User Manual for a Beta Streamflow Duration Assessment Method for the Arid West of the United States

Version 1.1
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Cover images

The top row shows the biological indicators included in the streamflow duration assessment method for the Arid West: number of hydrophytic plant species, such as seep monkey flowers; abundance of aquatic invertebrates, such as black fly larvae; evidence of mayfly, stonefly, and caddisfly taxa, such as a larva or pupal case of *Dicosmoecus gilvipes* (photo credit: California Department of Fish and Wildlife's Aquatic Bioassessment Lab); and algal cover on the streambed.

The bottom row shows examples of perennial (Virgin River, Utah), intermittent (Pine Valley Creek, California), and ephemeral (Red Rock Canyon, Nevada) streams.

Acknowledgments

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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 regulatory 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. 2012), 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 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 photos 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 streamflow duration assessment method for the Pacific Northwest, and they are not identical to the definitions found in the Navigable Waters Protection Rule of 2020 at 33 CFR 328.3(c) / 40 CFR 120.2.

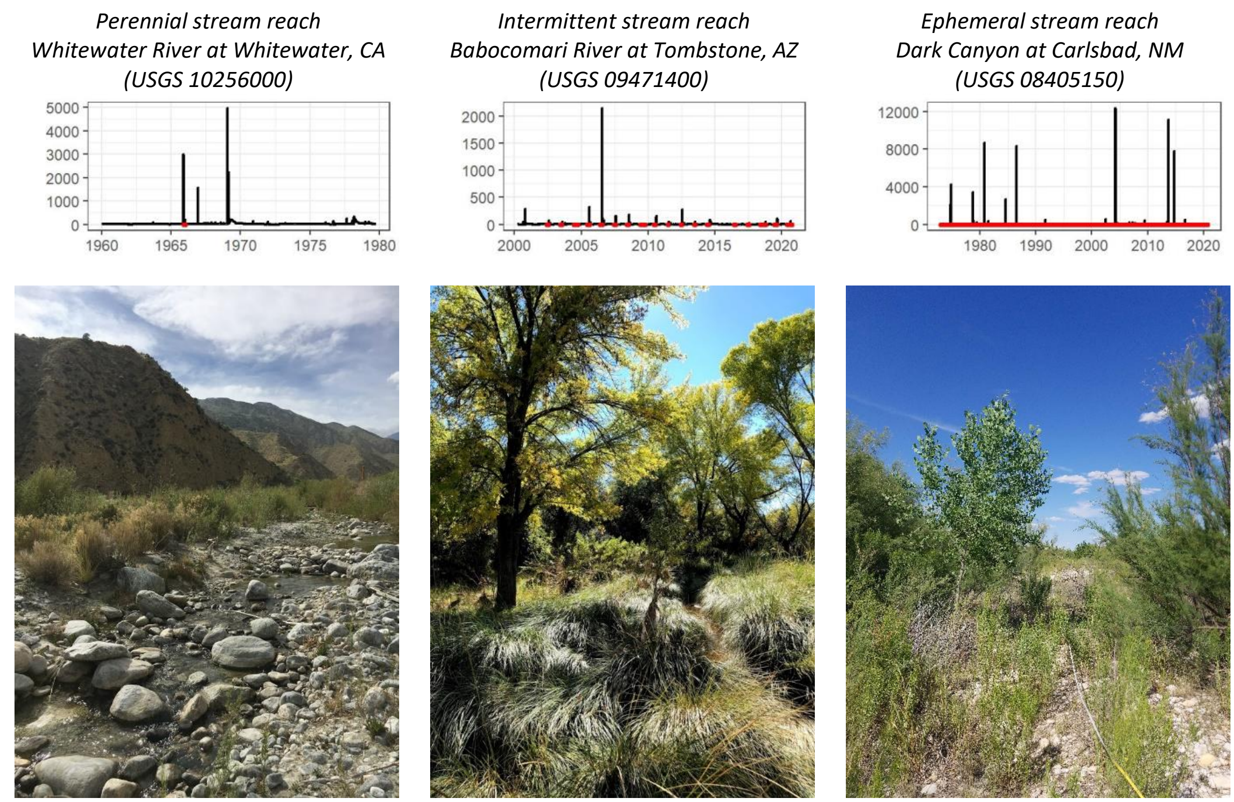


Figure 1. Examples of stream reaches in each streamflow duration class. Hydrographs are in cubic feet per second. Red dots indicate gauge readings of zero (i.e., dry conditions). Photo credits: Raphael Mazor (left, middle) and Emma Haines (right).

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 a beta Streamflow Duration Assessment Method (SDAM) that is intended to distinguish flow duration classes of stream reaches in the Arid West (AW) region of the United States as defined in the National Wetland Plant list (USACE 2018), excluding the AW region that overlaps with the states of Washington, Oregon, and Idaho, which are covered by the SDAM for the Pacific Northwest described in Nadeau (2015); Figure 2. The SDAM AW is based on biological indicators that are known to respond to gradients of streamflow duration (Fritz et al. 2020). Biological indicators 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 observation 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.

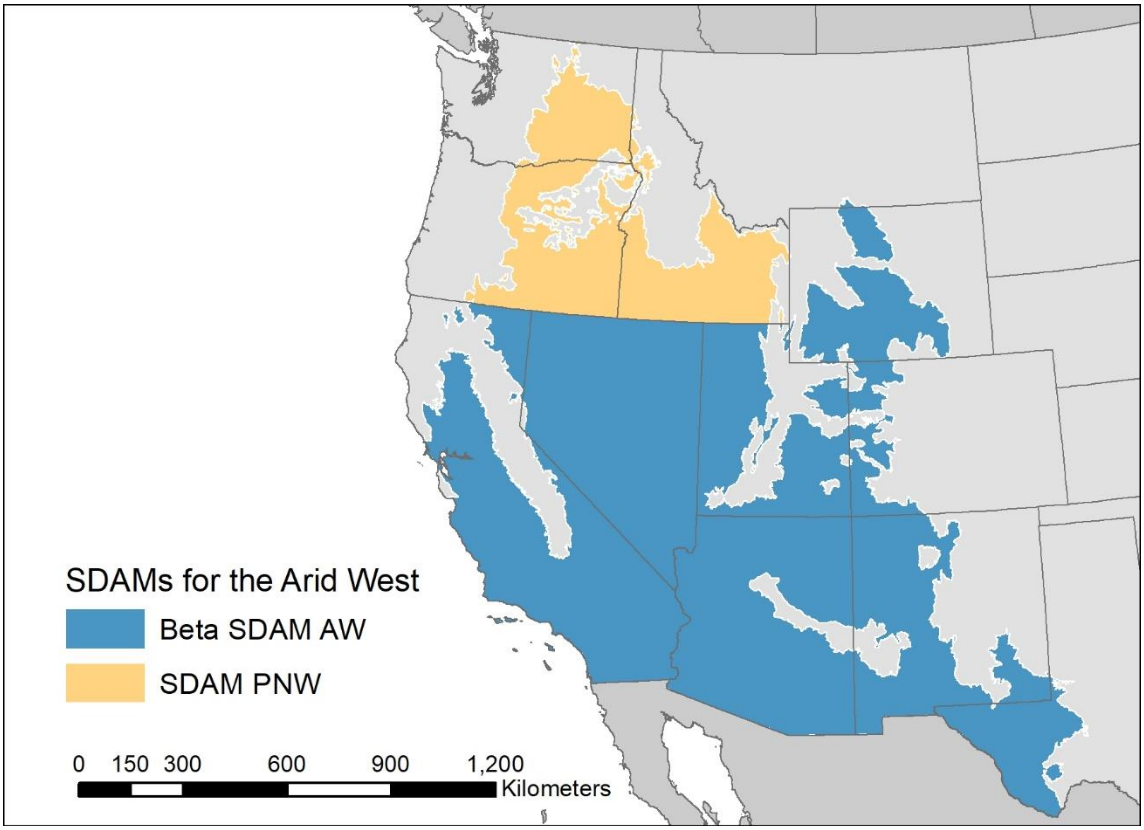


Figure 2. Arid regions of the western USA. The beta SDAM AW applies to the dark blue region shown above.

The Beta Method for the Arid West

This manual describes a protocol that uses a small number of indicators to predict streamflow duration class in the Arid West. All indicators are quantified during a single field visit and across the entire assessment reach. It is anticipated that the beta method will be made available for one year to allow the user community to provide feedback before a final SDAM AW is produced. For more information on the development of this SDAM, and SDAMs for other U.S. regions, please refer to EPA's SDAM website: https://www.epa.gov/streamflow-duration-assessment.

Five biological indicators form the basis of the method. The first four indicators are evaluated together to assign a preliminary flow duration class to a stream reach. In contrast, the fifth consists of *single indicators* whose presence determines that a reach is *At least intermittent*, either supporting or superseding the preliminary classification determined from the first four indicators. An *At least intermittent* classification indicates that the reach is confidently not ephemeral, but the indicator data do not specify if the reach is either perennial or intermittent with high confidence. *Less than perennial* indicates that the reach is confidently not perennial, but the indicator data do not specify if the reach is either intermittent or ephemeral with high confidence. The five indicators are:

1. How many hydrophytic plant species (up to five) are growing in the channel, or within one half-channel width of the channel?

2. How many aquatic macroinvertebrate individuals are found?
3. Is there evidence of aquatic stages of Ephemeroptera, Plecoptera, or Trichoptera (EPT) taxa?
4. Are algae found on the streambed?
5. Are single indicators (i.e., the presence of fish or $\geq$ 10% algal cover) of intermittent or perennial streamflow duration observed?

The observed indicators are compared with values in Table 1 to determine the streamflow duration classification. Each question is answered using field-measured indicator data starting with the first column on the left, and proceeding to the right. The values observed for each indicator determine which row should be followed until the appropriate classification is reached. Blank cells for an indicator mean that regardless of their presence or absence in the reach, a classification has already been determined by the other indicators. For the beta SDAM AW, it is recommended that all five indicators be measured and recorded during every assessment.

Table 1. Streamflow duration classifications based on key indicators.[2]

1. Hydrophytic plant species	2. Aquatic invertebrates	3. EPT taxa	4. Algae	5. Single indicators • fish present • algae cover ≥ 10%	Classification
None	None	Absent	Absent	Absent	**Ephemeral**
				Present	**At least intermittent**
			Present		**Intermittent**
	Few (1-19)	Absent	Absent	Absent	**Less than Perennial**
				Present	**At least intermittent**
			Present		**At least intermittent**
		Present	Absent		**Intermittent**
			Present		**Perennial**
	Many (20+)	Absent	Absent	Absent	**Ephemeral**
				Present	**At least intermittent**
			Present	Absent	**Ephemeral**
				Present	**At least intermittent**
		Present			**Intermittent**
Few (1-2)	None				**Intermittent**
	Few (1-19)	Absent			**Intermittent**
		Present	Absent		**Intermittent**
			Present		**Perennial**
	Many (20+)	Absent			**Intermittent**
		Present	Absent		**Perennial**
			Present		**Intermittent**
Many (3+)	None				**Intermittent**
	Few (1-19)	Absent	Absent		**Intermittent**
			Present		**Perennial**
		Present			**Perennial**
	Many (20+)				**Perennial**

[2] Shading provided to enhance readability by increasing the contrast between neighboring cells; empty cells indicate the classification will not change with additional information however it is recommended that all five indicators be measured and recorded during every assessment.

Intended use and limitations

The SDAM AW 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 AW region. Use of the SDAM AW may inform a range of activities where information on streamflow duration is useful, including certain jurisdictional determinations under the Clean Water Act; however, the SDAM AW is not in itself a jurisdictional determination. The method is not intended to supersede more direct streamflow duration measures (e.g., long-term records from stream gages). Other sources of information, such as aerial imagery, site photos, traditional ecological knowledge, and local expertise, can supplement the SDAM AW when classifying streamflow duration (Fritz et al. 2020).

Although the SDAM AW 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 assessment area. 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 mayflies, stoneflies, and caddisflies (i.e., Ephemeroptera, Plecoptera, and Trichoptera, or EPT taxa). Indeed, several studies have documented the absence of these sensitive taxa in effluent-dominated rivers in the Southwest (e.g., Halaburka et al. 2013, Hamdhani et al. 2020). However, upgrades to water treatment plants can lead to a recovery of mayfly taxa (Baker and Sharp Jr. 1998). Consequently, the SDAM AW may fail to identify perennial systems as *Perennial* in situations where water quality has been severely degraded by wastewater or other types of stress such that EPT taxa are eliminated. The SDAM AW includes other biological indicators that are less affected by poor water quality, and therefore it will typically classify such streams as *At least intermittent*.

