United States Environmental Protection Agency

Streamflow Duration Assessment Method for the Great Plains of the United States

US Army Corps of Engineers

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

October 2024
EPA-843-B2-24001

Streamflow Duration Assessment Method for the Great Plains of the United States

Version 2.0

October 2024

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Suggested citation:

James, A., Fritz, K.M., Topping, B., Nadeau, T.-L., Fertik Edgerton, R., Nicholas, K., and Mazor, R. 2024. Streamflow Duration Assessment Method for the Great Plains of the United States. Version 2.0. Document No. EPA-843-B-24001.

Photographs courtesy of the U.S. Environmental Protection Agency unless otherwise noted.

Acknowledgments

We thank Abel Santana, Robert Butler, Duy Nguyen, Kristine Gesulga, Kenneth McCune, Adriana LeCompte Santiago, and Anne Holt for assistance with data management, and Kort Kirkeby, Abe Margo, Alex Swain, Addison Ochs, Morgan Proko, Alec Lambert, Zak Erickson, Alex Berryman, Jack Poole, Joe Kiel, Joe Klein, Jackson Bates, Buck Meyer, Margaret O'Brien, Elliot Broder, Jason Glover, and James Treacy for assistance with data collection.

Numerous researchers and land managers with local expertise assisted with the selection of study reaches to calibrate the method: Tim Bonner, Jeffrey Brenkenridge, Taylor Dorn, Tim Fallon, John Genet, Linda Hansen, Garret Hecker, Stephanie Kampf, Julie Kelso, Kort Kirkeby, Ji Yeow Law, John Lyons, Kyle McLean, Miranda Meehan, Steve Robinson, Mateo Scoggins, Patrick Trier, Linda Vance, Ross Vander Vorste, and Jason Zhang.

This work was funded through EPA contract 68HERC21D0008 to Ecosystem Planning and Restoration and EPA contracts EP-C-16-006 and 68HERC22D0002 to ESS Group.

Disclaimers

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Section 1: Introduction and Background

Streams exhibit a diverse range of hydrologic regimes, and the hydrologic regime strongly influences the physical, chemical, and biological characteristics of active stream channels and adjacent riparian areas. Thus, information describing a stream's hydrologic regime is useful to support resource management decisions, including Clean Water Act Section 404 decisions. One important aspect of the hydrologic regime is streamflow duration—the length of time that a stream sustains surface flow. However, hydrologic data to determine flow duration has not been collected for most stream reaches nationwide. Although maps, hydrologic models, and other data resources exist (e.g., the National Hydrography Dataset, McKay et al. 2014), these may exclude small headwater streams and unnamed second- or third-order tributaries, and limitations on accuracy and spatial or temporal resolution may reduce their utility for many management applications (Hall et al. 1998, Nadeau and Rains 2007, Fritz et al. 2013). Therefore, rapid, field-based methods are needed to determine flow duration class at the reach scale (defined in Section 2: Overview of the GP SDAM and the Assessment Process) in the absence of long-term hydrologic data (Fritz et al. 2020).

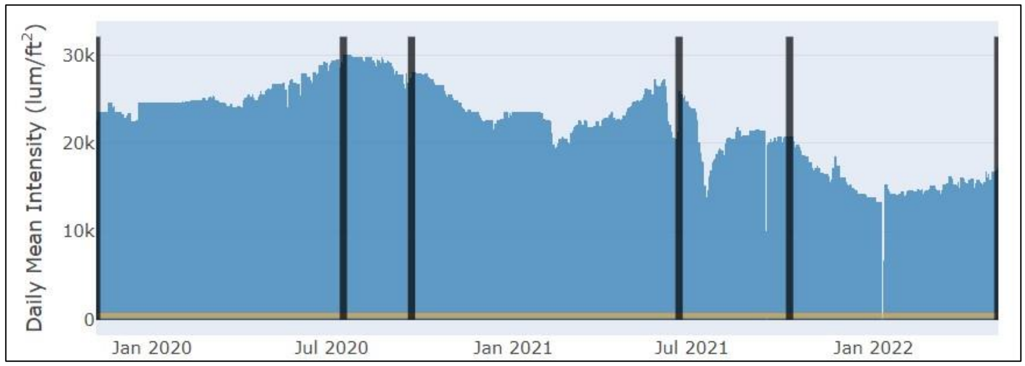
This method is intended to classify stream reaches into one of three streamflow duration classes[1]:

