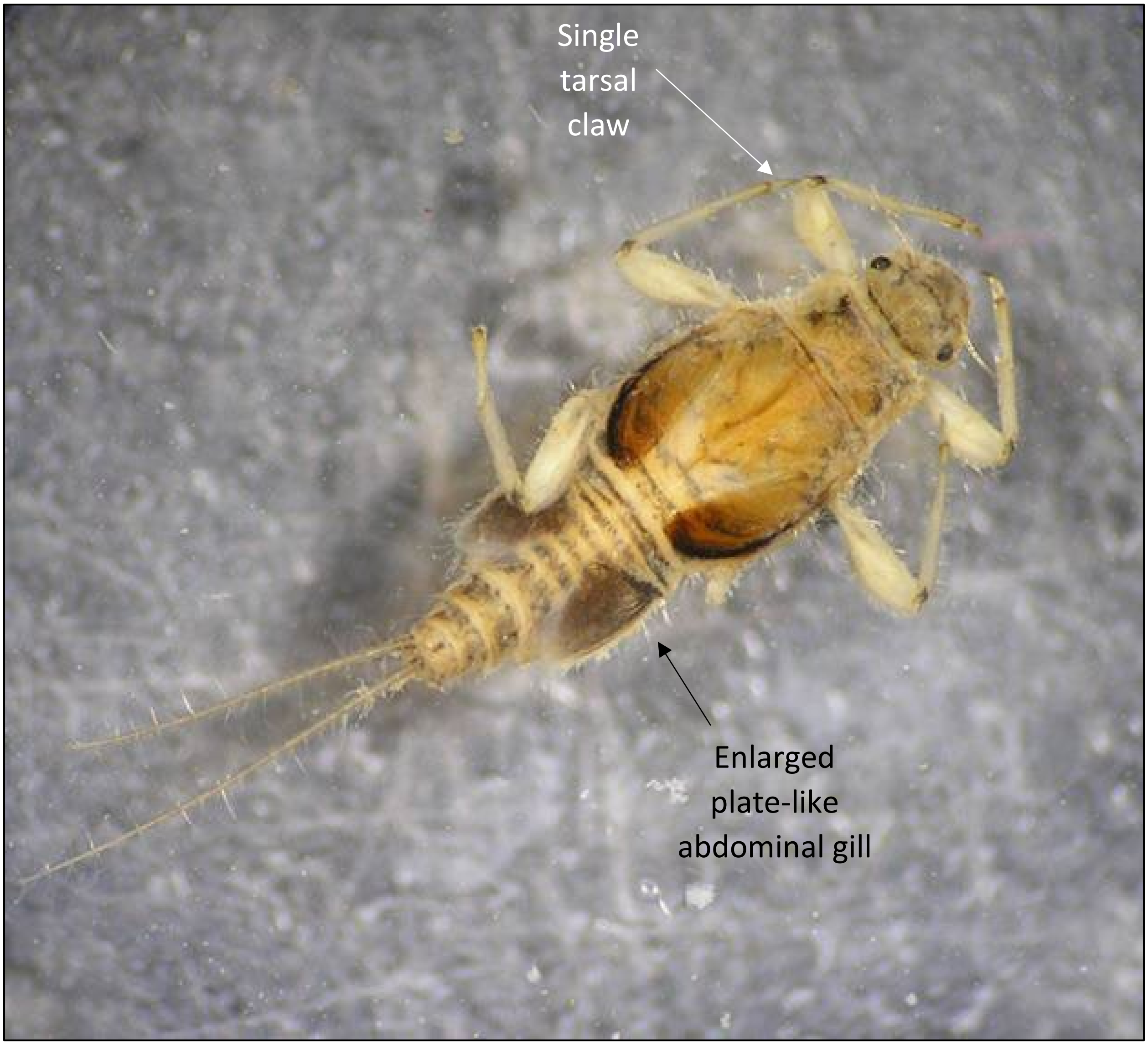
Baetidae (small minnow mayflies). This family has a streamlined appearance and appears to swim like a minnow. This specimen is *Baetis.* In some species of *Baetis*, only two cerci are evident. Baetidae was the most common and abundant EPT family collected during the field sampling to develop the beta SDAM GP. Image credit: CADFW.



Caenidae (square-gilled mayflies). This family of mayflies prefers slow moving or stagnant water where there is an abundance of loose sediment. The square, semi-operculate (i.e., hardened) gills that generally have a fringe of long hairs set this family apart from other mayflies. This specimen is *Caenis*; Caenidae was often the second most common and/or abundant mayfly family collected (after Baetidae) during the field sampling to develop the beta SDAM GP. Image credit: Macroinvertebrates.org



Heptageniidae (flat-headed mayflies). Heptageniid mayflies often have a flattened appearance, and cling to the undersides of cobbles in fast-flowing water. Still, they have the single tarsal claws, abdominal gills, and three cerci typical of mayflies. This specimen is *Maccaffertium*; there are a few *Maccaffertium* species present in the GP (e.g., *M. exiguum, M. mediopunctatum*). Image credit: Macroinvertebrates.org.