Development of the Beta Arid West SDAM

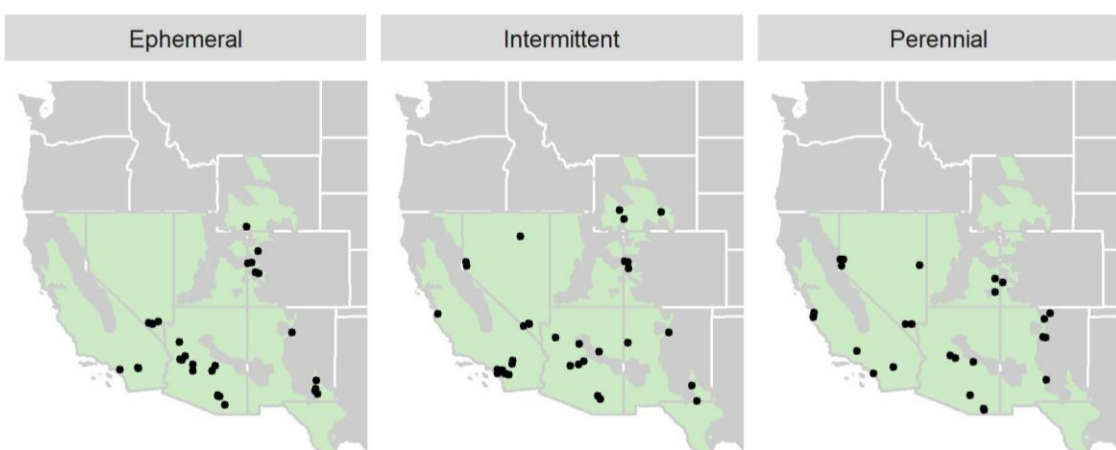


Figure 3. Locations of ephemeral, intermittent, and perennial stream reaches used to develop the SDAM AW.

The beta SDAM AW resulted from a multi-year study conducted in numerous locations across the Arid West (Figure 3) following the process described in Fritz et al. (2020). Twenty-one candidate indicators expected to control or respond to streamflow duration were tested at 89 study sites with a known flow duration class: 30 ephemeral sites, 34 intermittent sites, and 25 perennial sites. Through statistical analyses, the subset of indicators with the highest diagnostic accuracy of flow duration class was combined into the beta SDAM AW. An expanded data collection effort is planned to begin in 2021 to inform the development of the final SDAM AW. The expanded effort's primary goals are to improve upon the precision and accuracy of the beta SDAM AW and address any shortcomings or limitations identified during the one-year period following publication of the beta method. For more information, refer to EPA's SDAM website: https://www.epa.gov/streamflow-duration-assessment.

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

- Conducted a literature review with two goals:
    - Identified existing SDAMs, focusing on those in the Arid West and comparable arid regions
    - Identified potential biological, hydrologic, and physical indicators of streamflow duration for evaluation in the Arid West
- Identified candidate study sites with known streamflow duration class, representing diverse environmental settings throughout the region
- Collected indicator data at 90 study sites
- Calibrated a classification model using a machine learning algorithm (i.e., random forest)
- Refined and simplified the model for rapid and consistent application

The literature review (McCune and Mazor 2019) identified eight flow duration methods for arid regions, two of which cover portions of the Arid West as defined for this project: the SDAM for the Pacific Northwest (Nadeau 2015) and the New Mexico method (NMED 2011). From these methods and the scientific literature, a large number of geomorphological, hydrological, and biological candidate indicators were identified. These candidate indicators were screened using several criteria, including consistency, repeatability, defensibility, rapidness, and objectivity, and then evaluated for their ability to discriminate among streamflow duration classes. The final set of metrics was simplified to reduce the amount of time required to conduct measurements in the field while maintaining the performance of the method (e.g., by converting continuous measurements to discrete or presence/absence measurements). These metrics were then used to calibrate a model that could classify a stream based on the observed indicators. If the model can rule out ephemeral status, but cannot confidently determine if a stream is perennial or intermittent, the stream is classified as *At least intermittent*. If the model can rule out perennial status, but can not confidently determine if a stream is intermittent or ephemeral, the stream is classified as Less than perennial. If a single indicator of intermittent or perennial streamflow duration (i.e., fish presence or algae cover ≥ 10%) is observed at a site that would otherwise be classified as *Ephemeral* or *Less than perennial* then the classification becomes *At least intermittent*.

Section 2: Overview of the Beta SDAM AW 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, and the Beta SDAM AW does not incorporate that broad scope of analysis. Rather, the method provides information that may support timely decisions because it helps determine the duration of streamflow.

Scales of assessment

The SDAM AW protocol applies to an assessment reach, the length of which scales with the mean channel width (from a minimum of 40 m to a maximum of 200 m). Indicator observations are restricted to the channel and within one-half channel width. Floodplains and wetlands extending beyond the immediate area are not included in the assessment of SDAM AW indicators. However, ancillary information from outside the assessment reach (such as surrounding land use) is also recorded. The minimum reach-length of 40 m is necessary to ensure that a sufficient area has been assessed to observe indicators.

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 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 vegetation indicators, such as willows and other deep-rooted hydrophytic plants, 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 fractured bedrock, volcanic parent material, recent or extensive relic colluvial activity (landslides or debris flows), and 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 the appearance of 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, algal growth may be detected in a streambed only following a few weeks of sustained inundation. In contrast, long-lived riparian plants tend to reflect long-term patterns, and changes in flow regimes may take several years to result in changes in the hydrophytic plant community. 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 expression of algal or aquatic invertebrate indicators. Through the inclusion of multiple indicators having different lifespans and life-history traits, SDAM AW classifications reflect both recent and long-term patterns in flow duration.

Ditches and modified natural streams

Streamflow duration assessments are sometimes needed in canals, ditches, and modified natural streams that are primarily used to convey water. These systems tend to have altered flow regimes, and the SDAM AW may determine if these flow regimes support indicators consistent with different streamflow durations. Thus, the SDAM AW may be applied to these systems when streamflow duration information is needed.

Braided systems

Assessors should identify the extent of the channels, based on the outer limits of ordinary high-water mark (OHWM), and apply the method to that area as a whole. Some indicators may be present or more apparent in the main channel versus the secondary channels; note these differences on the field assessment form.

Disturbed or altered streams

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 flow diversions, urbanization and stormwater management, septic inflows, agricultural and irrigation practices, effluent dominance, or other activities. In the development data set, the SDAM AW classified disturbed sites with the same accuracy as undisturbed sites. When the disturbance is severe enough to convert a reach from one streamflow duration class to another, the SDAM AW typically identifies the new class if sufficient time has passed since the disturbance.

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 hydrophytic vegetation in concrete channels). 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 site conditions” section of the field form.

Section 3: Data Collection

Order of operations in completing the SDAM AW assessment

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

1. Conduct desktop reconnaissance.
2. Prepare sampling gear.
3. Walk the reach.
    a. Measure the channel width at three locations and calculate the average to determine the total reach length.
    b. Record the presence of fish (i.e., one of the SDAM AW indicators), amphibians, and other organisms that may be disturbed by field crew activity.
    c. Take photos at appropriate locations (i.e., the top, middle, and bottom of the assessment reach) and begin sketching the site on the field form.
4. Determine the length of assessment reach and reach boundaries.
5. Record general site information on the data sheet.
6. Evaluate the remaining indicators:
    a. Record hydrophytic plant species.
    b. Collect invertebrates from 6 suitable locations. Tally individuals, and search for mayflies, stoneflies, and caddisflies in the sampled material.
    c. Visually estimate the percent cover of algae in the streambed.
7. Complete and review the field form.
8. Enter data into the web form or refer to Table 1.

Conduct desktop reconnaissance

Before a site visit, desktop reconnaissance helps ensure a successful assessment of a stream. During desktop reconnaissance, assessors evaluate site 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 site access. Plot the site or project area on a map to determine access routes and whether landowner permissions are required. Identify safety concerns or hazards that may affect sampling, such as road closures or landslides associated with wildfire. 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 the number of assessment reaches required for a project. Look for natural and artificial features that may affect streamflow duration at the site—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, and major tributaries. It may be possible to see bedrock outcrops or other features that modify streamflow duration in sparsely vegetated areas. A review of historical imagery may also indicate whether the site or its upstream watershed is influenced by snowmelt.

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 U.S. EPA WATERS GeoViewer, provide convenient online access to watershed information for most sites 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/
- U.S. EPA WATERS GeoViewer: https://www.epa.gov/waterdata/waters-geoviewer

Consult local experts and agencies to gain additional insights about site conditions and see if additional data are available. For example, state agencies may have records on water quality sampling, indicating times when the site was sampled, and when it was dry. Local experts may have information about changes in the site's streamflow duration.

A local flora listing plants known to grow in the project area may be available to assist with plant identification. Consult nearby public land managers (such as U.S. Forest Service or the National Park Service) to see if they have lists of common riparian plants in the vicinity of the sampling site. A number of online databases can generate regionally appropriate floras (Table 2).

Table 2. Online resources for generating local flora.

Resource	Geographic coverage
SEINet	Arizona, New Mexico, and Colorado
Calflora	California
Arizona Native Plant Society	Arizona and adjacent desert regions
Rocky Mountain Herbarium	Wyoming, Colorado, Utah, Arizona, and New Mexico
California Native Plant Society	California

Similarly, desktop reconnaissance can determine if native *Gambusia* are known in the project area; native *Gambusia* are treated as a single indicator, similar to other fish, whereas non-native *Gambusia* introduced for vector control are not. See the discussion below on mosquitofish for more detail.

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

Prepare sampling gear

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

- This manual, and copies of paper field forms.
- Clipboard/pencils/sharpies.
- Field notebook.
- Site maps and aerial photos (1:250 scale if possible).
- Global Positioning System (GPS) – used to identify the boundaries of the reach assessed. A smartphone that includes a GPS may be a suitable substitute.

- Tape measure – for measuring channel width and reach length.
- Kick-net or small net and tray – used to sample aquatic invertebrates.
- Mechanical tally counter (optional).
- Hand lens – to assist with macroinvertebrate and plant identification.
- Digital camera (or smartphone with camera), plus charger. Ideally, use a digital camera that automatically record metadata, such as time, date, directionality, and location, as part of the EXIF data associated with the photo.
- Polarized sunglasses – for eliminating surface glare when looking for fish, amphibians, and macroinvertebrates.
- Shovel, soil augur, rock hammer, hand trowel, pick or other digging tools to facilitate hydrological observations of subsurface flow.
- Macroinvertebrate field guides (e.g., *A Guide to Common Freshwater Invertebrates of North America*, Voshell and Wright 2002).
- 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., *Trees and Shrubs of California*, Stuart and Sawyer 2001; *Western Wetland Flora: An Introduction to the Wetland and Aquatic Plants of the Western United States*, Chadde 2019).
- The U.S. Army Corps of Engineers List of wetland plants for sites to be visited – http://wetland-plants.usace.army.mil/.
- Herpetological field guides (e.g., *A Field Guide to Western Reptiles and Amphibians*, Stebbins 2003).
- First-aid kit, sunscreen, insect repellant, and appropriate clothing.

Timing of sampling

Ideally, SDAM AW application should occur during the growing season when both riparian plants and aquatic invertebrates are active and most 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 measure at the time of assessment. However, several of the indicators included in the method persist well beyond a single growing season (e.g., hydrophytic vegetation, algal cover), 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 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). 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 invertebrates or increasing turbidity such that algae on the streambed are not visible). 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. Whenever interpreting SDAM AW data, it is recommended that precipitation data from nearby weather stations be evaluated after each sampling event to determine if storms may have affected data collection.

Assessment reach size, selection, and placement

An assessment reach should have a length equal to ***40 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. 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 deepest point within the channel). Reach length is measured along the thalweg. If site constraints (e.g., limited access) 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.

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.

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 site allows the assessor to examine the channel's overall form, landscape, parent material, and variation within these attributes as it develops or disappears 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. Walking alongside, rather than in, the channel is recommended for the initial review to avoid unnecessary disturbance to the stream and maximize the opportunity to observe single indicator organisms (e.g., fish). Walking 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 identify the areas along the stream channel where these 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 channel'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 a reach is moved or shortened, it 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. 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 stream extending through a large or heterogenous project area (and 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

Photos can provide strong evidence to support the SDAM AW's conclusions, 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 photo from the top (upstream) end of the reach, looking downstream.
- Two photos from the middle of the reach, one looking upstream and one looking downstream.
- A photo from the bottom of the reach, looking upstream.

These photos are also strongly recommended:

- Hydrophytic plants, showing diagnostic features and extent within the reach.
- Aquatic invertebrates, if practical.
- Algae on the streambed.
- Any vertebrates encountered (especially fish).
- Disturbed or unusual conditions that may affect the measurement or interpretation of indicators.

Conducting assessments and completing the field form

General site information

After walking the reach and determining the appropriate boundaries for the assessment area, enter the project name, site code or identifier, waterway name, assessor(s) name(s), and the date of the site 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.

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 site within 100 m of the assessment reach. 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).

Channel width and reach length

Record the channel width at three locations at bankfull elevation, and record to the nearest 0.1 m. 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 channel width.

Record the reach length, which should be 40 times the average 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). 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."

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 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

Check the boxes on the field form as you take the required photos from the bottom, middle, and top of reach. Record the photo ID on the designated part of the field form.

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, such as channelization, or vegetation removal that may affect the measurement or interpretation of several indicators (Figure 4). 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 4. Examples of difficult conditions that may interfere with the observation or interpretation of indicators, such as hydrophytic plants. Note that even in the photo on the right, some vegetation is evident; field crews should determine if these plants are hydrophytes. In contrast, the photo on the left shows no vegetation due to the recent channel maintenance; in this case, returning to the site in a month or so may allow plants to recolonize the channel. Photo credits: Raphael Mazor.

Observed hydrology

Surface flow

Visually estimate the percentage of the reach-length that has flowing surface water, or subsurface flow. The site 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 5). 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 with subsurface and surface flow (combined). That is, the percent of reach with subsurface flow should be greater than or equal to the percent of reach with surface flow (Figure 5).

The site 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. The site sketch should indicate the location of pools in the channel or on the floodplain. Only isolated pools within the channel are counted; count isolated pools within secondary channels below 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.