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

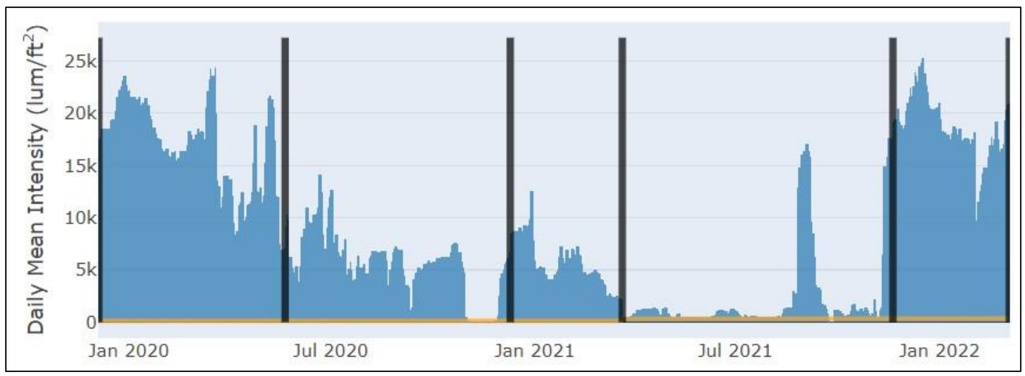
Example photographs and hydrographs of stream reaches in each class are shown in Figure 1.

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

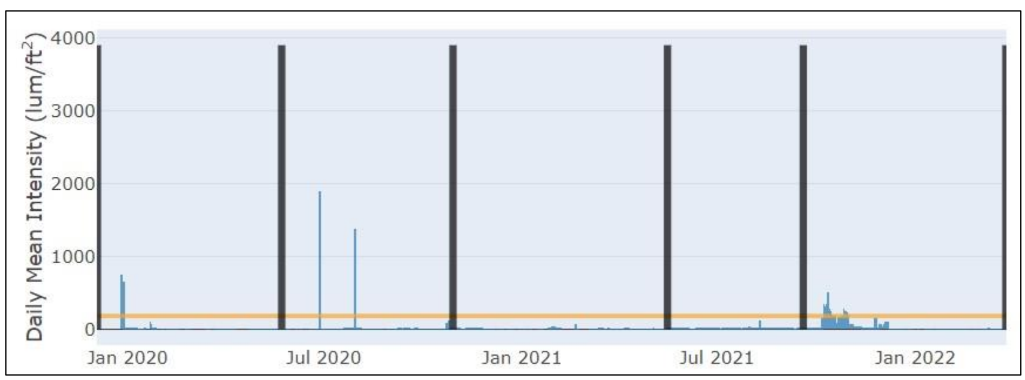
Section 1: Introduction and Background



Perennial stream reach
Grand River, Shadehill, SD



Intermittent stream reach
Dry Comal Creek, New Braunfels, TX



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

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

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

This manual describes the final Streamflow Duration Assessment Method (SDAM) intended to distinguish flow duration classes of stream reaches in the Great Plains (GP) region of the United States as defined in *Synthesizing the Scientific Foundation for Ordinary High-Water Mark Delineation in Fluvial Systems* (Wohl et al. 2016), which is based largely on vegetation type and precipitation levels (Figure 2). However the western boundary of GP is more precisely defined in the Arid West and Western Mountains, Valleys and Coast regional supplements to the U.S. Army Corps of Engineers wetland delineation manual (U.S. Army Corps of Engineers 2008, 2010).