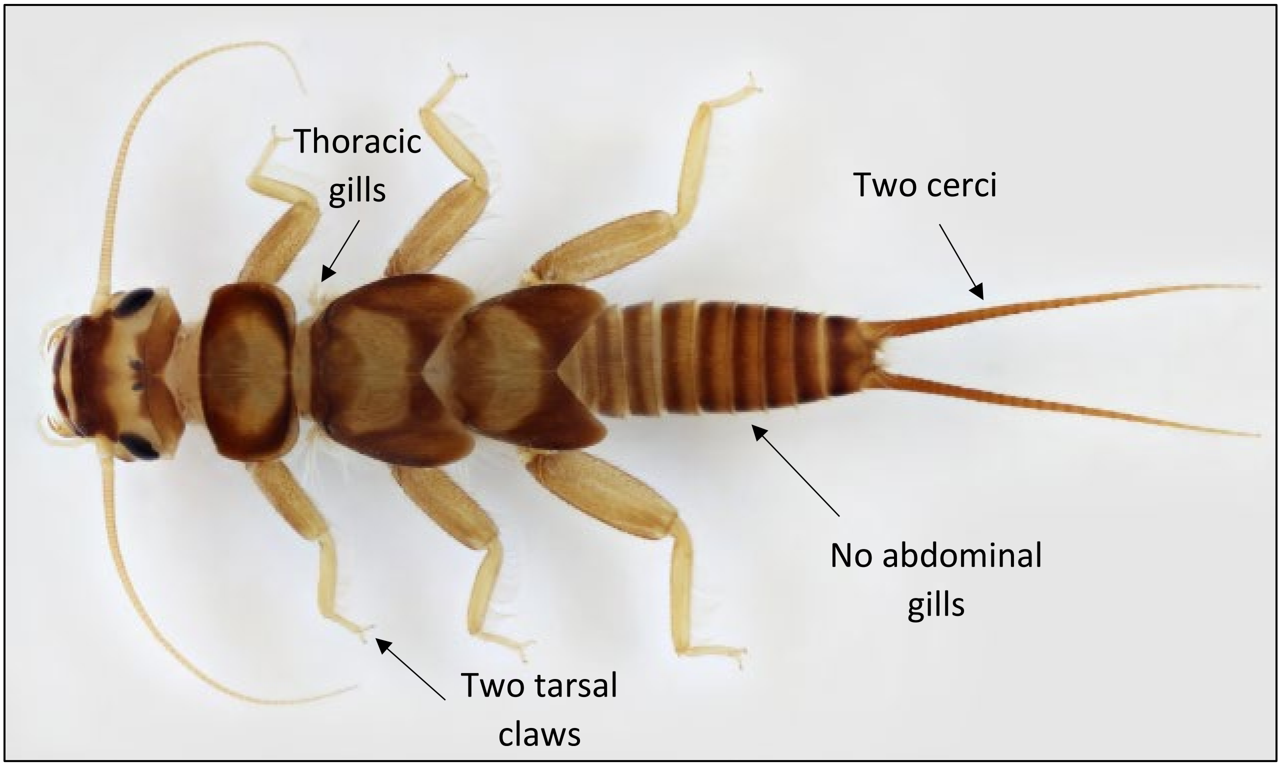
Leptohyphidae (little stout crawler mayflies). This family of mayflies has a pair of enlarged, hardened (i.e., sclerotized) abdominal gills that can cover the smaller, translucent abdominal gills. The family typically has three cerci, but the right one has broken off in this specimen. Image credit: CADFW.

Ephemeridae (burrowing mayflies). This family of mayflies prefers to burrow in soft, silty sediments. Although it is more common in lakes, it may be found in pools and slow-moving portions of rivers. The long feathery gills and single tarsal claws make this recognizable as a mayfly. This specimen is a *Hexagenia*; *Hexagenia limbata* is widespread throughout the Great Plains. Image credit: Macroinvertebrates.org

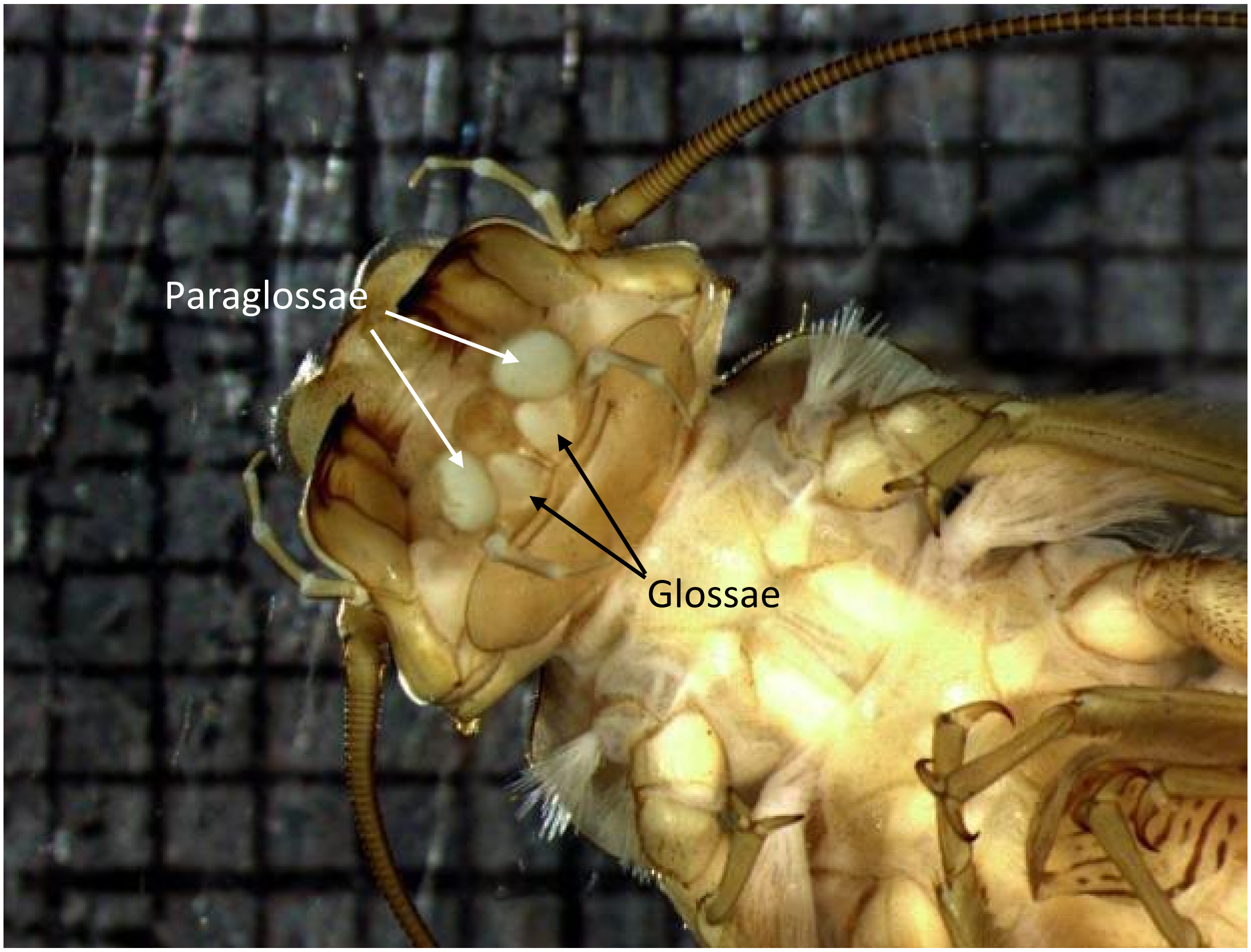
Leptophlebiidae (prong-gilled mayflies). This family of mayflies prefers gravel-bottomed streams, in woody debris or among roots protruding from the bank. They tend to be clingers with relatively flat bodies. The gills often have long forked prongs, giving this family its name. These specimens are *Leptophlebia,* which have lost large parts of their gills and tails. Image credit: James Treacy.