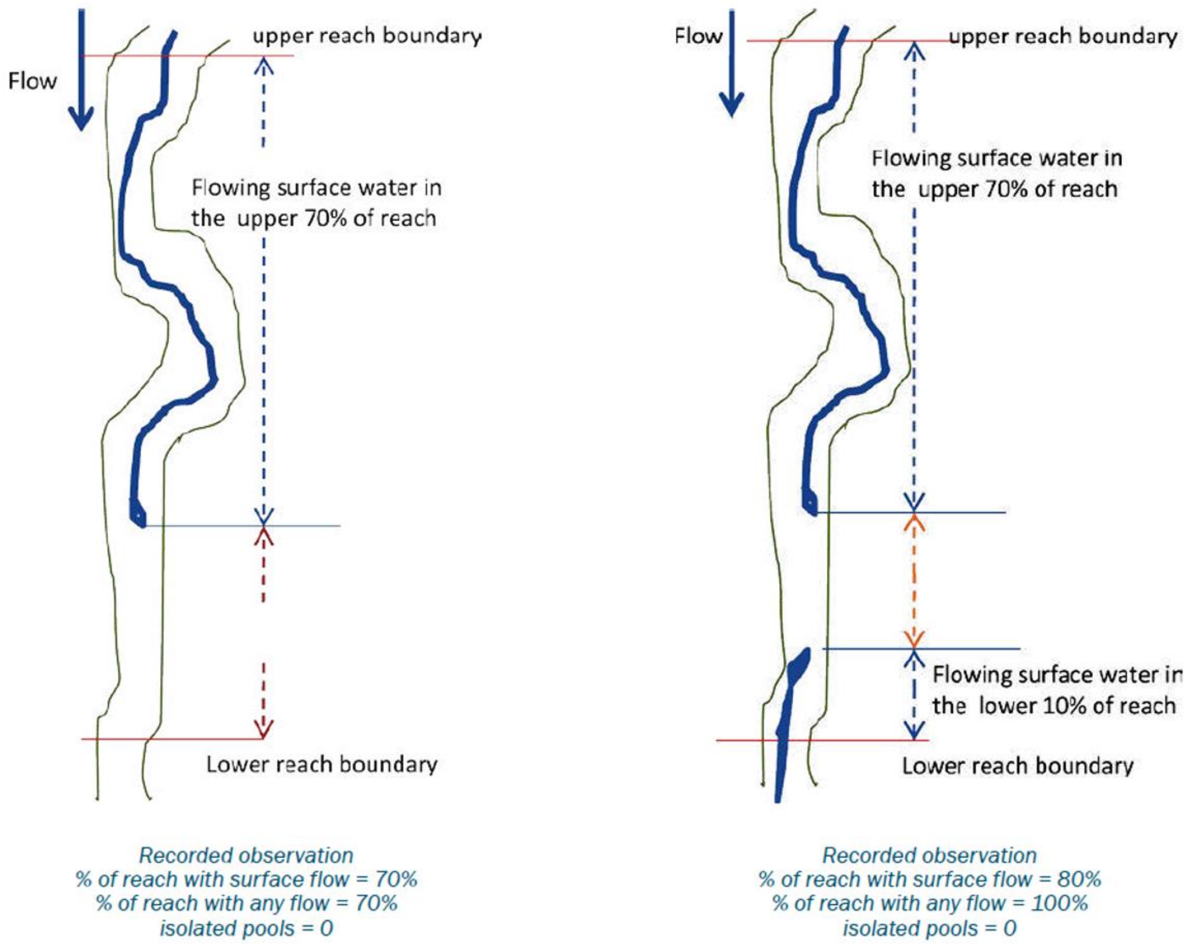


Figure 5. Examples of estimating surface and subsurface flow. Black lines represent the channel banks and the blue represents surface water in the channels. In the example on the right, subsurface flow is described because flow resurfaces downstream of the dry portion of the reach. Figure adapted from Nadeau (2015).

Site 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 photos are taken and where channel measurements are made.

How to measure indicators of streamflow duration

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

1. How many hydrophytic plant species (up to five) are growing in the channel, or within one half-channel width of the channel?
2. How many aquatic macroinvertebrates are found?

3. Is there evidence of aquatic stages of Ephemeroptera, Plecoptera, or Trichoptera (EPT) taxa?
4. Are algae found on the streambed?
5. Are single indicators (i.e., the presence of fish or $\geq$ 10% algal cover) of intermittent or perennial streamflow duration observed?

The presence of these indicators is associated with longer duration of flow, and absence is associated with shorter, more ephemeral flows. The classification is determined by comparing measured indicators to the values shown in Table 1. For the beta SDAM AW, all five indicators should be measured and recorded during every assessment.

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 taken into account when drawing conclusions. Under each indicator, some common ways that disturbances can interfere with indicator measurement are described.

1. How many hydrophytic plant species (up to five) are growing in the channel, or within one half-channel width of the channel?

The SDAM AW relies on the detection of hydrophytic vegetation growing within the channel and/or riparian zone (up to a half-channel width outside the channel). For the SDAM AW, hydrophytes are defined as those with a FACW or OBL wetland indicator status in the National Wetland Plant List (NWPL, USACE 2018). The NWPL, formerly called the National List of Plant Species that Occur in Wetlands, was revised by the USACE, U.S. Fish and Wildlife Service, USEPA, and the Natural Resource Conservation Service in 2013, biannually since, and is available at: http://wetland-plants.usace.army.mil/. The Arid West has a regional plant list, which differs in some respects from adjacent regions. For example, red alders (*Alnus rubra*) are FACW in the Arid West, and FAC in the Western Mountains, whereas California sycamores (*Platanus racemosa*) show the opposite pattern. Therefore, make sure to consult the correct list when determining indicator status.

Identify up to five hydrophytic plant species growing within the channel or up to one half-channel width from the channel. Hydrophytes growing at greater distances from the channel are likely supported by local water sources not closely related to streamflow. The method requires that up to five species be identified to provide redundancy (as opposed to three) and minimize the impacts of misidentifying non-hydrophytes as hydrophytes.

In general, it is recommended to focus on the most dominant species in the reach, but 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 (e.g., the site on the left in Figure 4), check the box marked "No vegetation within reach." If vegetation is present but lacking in hydrophytes (e.g., Figure 6), check the box marked "No hydrophytes in reach."

Figure 6. Example of an ephemeral stream lacking hydrophytic vegetation. The riparian zone in this Arizona stream is dominated by mesquite, ironwood, and other upland plant species. Photo credit: Raphael Mazor.

Unusual or odd distributions

Note if the plant exhibits an odd or unusual pattern in its distribution that may affect its interpretation for streamflow duration assessment. Examples include:

- 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. Commonly, this occurs at road crossings, where road runoff increases water availability to vegetation (Figure 7).
- 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 8).
- 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 9).

These species may be recorded on the field form, along with notes explaining the unusual distributions.

Figure 7. 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 8. Although red alders (*Alnus rubra*) were abundant at Mission Creek in the Mojave Desert, they were only observed as seedlings at this site. Photo credit: Raphael Mazor.*

Figure 9. Water-stressed riparian trees near Oro Grande on the Mojave River. Reproduced from Lines (1999).

Common questions about identifying hydrophytes

Are FACW and OBL plants equally important?

Yes. For this method, OBL and FACW plants are equally important for determining streamflow duration.

Do FAC or FACU status plants count?

Although some applications of the NWPL treat FAC or FACU plants as hydrophytes, they do not count towards this indicator for the SDAM AW. Some important, high-profile riparian species, such as California sycamores (*Platanus racemosa*), coast-live oaks (*Quercus agrifolia*), desert willow (*Chilopsis linearis*), and mulefat (*Baccharis salicifolia*) are FAC, and do not count for this indicator. 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 (such as Great Basin sagebrush, *Artemsia tridentata*), 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.)

Freemont cottonwoods (*Populus fremontii*) are not included in the most recent (2018) NWPL because they are considered a subspecies of eastern cottonwoods (*P. deltoides*), which are FAC and therefore do not count as a hydrophyte for the SDAM AW.

Are genus-level identifications 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., *Typha*). Across most of the Arid West, nearly all willow (*Salix*) species are hydrophytes (with 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 10). 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.

Figure 10. Examples of plants determined to be hydrophytes based on context. Left: An emergent macrophyte growing within the channel. Right: Sedges and rushes growing exclusively in saturated and absent from adjacent uplands. Photo credits: Raphael Mazor.

2. How many aquatic macroinvertebrate individuals are found?

Aquatic invertebrates require the presence of water (and in many cases flowing water) for their growth and development for at least part of their life cycle. A wide range of taxonomic groups are considered aquatic invertebrates, including insects (e.g., mayflies, stoneflies, caddisflies, hellgrammites, midges), amphipods, isopods, annelids (worms and leeches), mollusks (e.g., bivalves, gastropods), and crayfish.

Only invertebrates that can be seen without magnification (i.e., macroinvertebrates) are counted as part of this indicator.

Such invertebrates are good indicators of streamflow duration because they require aquatic habitat to complete specific life stages. For example, several mollusk species cannot survive extended periods outside of water, in contrast to some stonefly or alderfly larvae that resist desiccation in some seasons of the year by burrowing into the hyporheic zone. Some invertebrates can survive short periods of drying in damp soils below the surface in egg or larval stages that are resistant to drying. Others are quick to colonize temporary water and complete the aquatic portion of their life cycle during the wettest part of the year when sustained flows are most likely.

Invertebrates are assessed within the defined reach using a single search. Aquatic invertebrate indicators do not differentiate between live organisms and non-living material such as shells, casings, and exuviae (i.e., the shed skins of larvae and nymphs left behind as they emerge as winged adults). In other words, mussel shells are treated the same as live mussels, and empty caddisfly cases are treated the same as cases with living caddisflies. Note if the distribution of the dead material suggests that it may have been transported from outside the assessment reach. For example, shells found within wrack lines may indicate transportation from upstream sources by a flood, and shells found within middens (i.e., mounds of bones, shells, and other unconsumed food scraps) may indicate transportation from other waterbodies by an animal.

Although they require aquatic habitats, mosquitos in larval or pupal form should **not** be counted. Their rapid lifecycles make them unsuitable for use as indicators of streamflow duration.

A kick-net or D-frame net and a hand lens are required to collect and identify specimens. Begin sampling at the most downstream point in the assessment reach and move upstream to each new sampling site. Place the kick-net perpendicular against the streambed and stir the substrate 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 habitat areas found in the reach. Empty contents of the net into a white tray with fresh water for counting and identification. Many individuals will appear the same until seen against a contrasting color background, and some bivalves and other invertebrates 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 the coarse inorganic particles (pick up rocks and loose gravel). To find mollusks, one should examine hard substrates, such as sticks and rocks for mussels, clams and snails, silty areas of the stream bed for clams, and aquatic plants for snails. Empty clam shells can be found washed up on banks and bars and in coarse sand or gravel deposits.

Dry channels: Assessors should first walk the reach to ascertain whether it is completely dry or if areas of standing water are present. Focus the search on areas serving as refuge such as any remaining pools or areas of moist substrate for living macroinvertebrates, the sandy channel margins for mussel and aquatic snail shells, and under cobbles and other larger bed materials for caddisfly casings. Exuviae of emergent mayflies or stoneflies may be observed on dry cobbles or stream-side vegetation (Figure 11). In summary, sampling methodology consistent with the Xerces Society's recommendations on using aquatic macroinvertebrates as indicators of streamflow duration (Mazzacano and Black 2008) 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 aquatic invertebrates. However, do not ignore dry areas.

When searching dry channels (or dry portions of partially wet channels), be sure to avoid counting terrestrial invertebrates in the streambed (Figure 12). Some insect families, such as crane flies (Diptera: Tipulidae), include both aquatic and terrestrial species. If you are unsure whether the invertebrates you encounter are aquatic or terrestrial, collecting a specimen and identifying it in a lab setting or consulting an entomologist is recommended.


Figure 11. Examples of aquatic invertebrates found in dry streambeds. Top left: Some species of dobsonfly (Megaloptera: Corydalidae) construct chambers in the moist substrate of dry streambeds. Top 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. Bottom left: Caddisfly cases may persist under large cobbles or boulders well after the cessation of flow. Bottom right: Snail shells (especially in the Hydrobiidae and Physidae families) are among the most frequently encountered aquatic invertebrates in dry streambeds, but care should be taken to avoid mistakenly counting terrestrial snails as aquatic snails (e.g., Figure 12). Photo credits: Michael Bogan (top left) and Raphael Mazor (other photos).


*Figure 12. The larvae of terrestrial soldier flies (Stratiomyidae, left), and terrestrial garden snails (*Cornu aspersum*) may be found in dry stream channels. Care should be taken to avoid mistaking terrestrial invertebrates for aquatic invertebrates with similar appearances. Photo credits (Raphael Mazor).*

Count the number of live or dead individual aquatic invertebrate individuals (any species) found during the search, and indicate the total abundance on the data sheet in one of these three categories:

- None detected
- 1 to 19 individuals
- 20 or more individuals

3. Is there evidence of aquatic stages of Ephemeroptera, Plecoptera, or Trichoptera (EPT) taxa?

Mayflies, stoneflies, and caddisflies (sometimes called "EPT" taxa, after their orders: Ephemeroptera, Plecoptera, and Trichoptera) are widespread insects in perennial and intermittent streams but are not typically found in ephemeral streams. Indicate on the field form if any mayflies, stoneflies, or caddisflies are encountered in the reach among the individuals collected in assessing indicator #2 (i.e., number of aquatic macroinvertebrates). They may be present in any number (only their presence or absence matters). Living material (e.g., live larvae or pupae), and non-living material (e.g., caddis cases, shed exuviae) are equally considered for this indicator. Images highlighting diagnostic features are shown in the call-out box, and photos are included in Appendix B.