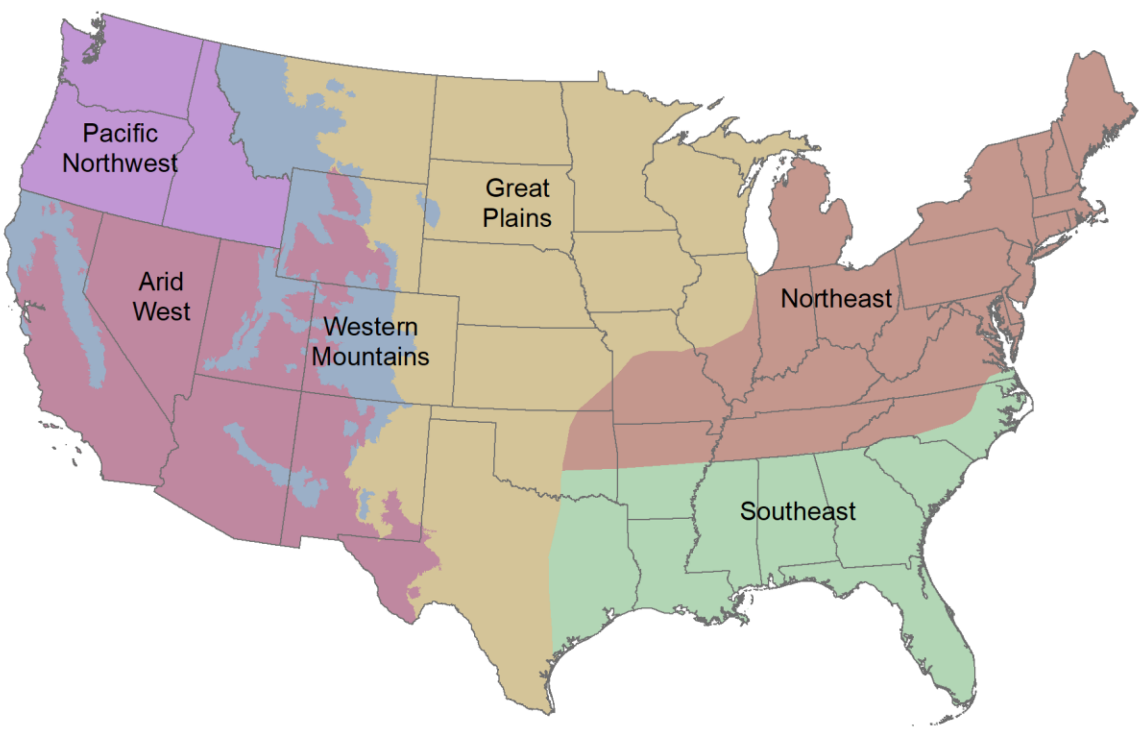


Figure 2. Map of flow duration study regions.

The GP SDAM is based on biological and geomorphological indicators. Biological indicators, known to respond to gradients of streamflow duration (Fritz et al. 2020), have notable advantages for assessing natural resources. The primary advantage of these indicators is the ability to reflect long-term environmental conditions (e.g., Karr et al. 1986, Rosenberg and Resh 1993) making them well suited for assessing streamflow duration, because some species reflect the aggregate hydrologic conditions that a stream has experienced over multiple years. As a result, relatively rapid field observations of biological indicators made at a single point in time can provide long-term insights into streamflow duration and other hydrological characteristics of a stream reach. Geomorphological indicators can also be rapidly measured and provide information about the hydrologic drivers of streamflow duration. For example, wide channels in areas with low precipitation are associated with shorter durations of streamflow; in wetter areas, narrow channels are typically associated with headwaters, where the contributing catchments may be too small to generate long-duration flows.

1.1 The SDAM for the Great Plains

This manual describes a method that uses a small number of indicators to predict the streamflow duration class of stream reaches in the GP. All indicators are measured during a single field visit. A beta SDAM for the GP was released in September 2022 (James et al. 2022a). After additional data collection, analysis, and user feedback, this final SDAM was developed, reflecting somewhat different indicators from the beta method. For more information on the development of the GP SDAM or SDAMs for other U.S. regions, please refer to the U.S. Environmental Protection Agency's (EPA's) SDAM website.