Plecoptera (stonefly) larvae

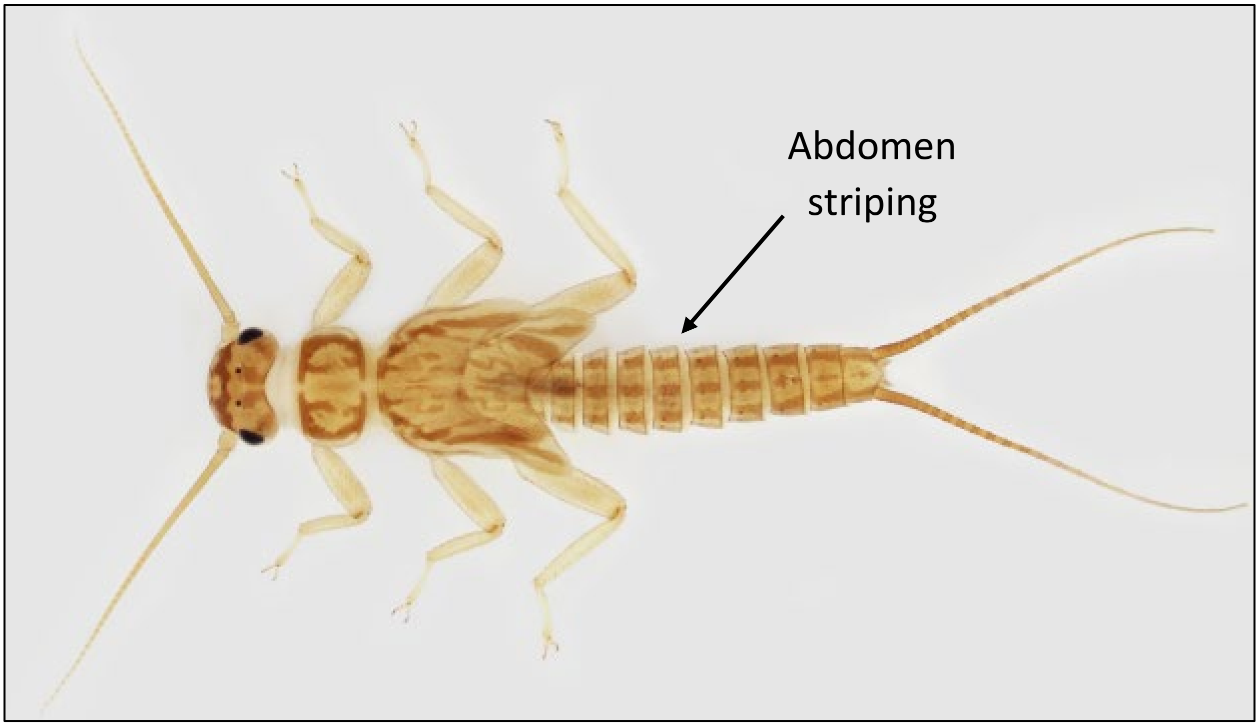
Nine families of stoneflies are found in North America, though stonefly diversity in the Great Plains is relatively low. Stoneflies usually have tuft-like gills on the thorax (and sometimes also on the first few abdominal segments), two (not one) tarsal claws at the end of each leg, and always have two (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.