A series of photos should be taken of any species 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, you may collect specimens in 70% ethanol and confirm identities in a lab setting with an appropriate key or identification guide (e.g., Merritt et al. 2019) or consult an entomologist. Collection of aquatic invertebrates may require permits in certain states (e.g., California).

Identification of mayflies, stoneflies, and caddisflies

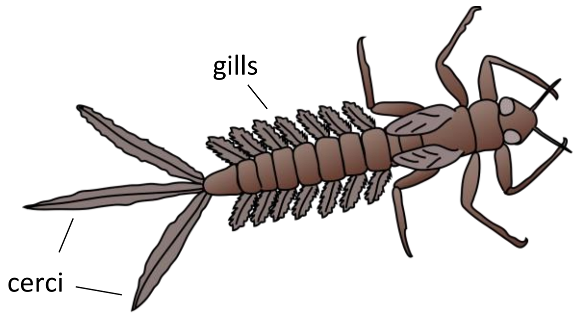


Image by Dieter Tracey

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.

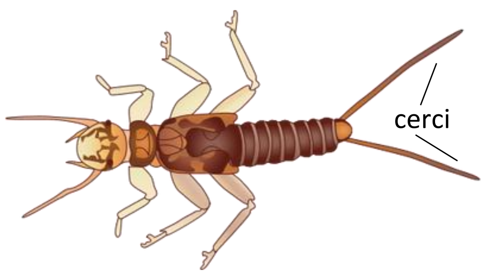


Image by Tracey Saxby

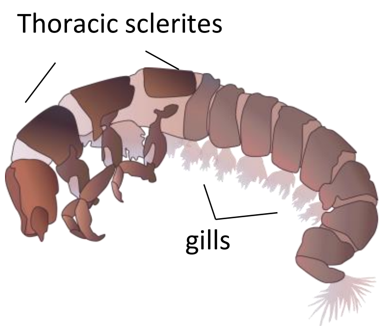


Image by Tracey Saxby

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.

4. Are algae found on the streambed?

Visually estimate the extent of algal cover on the streambed (from the toe of one bank to the toe of the other) over the entire assessment reach. Algal cover is based on the entirety of the streambed and is not restricted to the wetted channel. In braided systems, estimate algae cover as a percent of the streambed of entire active channel.

Algae are visible as a pigmented mass or film, or sometimes hair-like growths on submerged surfaces of rocks, logs, plants, and any other structures within the channel, and may form mats that cover portions of the streambed. Microscopic algae associated with biofilm can be felt as a slippery film on substrates, but growth must be extensive enough to be visible to the naked eye to be counted. Periphyton growth is influenced by chemical disturbances such as increased nutrient (nitrogen or phosphorus) inputs and physical disturbances such as increased sunlight to the stream from riparian zone disturbances. All macroscopic algal forms (filamentous algae, mats, periphyton, macroalgal clumps, or microalgae growing as a visible biofilm or mat) count, whether living, dead, or dying. Estimates should fall into one of the following categories:

- Not detected
- ≤ 10% cover
- > 10% cover

Figure 13 shows photos of low (< 2%) and high ($\geq$ 10%) algae cover in a streambed, and Figure 14 shows diagrams that can assist with visual estimates of algae cover.

Figure 13. Examples of low (left) and high (right) algae cover in flowing (top) and dry (bottom) streams. Photo credits: Raphael Mazor.

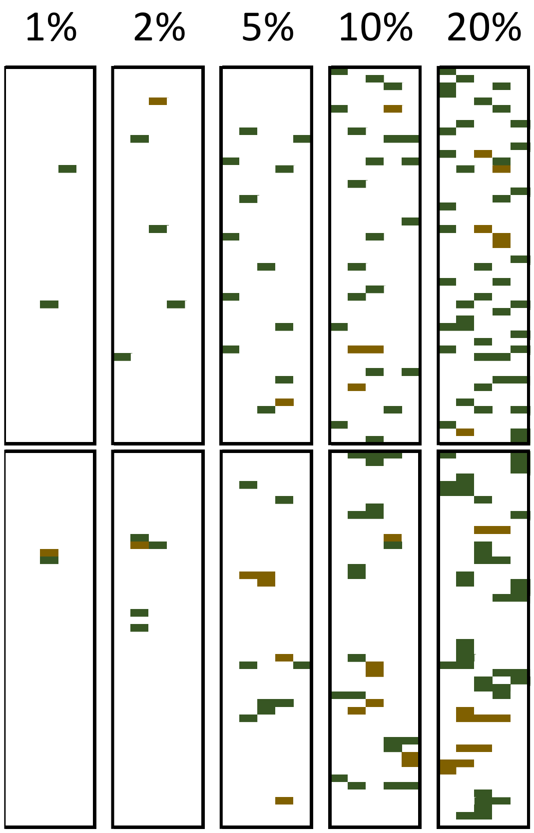


Figure 14. Visual guides to assist estimates of algal cover on a streambed. The top row shows a relatively dispersed distribution, whereas the bottom row shows a more clustered distribution.

Live algae typically have a dull to bright green color, whereas biofilms made of diatoms are typically golden-brown. In contrast, dead algal mats are typically dull brown under wet conditions or powdery white when desiccated (Figure 15). It is possible to observe dead algal mats submerged under water if a stream has only recently started to flow.

Figure 15. Examples of live (top row) and dead/dying (bottom row) algae. Photo credits: Raphael Mazor.

In some circumstances, it may be possible to determine if an algal mat originated locally or washed in from an upstream location. Sloughed algal mats tend to collect in snags or on top of boulders, rest unevenly on the streambed, or cling to overhanging branches (Figure 16). In contrast, mats with a local origin are often found in pools, depressions, or areas of flow accumulation. In some cases, algal mats may wash in from upstream and continue to grow if local conditions are favorable. If ***all*** observed algae appear to have an upstream origin, check the appropriate box on the field form. The presence of algae deposited from upstream sources is not an indicator used in the SDAM AW, but it can provide useful supplemental information.

Figure 16. The greenish algal mat shows signs of recent deposition from an upstream source: note the way that it is bunched up around the boulder in the foreground. However, there are several signs that this mat has regrown since depositing closer to the top of the photo. The white remains of an older mat show additional evidence of local growth. Photo credit: Raphael Mazor.

5. Are single indicators of intermittent or perennial streamflow duration observed?

Two indicators may be used in the SDAM AW as single lines of evidence to classify a stream as at least intermittent (these indicators are not present in ephemeral streams, but their absence is not necessarily indicative of a stream being ephemeral). Although some protocols (e.g., NMED 2011, Nadeau 2015) consider single indicators sufficient evidence to make a streamflow duration determination (and thus field data collection may end once they are observed), completing data collection for the beta method whether or not single indicators are observed is recommended.

i. Are there any fish within the reach (aside from mosquitofish)?

Fish are rarely found in ephemeral streams, and their presence is a strong sign that a stream is intermittent or perennial. Record the presence of any live fish observed. If the only fish present are non-native mosquitofish (*Gambusia* sp., typically *G. affinis,* Figure 17), record their presence, **but do not treat them as a single indicator of intermittent or perennial flow.** Mosquitofish are widely stocked in waterbodies, including ephemeral streams, as a method of vector control. Native species of *Gambusia* should be counted the same as other species of fish; desktop reconnaissance can determine if native species of *Gambusia* occur in the project area. Most native *Gambusia* are found in small ranges within New Mexico and Texas:

- *G. nobilis*: Pecos River drainage, NM & TX

- *G. senilis*: Devil's River (Rio Grande drainage), TX
- *G. speciosa*: Devil's River (Rio Grande drainage), TX
- *G. gaigei*: Spring-fed pond in Big Bend National Park, TX
- *G. geiseri*: San Marcos & Guadalupe River drainages, TX
- *G. heterochir*: Spring in Clear Creek (San Saba River drainage), TX
- *G. krumholtzi*: Lower Rio Grande drainage, TX
- *G. georgei* (presumed extinct): San Marcos Spring and River, TX
- *G. amistadensis* (presumed extinct): Goodenough Spring (Rio Grande drainage), TX
- *G. clarkhubbsi*: San Felipe Creek (Rio Grande drainage), TX

All available habitats should be observed when looking for fish, including pools, riffles, root clumps, and other obstructions (to greatly reduce surface glare, the use of polarized sunglasses is recommended). Fish may be found in the hyporheic zone in dry reaches of intermittent rivers. In small streams, the majority of fish species usually inhabit pools and runs. Fish will seek cover once alerted to your presence, so be sure to look for them slightly ahead of where you are walking during your initial walk along the reach. Check several areas along the assessment reach, especially below undercut banks or overhanging vegetation. Dead fish do not count as a single indicator, but may be noted on the field forms.

In the Arid West, fish may disperse through ephemeral reaches during extreme high flow events associated with large storms. Thus, this indicator may not be easily interpreted immediately after a storm.

*Figure 17. Western mosquitofish (*Gambusia affinis*). This species is native to Gulf Slope drainages, including small portions of the Arid West. However, it has been widely introduced into waterbodies throughout the West as a method of vector control, and it should not be used as a single indicator of intermittent or perennial streamflow. Photo credit: Robert McDowell, US Geological Survey.*

ii. Do algae cover more than 10% of the streambed?

Although algae may grow sparsely in ephemeral streams, heavy algal growth is usually a sign of longer-duration flows, particularly in dry streambeds where few other indicators may be evident. This indicator is also measured as part of this SDAM. Take extra care to ensure that the distribution of algae in the streambed is consistent with local growth, not deposition from upstream sources; deposition of algal mats in ephemeral streams is possible where they are closely connected to upstream perennial sources.

Supplemental information

Although not required for flow duration classification, additional flow duration measures may be observed during the SDAM assessment. These observations should be noted to provide additional contextual information in support of a streamflow duration classification. It is recommended that supplemental measures be documented at all sites where streamflow duration is assessed, and evaluated to determine if they corroborate the SDAM AW classification or provide more clarity to *Need more information* classifications (as described below).

Aquatic or semi-aquatic amphibians and reptiles

Like fish, aquatic or semi-aquatic amphibians, snakes, and turtles are rarely found in ephemeral streams; if any are encountered during the assessment, their presence should be recorded. Certain frogs and salamanders inhabit the shallow, slow-moving waters of stream pools and near the sides of banks. Note if any adult frogs are seen or vocalizations are heard, even if no frogs are visually observed.

Many aquatic vertebrate species are protected by state and federal law, and therefore should not be collected for streamflow duration assessment. Instead, identifications should be made on-site, without disturbing the organisms. It is recommended that a series of photos be taken of any species in question to allow further identification to be made off-site, if necessary. If unable to closely observe and/or photo any vertebrate species and the identification is uncertain, then describe any distinguishing features that were observed in the notes. As with fish, dead specimens may be noted on the field forms.

Amphibians

Amphibians are typically associated with aquatic habitats, and some amphibians require aquatic habitat for much or all their lives (

Table 3). Aquatic life stages include eggs and tadpoles or larvae of many amphibian species; adults of several species are aquatic or semi-aquatic as well, and their presence should also be noted (Figure 18).

Aquatic salamanders in the Arid West include the genera *Rhyacotriton* (torrent salamanders), *Taricha* (Pacific newts), and *Dicamptodon* (giant salamanders). The genus *Rhyacotriton* is aquatic throughout most of its life, whereas the latter two taxa may have terrestrial adult phases that return to the water to breed. *Ambystoma* (mole salamanders) is another western genus with fully aquatic life stages, but this group is rarely found in flowing water. All other salamander species found in the Arid West are primarily terrestrial and are only found in California and a small portion of New Mexico.

Many frog and toad species lay eggs in the water and have aquatic tadpole, metamorph, and juvenile stages. Although several of these species have terrestrial adults that only return to the water to breed, some species (such as bullfrogs, *Lithobates catesbeianus*¸ and red-legged frogs, *Rana draytonii*) remain primarily aquatic as adults. An introduced species, the African clawed frog (*Xenopus laevis*) has an exclusively aquatic life cycle.

*Figure 18. A tadpole of a Great Basin spadefoot toad (*Spea intermontana*, top left), a California tree frog (*Pseudacris cadaverina*, top right), and a California newt (*Taricha torosa *bottom). Photo credits: Robert Leidy (top left), Raphael Mazor (top right) and Alex Heyman (bottom).*

Snakes

In the western U.S., most species of garter snakes (*Thamnophis* spp.) are semi-aquatic (Figure 19). The northwestern garter snake (*T. ordinoides*) is an exception, being found primarily in terrestrial habitats. Water snakes (*Nerodia* spp.) are found in the eastern part of the Arid West region. Note that several non-aquatic snakes (such as king snakes, gopher snakes, and rattle snakes) may congregate near streams and even bathe in the water during hot weather. Snakes often disperse through ephemeral and intermittent stream channels, and along the riparian corridors of streams of all flow duration classes.