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

The method was developed using a machine learning model known as a random forest. Random forest models are increasingly common in the environmental sciences because of their superior performance in handling complex relationships among indicators used to predict classifications (Cutler et al. 2007). In some cases, a random forest model can be simplified into a decision tree or table (e.g., Nadeau et al. 2015, Mazor et al. 2021); however, that was not possible for the GP model. To obtain a flow classification for an individual assessment reach, there is an open-access, user-friendly web application for entering indicator data and running the region-specific

> Indicators of the GP SDAM
>
> *Biological indicators*
> - Total aquatic macroinvertebrate abundance
> - Number of hydrophytic plant species
> - Presence/absence of rooted upland plants in the streambed
> - Differences in vegetation
>
> *Geomorphological indicators*
> - Bankfull channel width
> - Riffle-pool sequence
> - Particle size or stream substrate sorting
> - Sediment on plants or debris

random forest model. No data entered into the web application are visible to or stored by the EPA or any other agency.

1.2 Intended use and limitations

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

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

1.3 Development of the GP SDAM

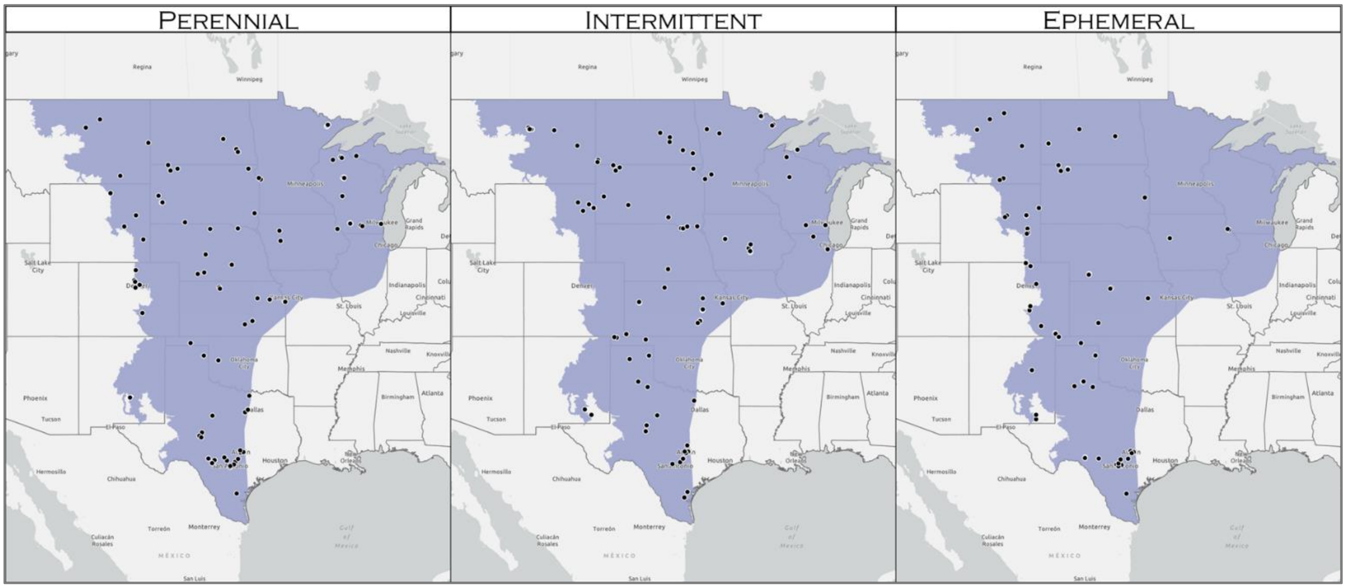


Figure 3. Locations of ephemeral, intermittent, and perennial stream reaches used to calibrate the GP SDAM.

This method resulted from a multi-year study conducted in 287 locations across the Great Plains. Of these, data from 268 sites (or reaches) where flow class could be determined from direct hydrologic data were used to develop the GP SDAM (Figure 3). Of these 268 reaches, 72 were ephemeral, 103 were intermittent, and 93 were perennial. Streamflow duration class was directly determined from continuous (hourly interval) data loggers deployed at the study reaches (170) or from active U.S. Geological Survey (USGS) stream gages (28). Multiple sources of hydrologic data (e.g., inactive USGS stream gage data, published studies, consultation with local experts) were used to classify the remaining reaches (70), that did not have continuous data loggers deployed for this study.