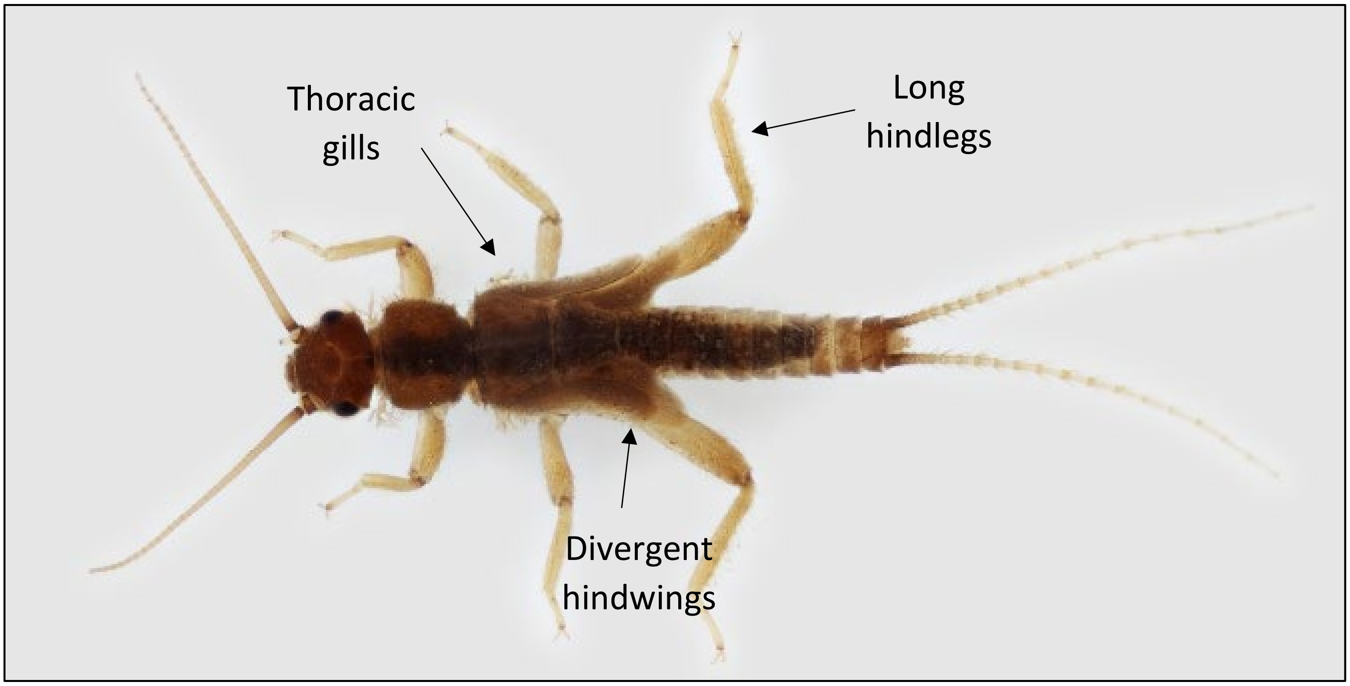
Perlidae (common stoneflies). The Perlidae family is large and conspicuous, often with ornate patterns on the head and thorax. This family has gills on the thorax (not abdomen) and has glossae much shorter than the paraglossae (see image on next page). Perlids were the most common and abundant stoneflies identified during field sampling to develop the beta SDAM GP. This specimen is *Neoperla*. Image credit: Macroinvertebrates.org.



Perlidae. Mouthparts can be seen in this view (*Acroneuria*). The glossae are shorter than the paraglossae. Image credit: NAAMDRC.



Perlodidae (stripetails). Members of this family have a patterned head and thorax and often longitudinal black-and-yellow striping on the abdomen. While most Perlodids are predators, some species in this group are also facultative shredders or collector-gatherers. They can often be found clinging to the substrate, plants, or other materials in the stream. This specimen is *Isoperla*, which is represented by several species that can found in part of the GP including *I. longiseta* and *I. quinquepunctata*. Image credit: Macroinvertebrates.org.



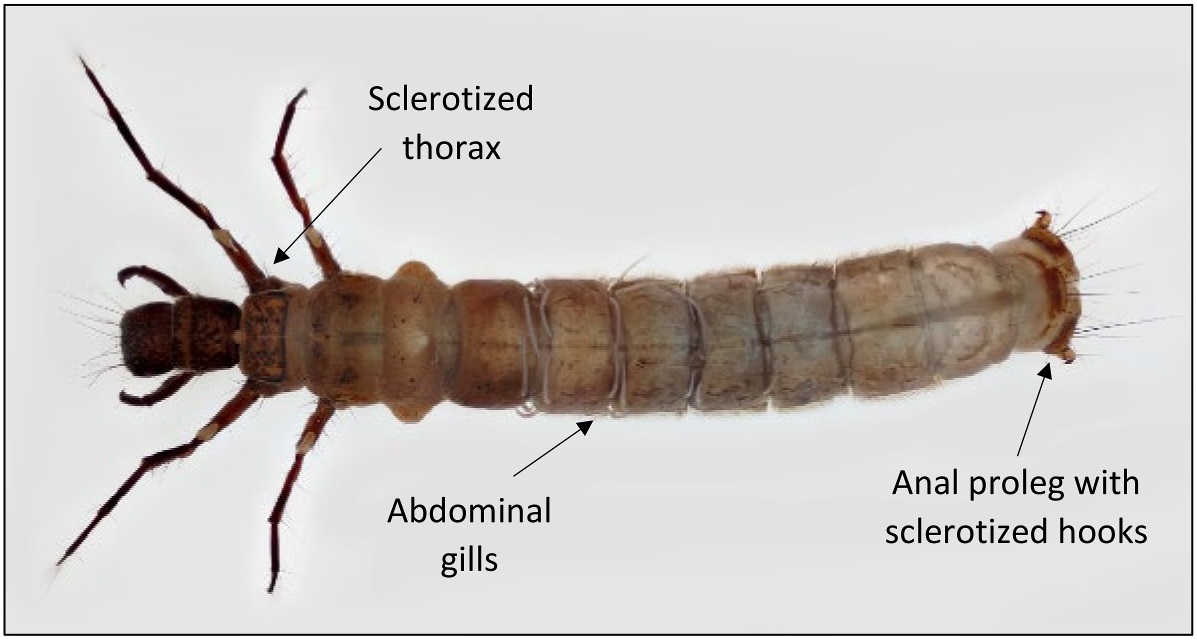
Nemouridae (nemourid stoneflies). This family is relatively small and contains species that prefer smaller rivers, streams, and springs. It is distinguished from other stonefly families by hindwings that diverge conspicuously from the boxy axis, and long hindlegs that can extend to the tip of the abdomen. This specimen is *Amphinemura*. Image credit: Macroinvertebrates.org.