*Figure 19. A two-striped garter snake (*Thamnophis hammondii*) in a perennial stream in California. Photo credit: Raphael Mazor.*

Turtles

A large number of aquatic turtles have been introduced to ponds and other lentic habitats throughout the West, but only a few are found in flowing habits. These include the western pond turtles (*Actinemys* spp., Figure 20), mud turtles (*Kinosternon* spp.), and softshell turtles (*Apalone* spp.). Mud turtles are known to disperse within dry ephemeral stream channels to search for persistent pools.

*Figure 20. A juvenile (left) and adult (right) southwestern pond turtle (*Actinemys pallida*) from California. Photo credit: Robert Leidy.*

Table 3. Aquatic and semi-aquatic amphibians, snakes, and turtles in the Arid West. A: Life stage is fully aquatic. S: Life stage is semi-aquatic. Blank cells indicate that the life stage is terrestrial.

		Life stages		
Species	Common name	Eggs and Larvae/ Tadpoles	Juveniles	Adults
	Salamanders and Newts			
Ambystoma spp.	Wide-mouthed salamanders	A	S	S
Dicamptodon spp.	Giant salamanders	A	A	S
Rhyacotriton spp.	Torrent salamanders	A	A	A
Taricha spp.	Pacific newts	A	S	S
	Frogs and Toad			
Acris spp.	Cricket frogs	A	S	S
Anaxyrus (Bufo) spp.	Toads	A	S	S
Ascaphus truei	Coastal tailed frog	A	A	A
Gastrophryne olivaceae	Great Plains narrow-mouthed toad	A	S	S
Lithobates spp.	Leopard frogs and bullfrogs	A	S	S
Pseudacris spp.	Tree frogs	A	S	S
Rana sp.	True frogs	A	S	S
Scaphiophus spp.	Spadefoot toads	A	S	S
Spea spp.	Spadefoot toads	A	S	S
Xenopus laevis	African clawed frog	A	A	A
	Snakes			
Nerodia spp.	Water snakes		S	S
Thamnophis spp. (except *T. ordinoides*)	Gartersnakes		S	S
	Turtles			
Actinemys spp.	Western pond turtles		S	S
Apalone spp.	Softshell turtles		A	A
Kinotsernon spp.	Mud turtles		A	A

Aquatic invertebrates that prefer perennial streams

Although this protocol does not require the identification of aquatic invertebrates beyond the Order level, it may be possible to identify some taxa in the field with a preference for perennial (or long-duration intermittent) flows. Blackburn and Mazzacano (2012) identified 18 families of aquatic invertebrates (Table 4) as indicators of perennial flow in the Pacific Northwest. These families are used in the SDAM PNW (Nadeau 2015) to discriminate between intermittent and perennial stream reaches, and their presence in Arid West streams may indicate that a reach has long duration streamflow.

Table 4. Perennial indicator taxa identified by Blackburn and Mazzacano (2012) for use in SDAM for the Pacific Northwest (Nadeau 2015). Asterisks (*) indicate taxa that are known to occur with some regularity in intermittent streams in the Arid West. Double asterisk (**): Corydalidae in the Protochauliodes-Neohermes *group include taxa specialized for life in intermittent*

streams (see top left panel Figure 11); however, the Orohermes-Corydalus *group are typically found in perennial streams in the Arid West (Cover et al. 2015).*

Group	Order	Perennial indicator families
Mollusks	Snails (any life stage)	Pleuroceridae Ancylidae Hydrobiidae
	Freshwater mussels (any life stage)	Margaritiferidae Unionidae
Insects	Caddisfly larvae and pupae	Rhyacophilidae Philopotamidae* Hydropsychidae* Glossosomatidae
	Stonefly larvae	Perlidae Pteronarcyiidae
	Beetle larvae	Elmidae* Psephenidae
	Dragonfly and damselfly larvae	Gomphidae Cordulegastridae Calopterygidae
	Dobsonfly and fishfly larvae	Cordyalidae**

Iron-oxidizing fungi and bacteria

Iron-oxidizing bacteria and fungi are often (although not exclusively) associated with groundwater, which sometimes contains high concentrations of ferrous iron (Fe^{+2}). Microbes can derive energy by oxidizing ferrous iron to its ferric form (Fe^{+3}). In large amounts, iron-oxidizing bacteria/fungi discolor the substrate and give it a red, rust-colored appearance. It can be observed in small quantities as an oily sheen on the water's surface (Figure 21). An oily sheen indicates that the stream water is derived from a local groundwater source, and these features are most commonly seen in standing water on the ground's surface or in slow-moving creeks and streams. Filmy deposits on the surface or banks of a stream are often associated with the greasy "rainbow" appearance of iron-oxidizing bacteria. This is a naturally occurring phenomenon where there is iron in the groundwater. However, a sudden or unusual occurrence may indicate a petroleum product release from an underground fuel storage tank. One way to differentiate iron-oxidizing bacteria from oil releases is to trail a small stick or leaf through the film. If the film breaks up into small islands or clusters with jagged edges, it is most likely bacterial in origin. However, if the film swirls back together, it is most likely a petroleum discharge.

Figure 21. Oily sheen on water surface due to iron-oxidizing bacteria. Photo credit: Ken Fritz.

Additional notes and photos

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

Section 4: Data Interpretation

Classifications are determined by evaluating questions at the top of the columns in Table 1, starting with the first column on the left, and proceeding to the right. The measurement observed for each indicator determines which row should be followed until you reach the appropriate classification. For example, if three or more hydrophytes are observed, along with 20+ aquatic invertebrates the stream would be classified as perennial. However, if only one or two hydrophytes were observed, and none of the 20+ aqautic invertebrates were EPT taxa the site would be classified as intermittent. Blank cells indicate that a particular indicator is not needed and that a classification has already been determined. For the beta SDAM AW, all five indicators should be measured and recorded during every assessment.

In addition to using the classification table in Table 1, classifications may be obtained from the online reporting tool described below.

Outcomes of SDAM classification

Application of the SDAM can result in one of five possible classifications:

- Ephemeral
- Intermittent
- Perennial
- At least intermittent
- Less than perennial

The first three streamflow duration classifications correspond to the three classes of streams used to calibrate the SDAM (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. For example, the absence of hydrophytes, aquatic invertebrates, algae, and fish was consistent with 81% of ephemeral sites in the calibration data.

In some cases, the pattern of indicators was associated with multiple classes, and the Beta SDAM model cannot assign a single classification with high confidence. However, the Beta SDAM 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 is sufficient for management decisions, although additional investigations may be warranted.

In other cases, the SDAM model may rule out a perennial classification but cannot distinguish between ephemeral or intermittent classes with high confidence. In this case, the result is *Less than perennial*. In this circumstance, however, the two classes cannot be distinguished with confidence. In some cases, this information is sufficient for management decisions, although additional investigations may be warranted.

In the example shown in Figure 22, a site was classified as *Need more information*. No hydrophytes, aquatic invertebrates, or fish were observed, but sparse algae cover was noted. Further investigation of field notes revealed that the crew likely mistook a decayed cow patty for a dead algal mat. After correcting the data, the site was correctly classified as ephemeral.

In another example (Figure 23), a stream was classified as *Need more information* because only two hydrophytic plants were observed (a willow and a rush), but no other indicators were detected. Investigation of the stream gauge at this site shows that the stream is marginally intermittent and has not experienced long-duration flows in recent years, suggesting that it may be transitioning to ephemeral.

Figure 22. Placeritas Canyon, in Arizona. Initially, the site was classified as Need more information*. Closer investigation of the field notes resulted in a reclassification of Ephemeral. Photo credit: Matt Robinson.*

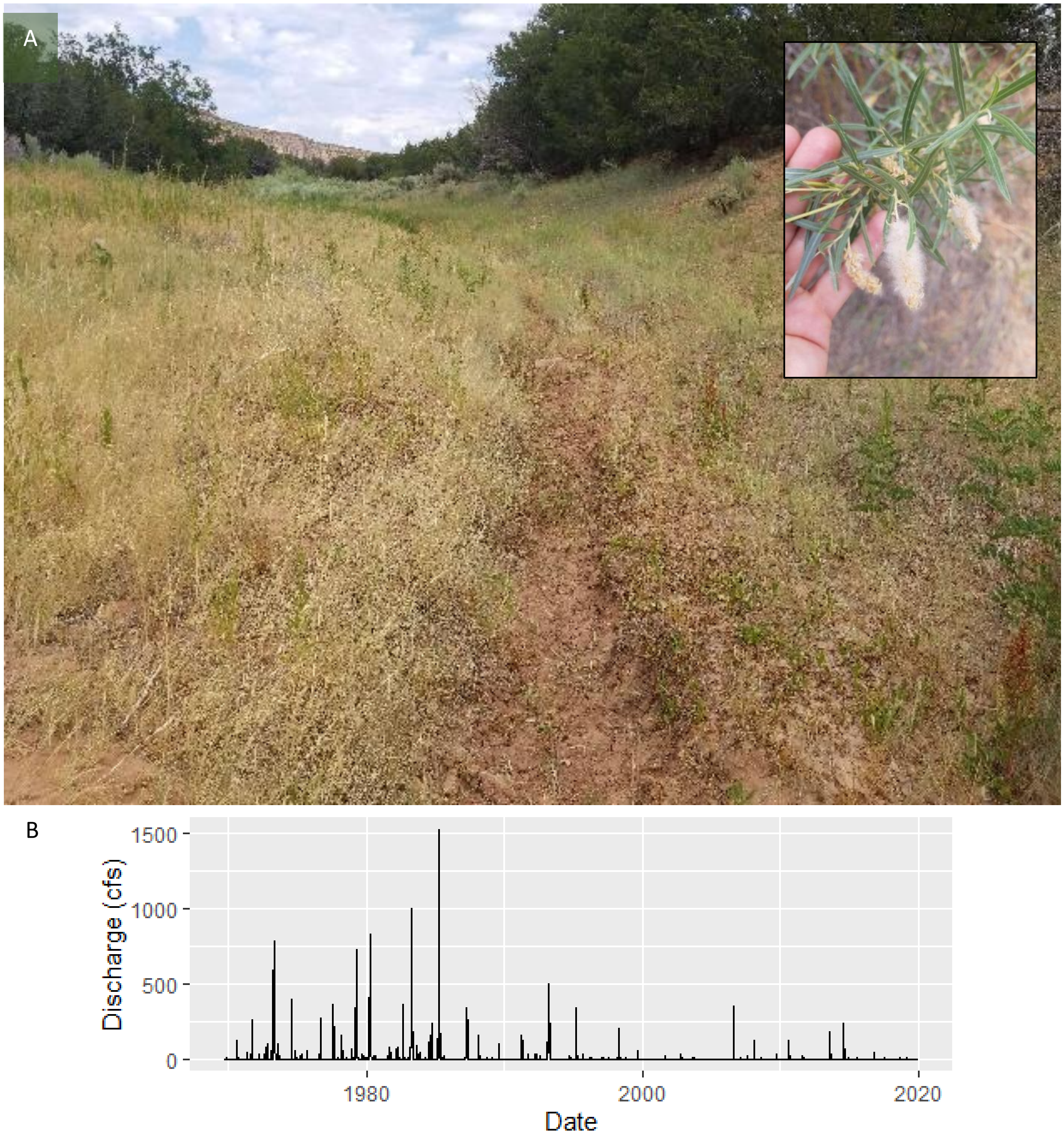


Figure 23. The Zuni River above Black Rock Reservoir, NM, a site classified as Need more information. *A. A photo of the reach. A thicket of willows is visible in the background. Inset: Close up of narrow-leaved willow leaves (*Salix exigua*), one of two hydrophytic plant species observed at the reach. B. Discharge data from a nearby stream gauge (USGS 09386950). Photo credits: Matt Robinson and Emma Haines.*

What to do if more information is needed?

The application of the SDAM should result in *perennial, intermittent,* or *ephemeral* classifications most of the time. If more information is required, it may help to examine other lines of evidence (such as the supplemental information included in the protocol) or conduct additional evaluations as described below.

Evaluate supplemental information collected during assessments

The SDAM classification is based on just five indicators. Still, the protocol includes the collection of supplemental information—specifically, the presence of aquatic life stages of amphibians or reptiles (

Table 3), aquatic invertebrates that prefer perennial streams (Table 4), and iron-oxidizing fungi or bacteria (Figure 21). In general, the presence of any of these organisms may be considered evidence of longer-duration flows.

Conduct additional evaluations at the same site

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

Conduct evaluations at nearby sites

Indicators may provide more conclusive results at sites 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 section above ("Reach selection and placement") for guidance.

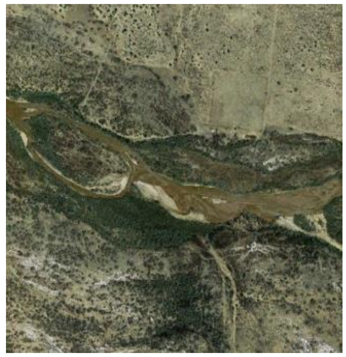
Review historical aerial imagery

In many parts of the Arid West, sequences of aerial imagery can provide information about streamflow duration. Google Earth's time slider offers a convenient method of reviewing historical imagery, particularly for desert systems with little riparian vegetation that could obscure the channel (however, note that the Google Earth time slider may not have accurate image dates), as does the USGS Earth Explorer. 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. Suppose surface water is never observed, even when other nearby intermittent streams show water. In this case, 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. This evidence is strong if the images with surface water occur in the dry season, and do not coincide with storm events.

Anytime that discrete observations of flow or no flow are used to inform a determination of flow duration class, it is recommended that such observations 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. A useful tool to determine the antecedent precipitation conditions for any particular site and date is the Antecedent Precipitation Tool (APT), developed by the U.S. Army Corps of Engineers (https://www.epa.gov/nwpr/antecedent-precipitation-tool-apt). 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 24.

Perennial site: Jemez River near Zia Pueblo, NM


11/2015: Flowing

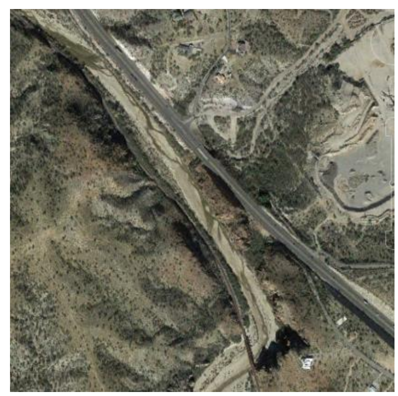

4/2017: Flowing


2/2018: Flowing

Intermittent site: Hassayampa River near Morristown, AZ


6/2007: Dry


9/2007: Flowing


12/2014: Flowing

Ephemeral site near Las Vegas, NV


4/2007: Dry


6/2012: Dry


3/2014: Dry

Figure 24. Examples of using aerial imagery to support streamflow duration classification. Images were taken from Google Earth using the time slider.

Conduct site revisits during regionally appropriate wet and dry seasons

A single well-timed site visit may provide sufficient hydrologic evidence about streamflow duration. For example, streams flowing at the end of the dry season (~September) in Mediterranean California are likely perennial, and streams that are dry a week after large monsoon events in Arizona are likely ephemeral, assuming typical climate patterns. As with observations from aerial imagery, anytime onsite observations of flow or absence of flow are used to inform a determination of flow duration class, it is recommended that such observations 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 sites. It may be possible to distinguish intermittent from ephemeral streams in just a single season, assuming typical precipitation.

Preparing a Streamflow Duration Assessment Report

The web application for the beta version of the Streamflow Duration Assessment Method for the Arid West (https://sccwrp.shinyapps.io/beta_awsdam_report/) provides a way to organize information about indicators and determine the appropriate classification. This website allows users to enter data and upload photos associated with each indicator, and then produce a PDF report in a standard format, which can be included in permit applications.

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Appendix A. Glossary of terms

Term	Definition
Abdomen	The terminal section of an arthropod body.
Algae	A large and diverse group of photosynthetic single- and multi-cellular organisms that live in waterbodies. Algae may grow suspended in water (i.e., phytoplankton), or, more typical for streams, attached to stable substrate, such as rocks or submerged logs (i.e., periphyton). For the SDAM AW, this group includes diatoms, cyanobacteria, green algae, and red algae. Vascular plants, mosses, and non-photosynthetic bacteria or fungi are not considered algae.
Active channel	A portion of the valley bottom that can be distinguished based on the three primary criteria of (i) channels defined by erosional and depositional forms created by river processes, (ii) the upper elevation limit at which water is contained within a channel, and (iii) portions of a channel without mature woody vegetation. Braided systems have multiple threads and channel bars that are all part of the active channel.
Alluvial	Refers to natural, channelized runoff from terrestrial terrain, and the material borne or deposited by such runoff.
Assessment reach	The length of reach, ranging from 40 m to 200 m, where SDAM AW 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.
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.
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.
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.
Exuviae	The shed exoskeletons of arthropods typically left behind when an aquatic larva or nymph becomes a winged adult. Singular: exuvium.
FACW	Facultative wetland plans. 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.)
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. For the SDAM AW, plants rated as FACW and OBL in the most recent version of the National Wetland Plant List are considered hydrophytes.
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 SDAM AW, indicators are rapid, field-based biological 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. For the SDAM AW, some hydrophytes are considered macrophytes, and all macrophytes are hydrophytes.
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.
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.

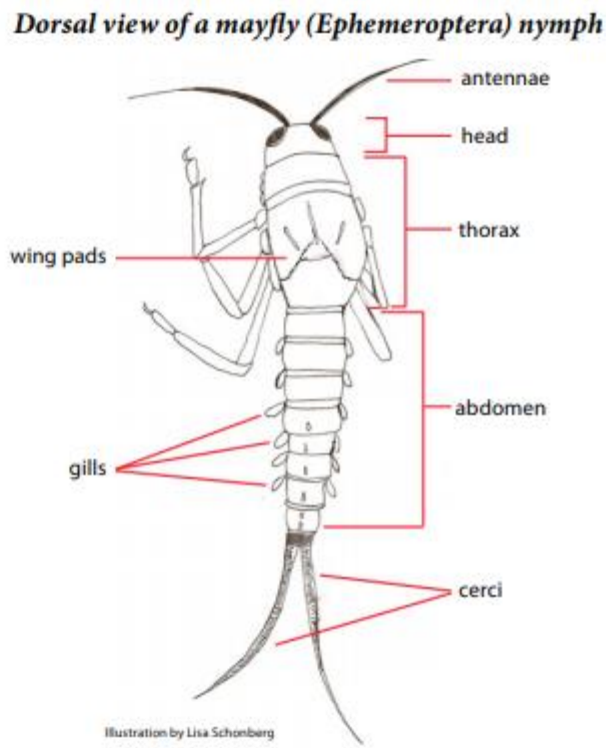
Ordinary high-water mark (OHWM)	The line on the shore established by the fluctuations of water and indicated by physical characteristics, such as a clear natural line impressed on the bank, shelving, changes in the character of the soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas. See 33 CFR 328.3(c)(7), 40 CFR 120.2(3)(vii). 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.
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.
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.
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.
Watershed	An area of land, bounded by a drainage divide, which drains to a channel or waterbody. Synonymous with catchment.

Appendix B. Images of Aquatic Invertebrates of the Arid West

Unless otherwise stated, these images are from the Digital Reference Collection of California Benthic Macroinvertebrates, maintained by the Aquatic Bioassessment Lab of the California Department of Fish and Wildlife. They are intended to help assessors learn to recognize common aquatic insect orders they may encounter while conducting streamflow duration assessments.

General insect anatomy

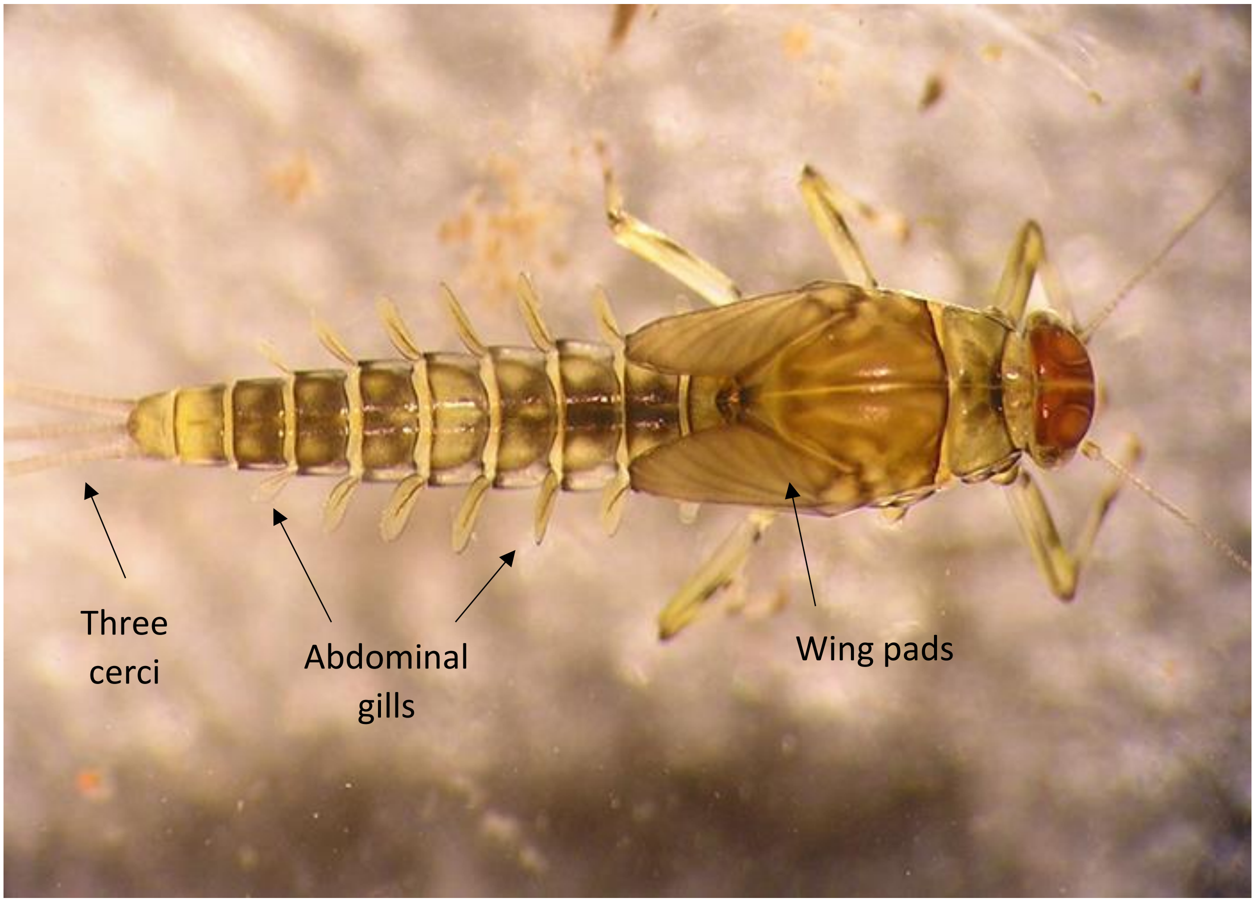


Familiarity with basic terms of insect anatomy can help distinguish major insect orders (from Mazzacano and Blackburn 2015).

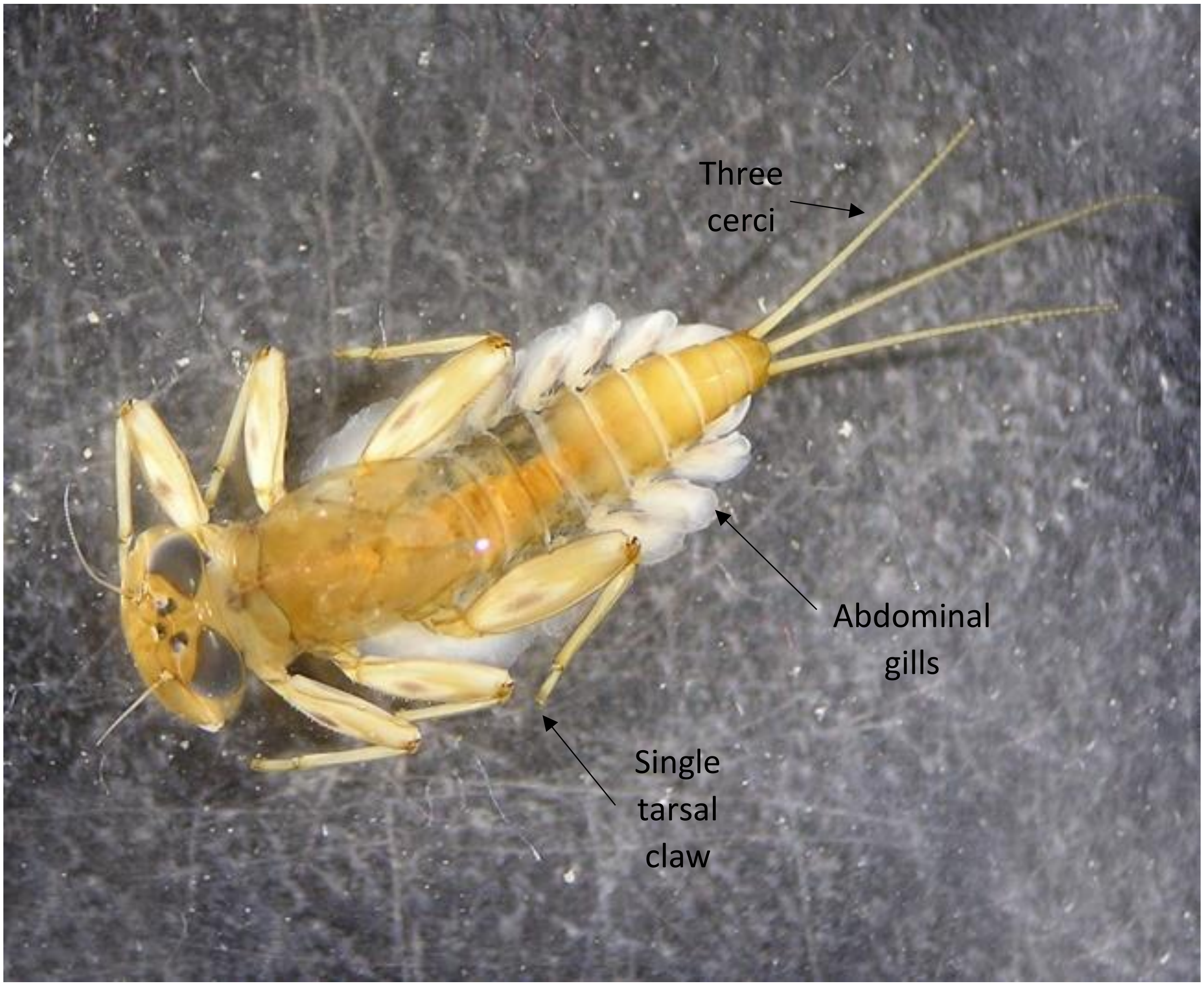
Ephemeroptera, Plecoptera, and Trichoptera (EPT)

Assessors need to learn to identify EPT orders in the field. With a bit of practice, recognizing these orders and differentiating them from other aquatic insect orders is relatively easy. These photos are intended to familiarize novices with the diversity of forms and appearances of these groups.