Capniidae (small winter stoneflies, also known as snowflies). Members of this family have long, slender bodies with no thoracic or abdominal gills. They are shredders and so the glossae and paraglossae are approximately equal (in contrast to Perlids). The hind legs do not extend past the abdomen and there is a pleural fold (see below) that connects the abdominal segments (1-9 segments). The family **Leuctridae** is very similar to Capniidae, but this pleural fold is less evident and does not usually extend past abdominal segment 7. This specimen is *Allocapnia* (Capniidae); representatives of this genus that overlap with the GP include *A. granulata* and *A. rickeri*. Image credit: Macroinvertebrates.org.

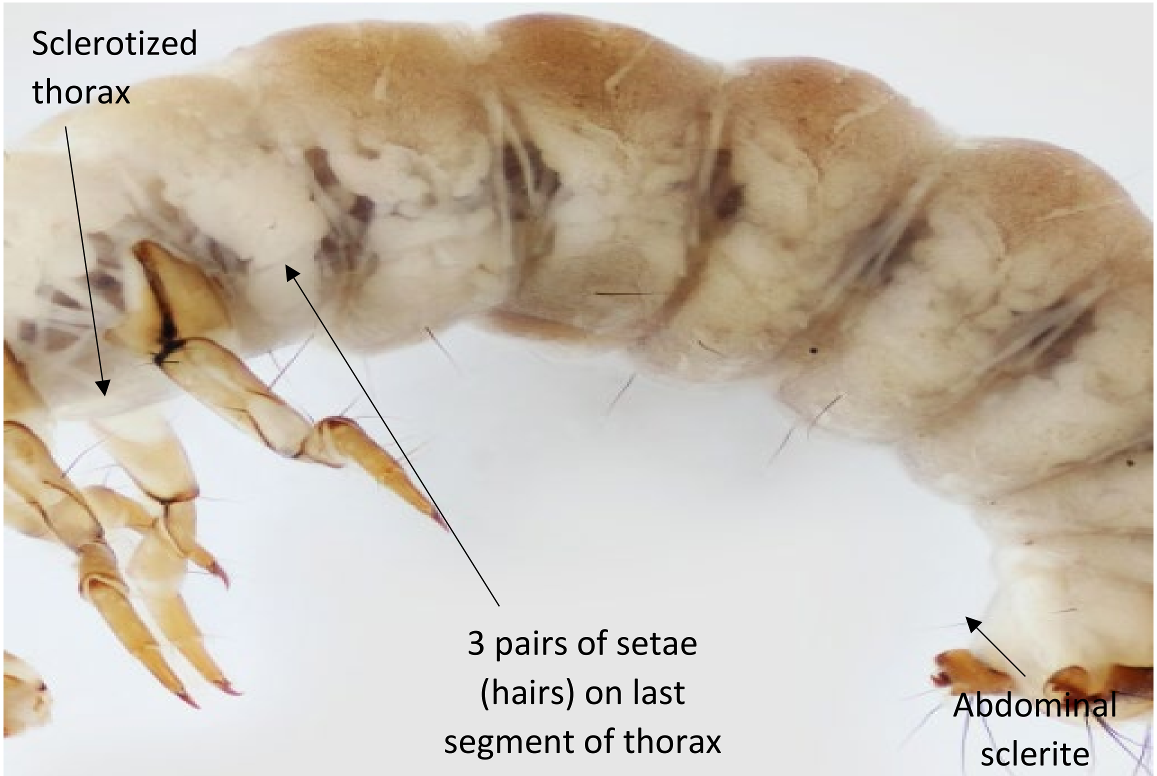
Image credit: NAAMDRC

Trichoptera (caddisfly) larvae and pupae

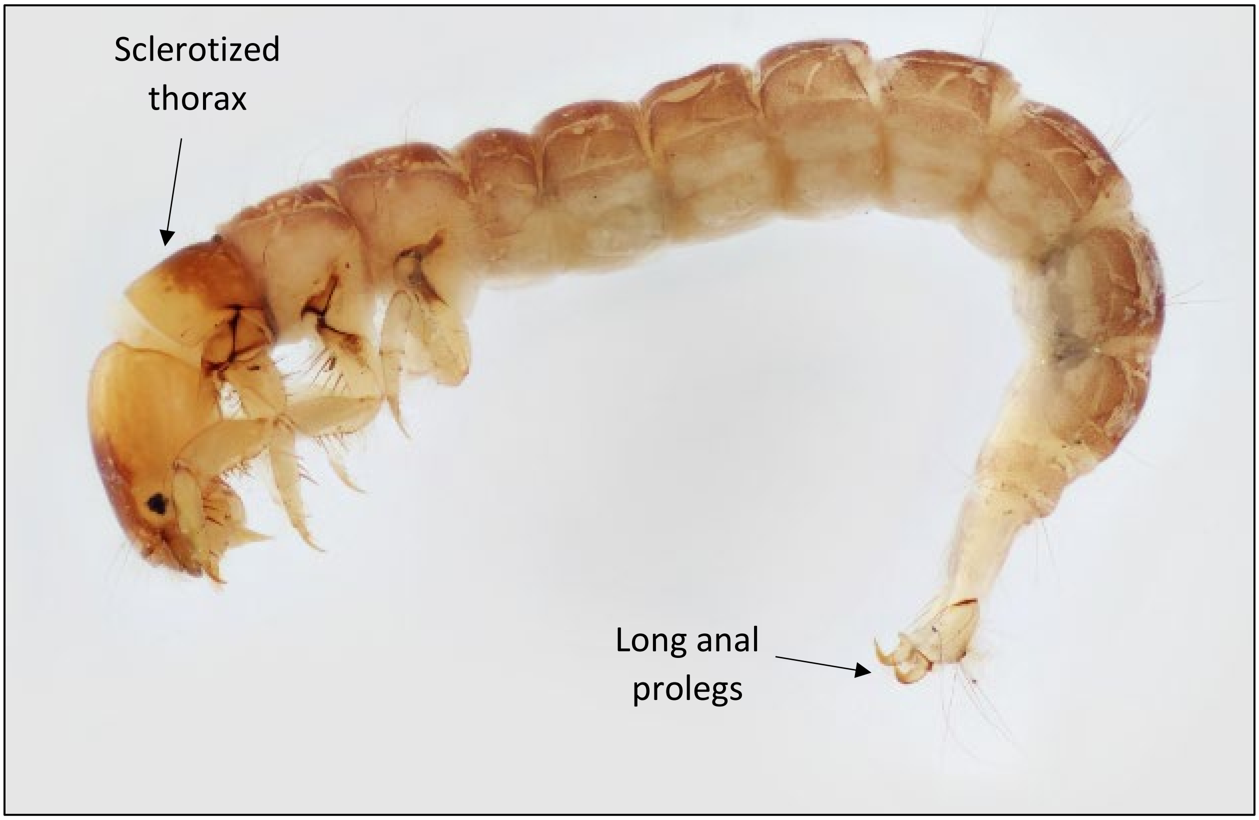
Caddisflies are closely related to moths and butterflies. Unlike mayflies and stoneflies, they have a pupal stage and undergo complete metamorphosis. Many taxa build conspicuous cases or retreats that may persist in dry streams. Some have filamentous gills on the ventral side (underside) of the abdomen (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.