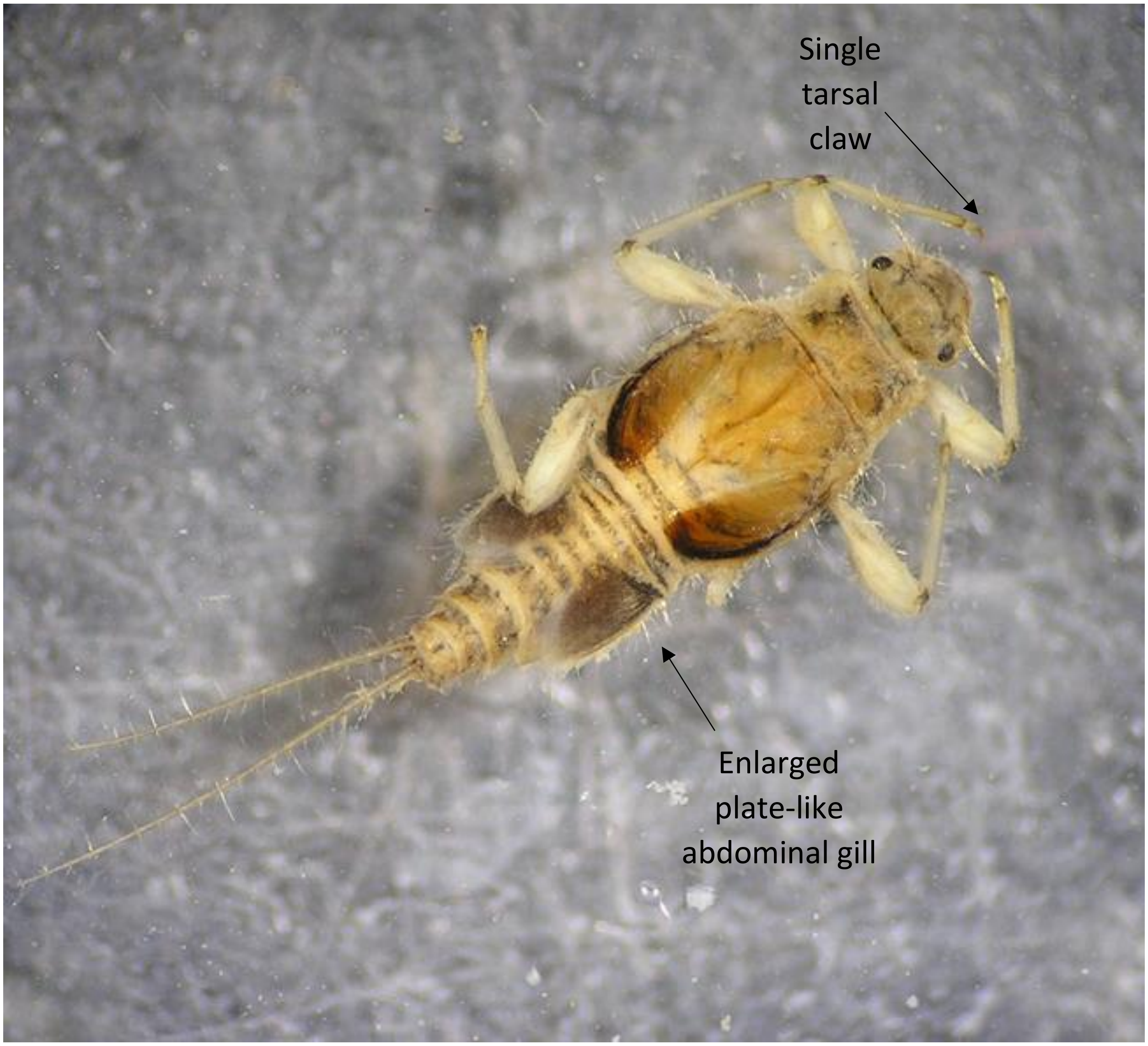
Ephemeroptera (mayfly) larvae



Baetidae (small minnow mayflies). This family has a streamlined appearance and appears to swim like a minnow. The abdominal gills and three cerci (tails) are conspicuous in this photo. Wing pads are usually visible. This specimen is *Baetis.* In some species of *Baetis*, only two cerci are evident.



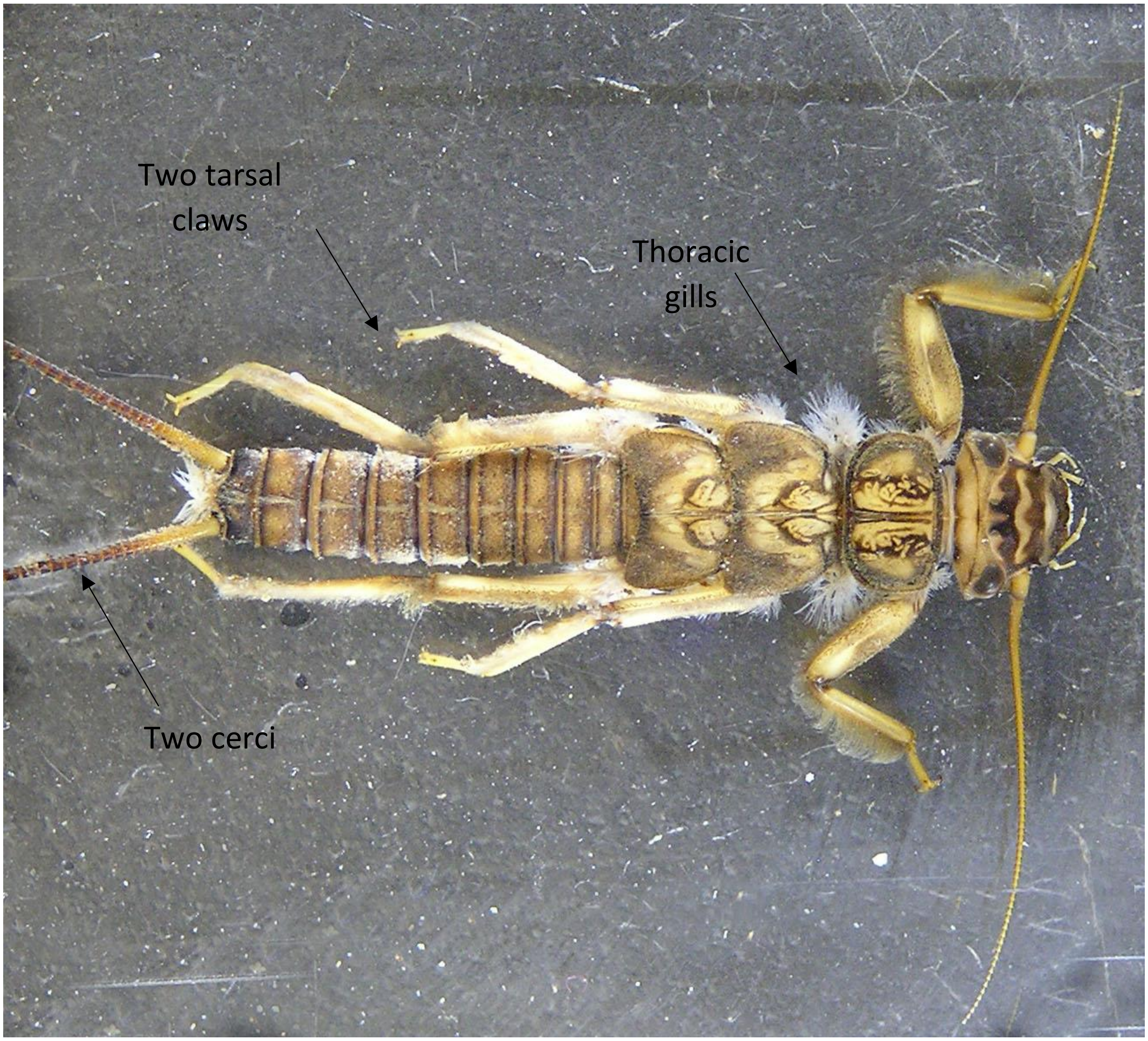
Heptageniidae (flat-headed mayflies). Some mayflies have a flattened appearance, and cling to the undersides of cobbles in fast-flowing water. Still, they have the single tarsal claws, abdominal gills, and three cerci typical of mayflies. This specimen is *Rhithrogena.*



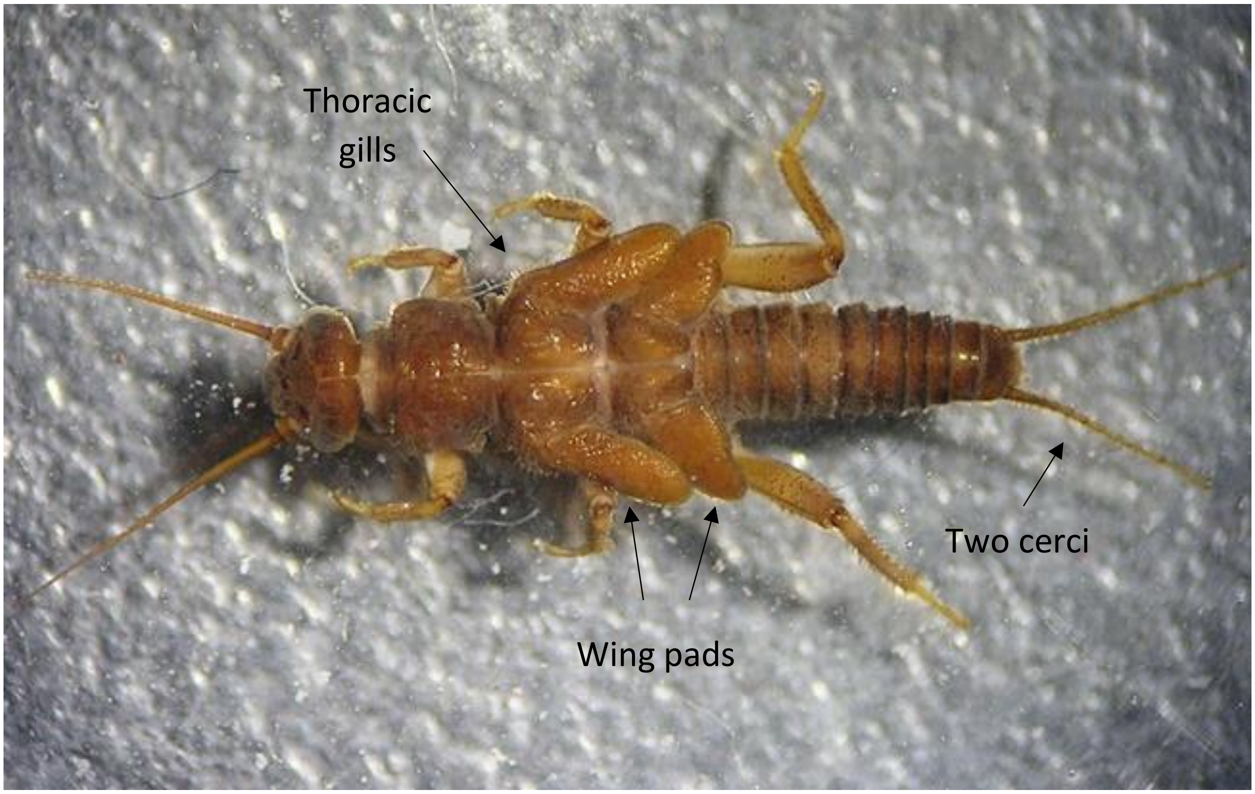
Leptohyphidae (little stout crawler mayflies). This family of mayflies has a pair of enlarged, hardened (i.e., sclerotized) abdominal gills that can cover the smaller, translucent abdominal gills. The family typically has three cerci, but the right one has broken off in this specimen. This specimen is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