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. This specimen is *Pycnopsyche*; representatives of this genus that overlap with the GP include *P. guttifera* and *P. subfasciata*. Image credit: Macroinvertebrates.org.



Glossosomatidae (saddle case-maker). This family has a distinctive case with two openings (although these are sealed in pupal cases). The larvae are distinguished from other caddisfly families by having only one sclerotized thoracic segment, a small sclerite on the next-to-last segment of the abdomen, and three pairs of setae (small hairs) on the last segment of the thorax. Image credit: Macroinvertebrates.org.



Polycentropodidae (trumpet-net, tube maker caddisflies). Members of this family prefer pools and areas of lesser current in streams and do not utilize a case; instead, they construct a tubular silken net. Only the first thoracic segment is sclerotized and no sclerotization occurs on the abdomen. The anal prolegs are long and freely moveable. This specimen is *Nyctiophylax;* representatives of this genus that overlap with the GP include *N. affinis* and *N. moestus*. Image credit: Macroinvertebrates.org.

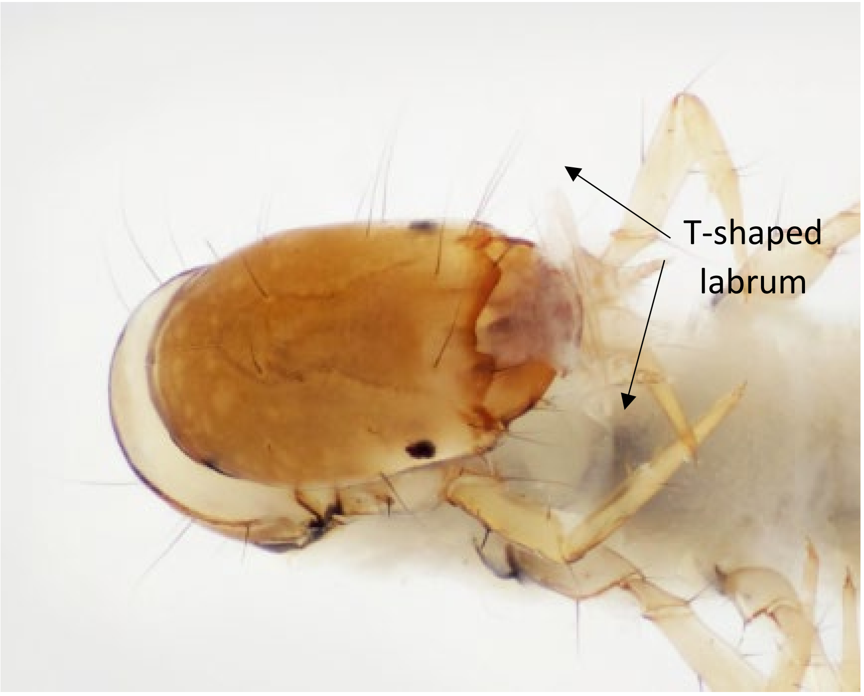
Leptoceridae (long-horned caddisflies). Members of this family are relatively small when mature but have the 'largest' antennae of the caddisflies. The antennae are still quite small but can be seen in profile. They can be found in a variety of habitats including still and flowing water and use plant or mineral materials or even pure silk to create their cases. This specimen is *Nectopsyche*; there are several representatives of this genus in the GP including *N. albida* and *N. exquisita*. The hind pair of legs in some genera, like *Nectopsyche* sp., are much longer than the front and middle pairs. However, not all Leptoceridae show this characteristic. Image credit: Macroinvertebrates.org.

Rhyacophilidae (free-roaming caddisflies). This family is usually found wandering freely on the undersides of boulders and cobbles, actively hunting for prey. Abdominal gills are present, but not evident in this photograph. Notice the long anal prolegs, which have large, sclerotized claws. Some species of this family have a striking blue-green coloration, which may fade when preserved in alcohol. Image credit: CADFW.

Hydroptilidae (micro caddisflies). These are small caddisflies (2-4 mm long) that build purse-like cases out of sand grains. They may be very abundant, but hard to see due to their size. Image credit: CADFW.

Helicopsychidae (snail case-makers) are unusual in that they build spiral-shaped, snail-like cases. Mnemonic device to remember name is they build “cases that are in a “helix”. Image credit: CADFW.