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 *Hexagenia limbata.*

Plecoptera (stonefly) larvae



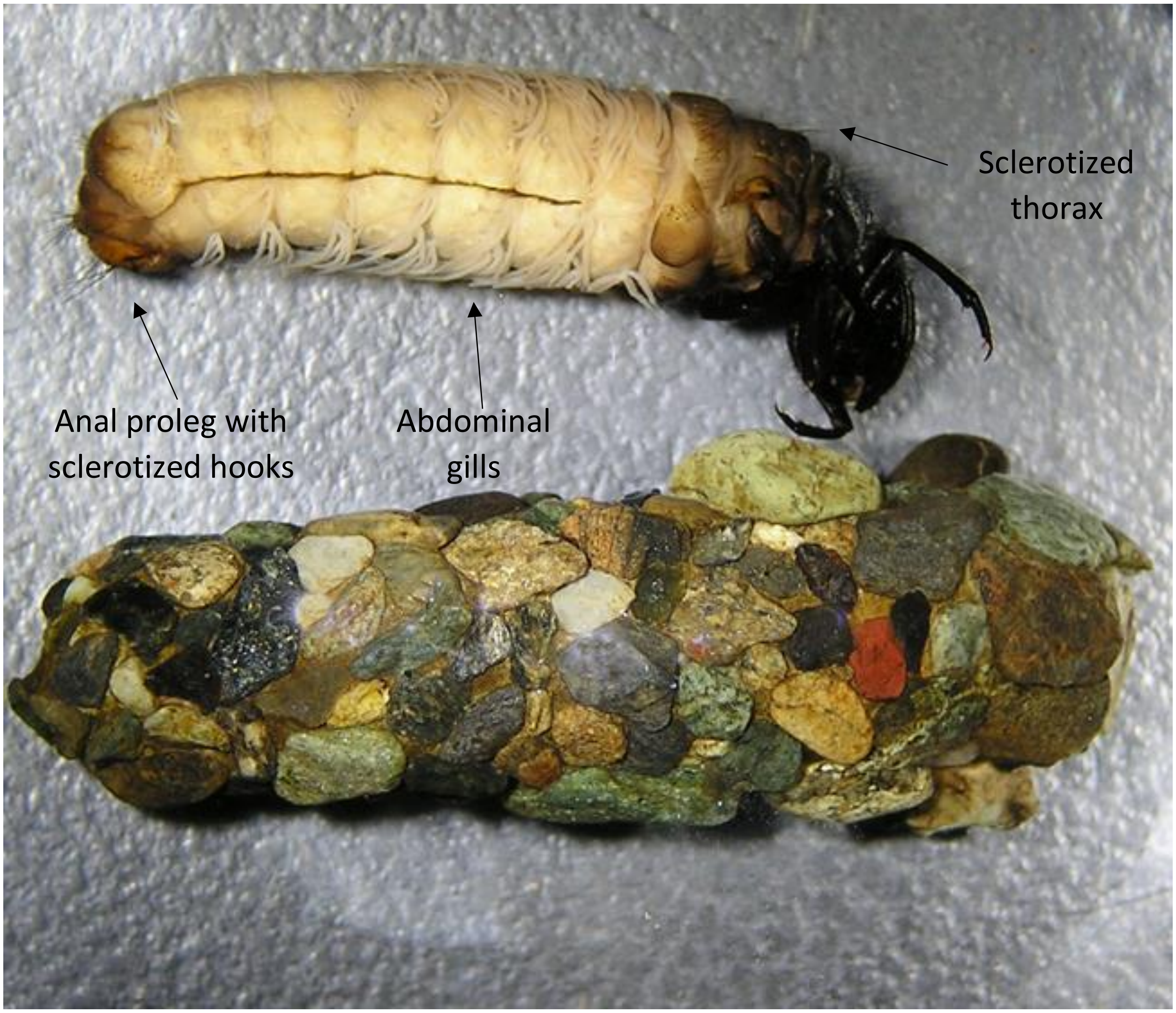
Perlidae (common stoneflies). Stoneflies have tuft-like gills on the thorax (not along the abdomen), two (not one) tarsal claw at the end of each leg, and always has two (never three) cerci, making them easily distinguished from mayflies. This family is large and conspicuous, often with ornate patterns on the head and thorax. Wing pads are usually visible. This specimen is *Claasenia sabulosa.*



Nemouridae (nemourid stoneflies). This family is relatively small and contains species that are well adapted to intermittent streams in the Arid West. This specimen is a species of *Soyedina.*

Peltoperlidae (roach-like stoneflies). Even more so than other stonefly families, peltoperlids have a roach-like appearance. This specimen is a species of *Sierraperla.*

Trichoptera (caddisfly) larvae and pupae



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. They all have filamentous gills on the ventral side of the abdomen (as opposed to the plate-like gills on the dorsal side 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 (less evident in this pudgy specimen). This specimen is a mature *Dicosmoecus gilvepes* and its case.

Lepidostomatidae. This specimen (*Lepidostoma*) builds its case out of leaf segments and silk.

Lepidostomatidae. This specimen (*Lepidostoma*) has a case made out of twigs.

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 photo. 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.

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. This specimen is a species of *Hydroptila.*

Helicopsychidae (snail case-makers) are unusual in that they build spiral-shaped, snail-like cases. This specimen is *Helicopsyche borealis.*

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.

Other Insect Orders

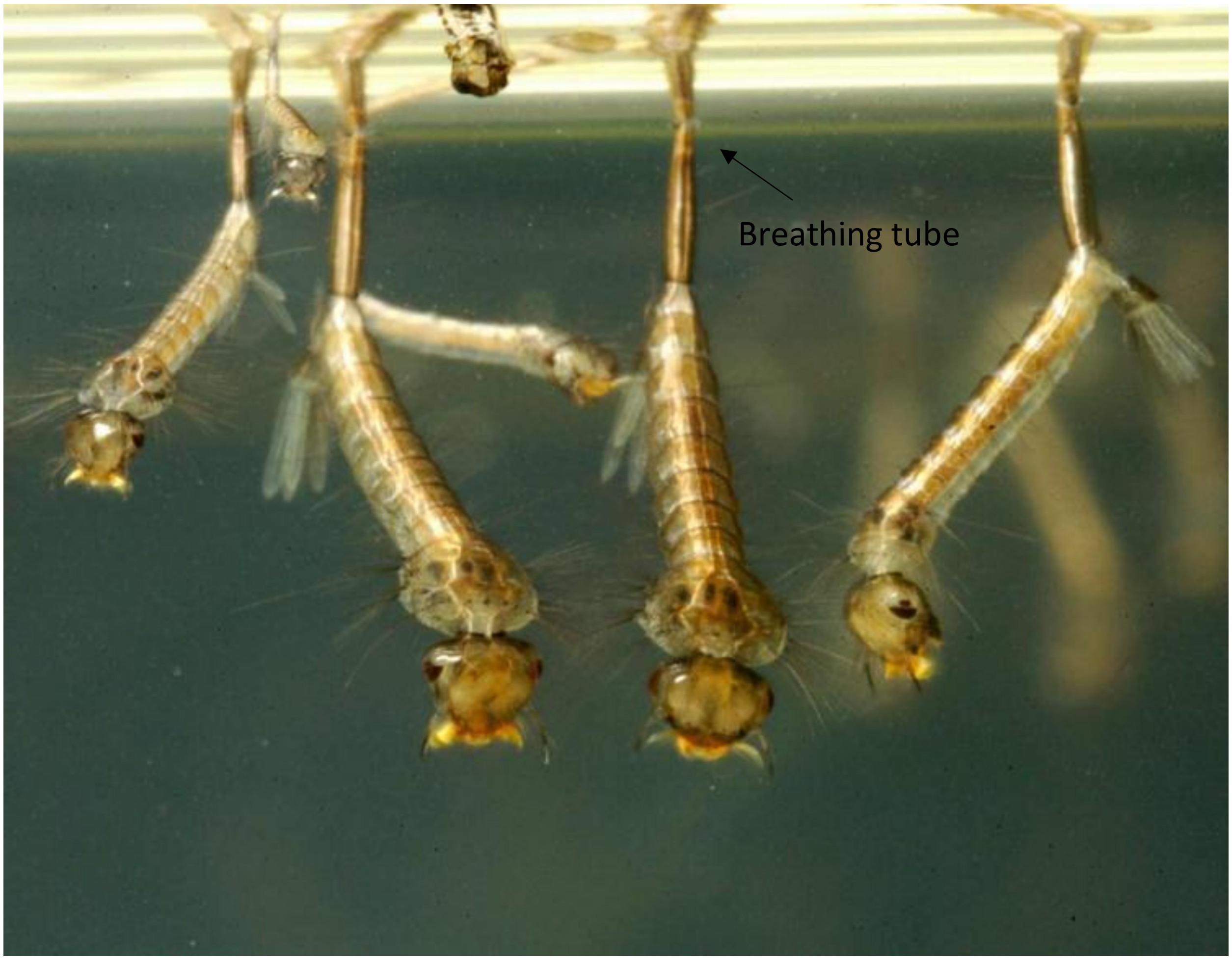
Assessors need to recognize other aquatic insect orders, and differentiate them from the EPT orders shown above. A few commonly encountered insects are shown here. These organisms contribute to the total count of aquatic invertebrates, but are not counted towards the EPT indicator.

Dytiscidae (diving beetles). Larvae of this group lack the gills and tarsal claws that characterize mayflies and stoneflies. Their thorax is not as strongly sclerotized as with caddisflies; conversely, caddisfly larvae never have sclerotized abdomens, unlike most beetle larvae. This specimen is a species of *Agabus.*

Elmidae (riffle beetles). These small insect larvae have a completely sclerotized body, unlike caddisflies which only have the thorax sclerotized. Also, 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).

Chironomidae (non-biting midges). Superficially, the larvae of this family of true flies resembles those of caddisflies, thanks to the C-shaped body and the posterior prolegs that resemble hooks. Furthermore, several species are found in tubes of silk lined with silt and muck, which can resemble a caddis case. While generally smaller, the sizes of the two groups can overlap considerably. Chironomidae are best distinguished from caddisflies by the lack of abdominal gills, the soft thorax, and the lack of true legs (i.e., three pairs of sclerotized, jointed legs). Some chironomids have bright red bodies, thanks to hemoglobin pigment, which helps them survive in low-oxygen conditions.

Corydalidae (hellgrammites, dobsonflies). This large, centipede-like insect larva has distinctive lateral filaments along the sides of the abdomen. They lack the C-shaped bodies of caddisflies, and the lateral filaments contrast with the gills on the ventral side of the abdomens of caddisflies. Although most species are associated with perennial streams, some species in California and Arizona persist in intermittent streams by building a chamber in sandy substrate beneath boulders, where they wait out the dry season; as a result, they are among the first invertebrates to be observed after the onset of flow.



Culicidae (mosquito larvae) hang at the water surface and breath air through a tube at the tip of the abdomen. When disturbed, they “wriggle” and swim away from the surface (leading to the common name “wrigglers”). Photo credit is the Missouri Department of Conservation.

Other invertebrates

Anodonta californiensis (California floater) is a freshwater mussel found in streams throughout the West. Most freshwater mussels are imperiled and should not be collected or disturbed during assessments. Photo credit: Michael Bogan.

Appendix C. Field Forms

Beta Arid West Streamflow Duration Assessment Method

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 (W): 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 channel width (m)	Reach length (m): 40x width; min 40 m; max 200 m.	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. Hydrophytic plant species

Record up to 5 hydrophytic plant species (FACW or OBL in the **Arid West** regional wetland plant list) 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 ☐ No hydrophytes in assessment area

Species	Odd distribution?	Notes	Photo ID

Notes on hydrophytic vegetation:

2 and 3. Aquatic invertebrates

2. How many aquatic invertebrates are quantified in a 15-minute search?

Number of individuals quantified:
- ☐ None
- ☐ 1 to 19
- ☐ 20 +

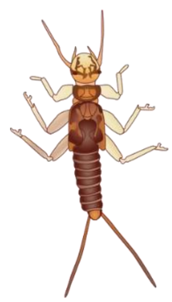
(Do not count mosquitos)

Photo ID:__________________

3. Is there evidence of aquatic stages of EPT (Ephemeroptera, Plecoptera and Trichoptera)?

Yes / No

Ephemeroptera larva
Image credit: Dieter Tracey



Plecoptera larva
Tracey Saxby

Trichoptera larva
Tracey Saxby

Notes on aquatic invertebrates:

4. Algal Cover

Are algae found on the streambed?			
Are algae found on the streambed? ☐ Check if *all* observed algae appear to be deposited from an upstream source.	☐ Not detected ☐ Yes, < 10% cover ☐ Yes, ≥ 10% (check Yes in single indicator below)	Notes on algae cover:	Photo ID:

5. Are single indicators observed?

Indicator	Present	Notes	Photo ID
Fish	☐ Yes ☐ No, no fish ☐ No, only non-native mosquitofish		
Algae cover ≥ 10%	☐ Yes ☐ No		

Supplemental information E.g., aquatic or semi-aquatic amphibians, snakes, or turtles; iron-oxidizing bacteria and fungi; etc.

Photo log

Indicate if any other photos taken during the assessment

Photo ID	Description

Additional notes about the assessment:

Classification: ______________________________

1. Hydrophytic plant species	**2. Aquatic invertebrates**	**3. EPT taxa**	**4. Algae**	**5. Single indicators** • **fish present** • **algae cover ≥ 10%**	**Classification**
None	None	Absent	Absent	Absent	**Ephemeral**
				Present	**At least intermittent**
			Present		**Intermittent**
	Few (1-19)	Absent	Absent	Absent	**Less than Perennial**
				Present	**At least intermittent**
			Present		**At least intermittent**
		Present	Absent		**Intermittent**
			Present		**Perennial**
	Many (20+)	Absent	Absent	Absent	**Ephemeral**
				Present	**At least intermittent**
			Present	Absent	**Ephemeral**
				Present	**At least intermittent**
		Present			**Intermittent**
Few (1-2)	None				**Intermittent**
	Few (1-19)	Absent			**Intermittent**
		Present	Absent		**Intermittent**
			Present		**Perennial**
	Many (20+)	Absent			**Intermittent**
		Present	Absent		**Perennial**
			Present		**Intermittent**
Many (3+)	None				**Intermittent**
	Few (1-19)	Absent	Absent		**Intermittent**
			Present		**Perennial**
		Present			**Perennial**
	Many (20+)				**Perennial**

Shading provided to enhance readability by increasing the contrast between neighboring cells; empty cells indicate the classification will not change with additional information however it is recommended that all five indicators be measured and recorded during every assessment.