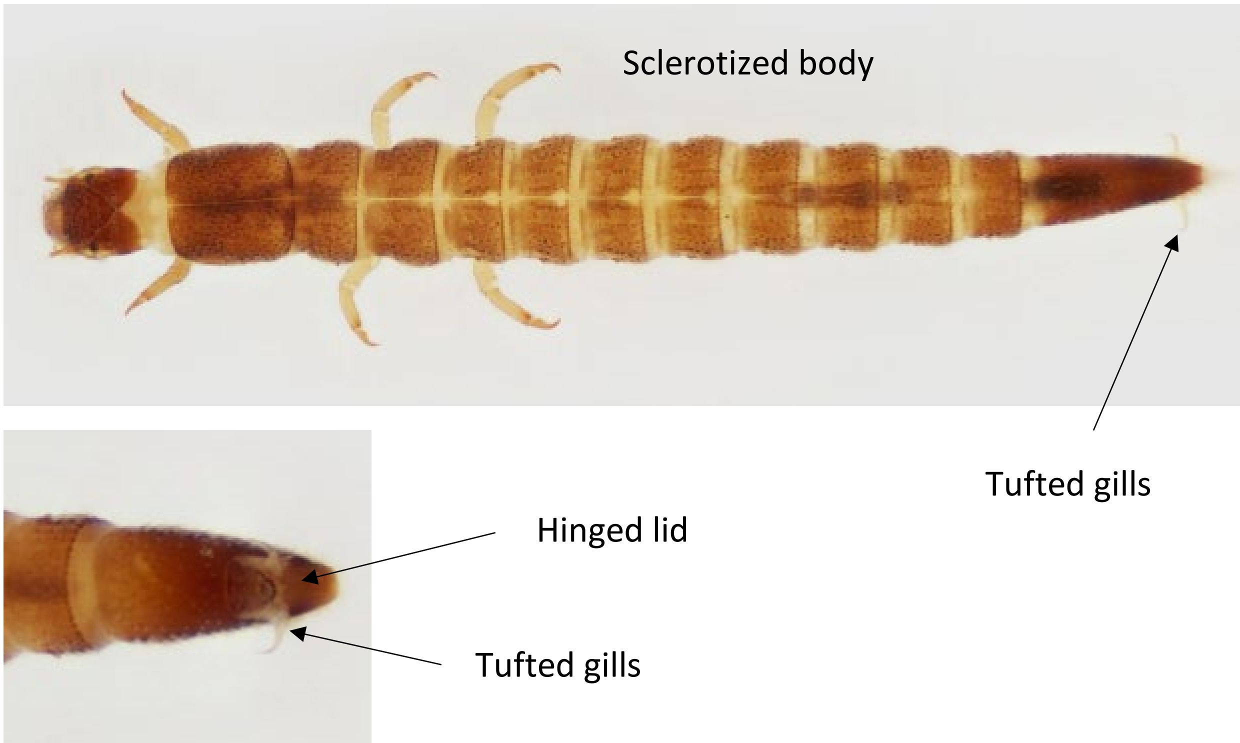
Hydropsychidae (net-spinner caddisflies). This group lives within nets in fixed locations out of silk, pebbles, and other materials. These nets are usually located in fast-flowing areas and on large, stable particles (such as large cobbles and boulders). Like a spider in a web, they wander about the retreat to catch prey that gets caught in the net. Turning over a boulder typically destroys these nets, but the larvae may be found crawling among the remains of the net. Hydropsychids were the most common caddisfly (and one of the most common families overall) collected during field sampling to develop the beta SDAM GP. Image credit: CADFW.



Philopotamidae (finger-net caddisflies). Like hydropsychid caddisflies, this family builds a retreat, but it is often found roaming free. It is distinguished from other families of caddisflies by its T-shaped labrum (extendable mouthpart). This specimen is *Chimarra* sp. Image credit: Macroinvertebrates.org.

Trichopteran Look-Alikes to Watch Out For

Other insect orders that include aquatic life stages have species that look superficially similar to caddisflies, and may be mistaken for them, especially if no case is present or the caddisfly is separated from its case or net during collection. These should not be counted as EPT taxa for Indicator 1. Examples include Elmid beetle and Chironomid midge larvae.



Elmidae (riffle beetle, larvae). These small insect larvae have a completely sclerotized body, unlike caddisflies which only have the thorax sclerotized. In addition, there are no gills along the abdomen, as in the caddisflies. Instead, gills are found at the tip of the abdomen (where the caddisfly's two anal prolegs with hooks would be found). The tufted gills may be withdrawn into a cavity that has a hinged lid. Image credit: Macroinvertebrates.org.

Chironomidae (non-biting midges). Chironomidae are among the most numerous and widespread aquatic invertebrates in water bodies. Compared to the caddisflies, their heads are small compared to the body and contained in a distinctive head capsule. And while they have prolegs on the thorax and abdomen (anal prolegs), they do not have 3 sets of segmented legs as caddisflies do. Image credit: Top row: Macroinvertebrates.org. Bottom row: CADFW.

Appendix C. Field Forms

Beta Streamflow Duration Assessment Method – Great Plains

General site information

Project name or number:			
Site code or identifier:	**Assessor(s):**		
Waterway name:			Visit date:
Current weather conditions (check one): ☐ Storm/heavy rain ☐ Steady rain ☐ Intermittent rain ☐ Snowing ☐ Cloudy (___ % cover) ☐ Clear/Sunny	Notes on current or recent weather conditions (e.g., precipitation in previous week):		Coordinates at downstream end (decimal degrees): **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 (m) (Indicator 5)	**Reach length (m):** 40x width; min 40 m; max 200 m.	**Site photographs**: Enter photo ID or check if completed Top down: __________ Mid down: __________ Mid up: _____________ Bottom up: __________	
Disturbed or difficult conditions (check all that apply): ☐ Recent flood or debris flow ☐ Stream modifications (e.g., channelization) ☐ Diversions ☐ Discharges ☐ Drought ☐ Vegetation removal/limitations ☐ Other (explain in notes) ☐ None	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. EPT Family Richness

Collect aquatic invertebrates from at least 6 locations in the assessment reach and determine if any specimens of EPT (Ephemeroptera, Plecoptera, Trichoptera) are present. Identify EPT to family and enumerate up to 5 taxa.

	Check one				
Taxon	**Mayfly (E)**	**Stonefly (P)**	**Caddisfly (T)**	**Notes**	**Photo ID**
	☐	☐	☐		
	☐	☐	☐		
	☐	☐	☐		
	☐	☐	☐		
	☐	☐	☐		
	☐	☐	☐		

☐ Number of EPT families identified from the assessment reach (Enter zero if none were found).

General notes on aquatic invertebrates**:**

2. Percent Shading

Densiometer readings Record # points covered (out of 17)		
Upper _____ Upstream _____ Left _____ Right _____ Downstream	Middle _____ Upstream _____ Left _____ Right _____ Downstream	Lower _____ Upstream _____ Left _____ Right _____ Downstream
Sum of all readings: ______ Percent Shading = Sum of readings/204 x 100: ______ %		

3. Number of Hydrophytic Plant Species

Record up to 5 hydrophytic plant species (FACW or OBL in the **Great Plains, Midwest, or Northeast-Northcentral** regional wetland plant lists, depending on location) within the assessment area: **within the channel or up to one half-channel width**. Explain in notes if species has an odd distribution (e.g., covers less than 2% of assessment area, long-lived species solely represented by seedlings, or long-lived species solely represented by specimens in decline), or if there is uncertainty about the identification. Enter photo ID, or check if photo is taken.

Check if applicable: ☐ No vegetation in assessment area

Species	Odd distribution?	Notes	Photo ID

☐ Number of hydrophytic plant species identified from the assessment reach without odd distribution (Enter zero if none were found).

Notes on hydrophytic vegetation:

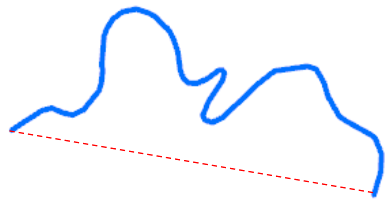
4. Absence of Rooted Upland Plants in Streambed

____ **Absence of Rooted Upland Plants in Streambed score (0-3)** Half-scores are allowed	Scoring guidance: 0: (Poor) Rooted upland plants are prevalent within the streambed/thalweg. 1: (Weak) Rooted upland plants are consistently dispersed throughout the streambed/thalweg. 2: (Moderate) Few rooted upland plants are present within the streambed/thalweg. 3: (Strong) Rooted upland plants are absent within the streambed/thalweg. *Recommended photos (record in photolog, below):* *1) channel vegetation, and* *2) upland vegetation*
Notes:	

5. Bankfull channel width (copy from first page of field form)

6. Sinuosity

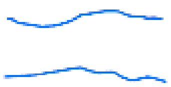
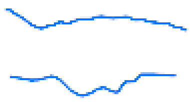
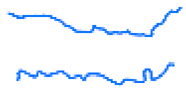
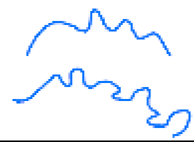
____ **Sinuosity score (0-3)**



Stream length: 200 m
Valley length: 107 m

Sinuosity = 200/107 = 1.87

Scoring guidance:

0: Poor	**1: Weak**	**2: Moderate**	**3: Strong**
1.0 to 1.05	1.05 to 1.2	1.2 to 1.4	Above 1.4
			

7. Floodplain and Channel Dimensions

____ **Floodplain and Channel Dimensions score (0-3)**

______ 2x Maximum Bankfull Depth

______ Flood-prone Width @ 2x Max Bankfull Depth

______ Entrenchment Ratio (Flood-prone Width/Bankfull Width)

Scoring guidance:

0: (Poor) Ratio of flood-prone width to bankfull width < 1.2.

1.5: (Moderate) Ratio between 1.2 and 2.5. Stream is moderately confined. Floodplain is present but may only be active during larger floods. Stream is incised, with a noticeably confined channel. Floodplain is narrow or absent, and typically disconnected from the channel

3: (Strong) Ratio > 2.5. Stream is minimally confined, with a wide, active floodplain.

Notes:

8. Particle Size or Stream Substrate Sorting

____ **Particle Size or Stream Substrate Sorting score (0-3)** Half-scores are allowed	Scoring guidance: 0: (Poor) Particle sizes in the channel are similar or comparable to particle sizes in areas close to but not in the channel. Substrate sorting is not readily observed in the channel. 1.5: (Moderate) Particle sizes in the channel are moderately similar to particle sizes in areas close to but not in the channel. Various sized substrates are present in the channel and are represented by a higher ratio of larger particles (gravel/cobble). 3: (Strong) Particle sizes in the channel are noticeably different from particle sizes in areas close to but not in the channel. There is a clear distribution of various sized substrates in the channel with finer particles accumulating in the pools, and larger particles accumulating in the riffles/runs.
Notes:	

9. Northern or Southern Plains

If the project is within CO, IA, IL, KS, MN, MO, MT, ND, NE, SD, WI, or WY, it is within the Northern Plains. NM, OK, and TX lie in both regions; check map in Figure 2 in user manual, or input latitude and longitude from page 1 of the field form into the web application to calculate for these states.

☐ **Northern Plains** ☐ **Southern Plains**

Photo log

Indicate if any other photographs taken during the assessment:

Photo ID	Description

Additional notes about the assessment:

Model Classification:

☐ Ephemeral

☐ At least intermittent

☐ Intermittent

☐ Perennial