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

Preparation

- Conducted a literature review (James et al. 2022b):
  - Identified existing SDAMs, focusing on those originating in the Great Plains or developed using a similar approach (see Nadeau 2015; NMED 2020).
  - Identified 27 potential field biological, hydrological, and geomorphological characteristics related to streamflow duration for evaluation in the Great Plains.
- Identified candidate study reaches with known streamflow duration class, representing diverse environmental settings throughout the region.

Data Collection: Beta Method Development

- Collected field data at 287 study reaches, visited up to 4 times.

Data Analysis

- Evaluated 95 candidate metrics from the field data and GIS metrics for their ability to discriminate among streamflow duration classes. GIS metrics included climatic measures that characterize hydrologic drivers of streamflow duration (e.g., long-term precipitation and temperature) and are straightforward to calculate.
- Calibrated a classification model using a machine learning algorithm (i.e., random forest).
- Refined and simplified the beta method for rapid and consistent application.

Evaluation / Beta Implementation

- Published a beta method, data analysis report, and data used to develop the method.
- Trained the EPA and Corps staff on the beta method.
- Collected public comment and agency experience using the beta method for more than a year.
- Collected additional data at study reaches for a maximum of 6 visits.

Re-Analysis and Evaluation

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

Implementation

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

The final method correctly classified 68% of study reaches among three classes (perennial vs. intermittent vs. ephemeral), while 93% of study reaches were classified correctly between ephemeral and at least intermittent and 75% between perennial and less than perennial. Generally, misclassifications among intermittent and perennial reaches were more common than misclassifications among ephemeral and intermittent reaches. The ability of the GP SDAM to discriminate ephemeral more accurately and consistently from at least intermittent reaches is consistent with previous studies evaluating streamflow duration indicators and assessment methods (Fritz et al. 2008, 2013, Nadeau et al. 2015).

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

2.1 Considerations for assessing streamflow duration and interpreting indicators

2.1.1 Clean Water Act jurisdiction

Regulatory agencies evaluate aquatic resources for jurisdiction based on applicable regulations, guidance, and policy. The GP SDAM does not incorporate that broad scope of analysis. Rather, the GP SDAM provides information that may be used to inform jurisdictional decisions because it helps determine streamflow duration as ephemeral, intermittent, or perennial in the absence of a hydrologic record.

2.1.2 Scales of assessment

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

2.1.3 Spatial variability

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

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

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

2.1.4 Temporal variability

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

Some indicators are highly responsive to temporal variability. For example, the GP is known to experience high intensity, short-lived flood events. After these scouring events, aquatic macroinvertebrates may be displaced from a stream reach. In contrast, rooted hydrophytic plants, if present, will likely remain. Similarly, greater numbers of aquatic macroinvertebrates may be able to colonize an ephemeral to intermittent reach during wet years, depending on the presence of upstream or downstream refugia; however, changes in flow regimes may take several years to result in changes to vegetation in the riparian corridor. For example, willows with well-established root systems are likely to survive in an intermittent reach experiencing severe drought, even when flow in a single year is insufficient to support aquatic macroinvertebrates in greater numbers or at all.

2.1.5 Ditches and modified natural streams

Assessment of streamflow duration is sometimes needed in canals, ditches, and modified natural streams that are primarily used to convey water. These systems tend to have altered flow regimes compared to natural systems with similar drainage areas (Carlson et al. 2019), and the GP SDAM may determine if these flow regimes support indicators consistent with different streamflow duration classes. Thus, the GP SDAM may be applied to these systems when streamflow duration information is needed.

Geomorphological indicators (specifically, bankfull channel width and riffle-pool sequence) may be difficult to assess in straightened or heavily modified systems. Indicator measurements should be based on present-day conditions, not historic conditions. Assessors should note if the channel geomorphology reflects natural processes or if it reflects the effects of management activities.

2.1.6 Other disturbances

Assessors should be alert for natural or human-induced disturbances that either alter streamflow duration directly or modify the ability to measure indicators. Streamflow duration can be directly affected by groundwater withdrawals, flow diversions, urbanization and stormwater management, septic inflows, agricultural and irrigation practices, effluent dominance, or other activities. In the method development data set, disturbed reaches were identified as those in urban or agricultural settings or those with notable impacts from grazing, mining, or other human activities; the GP SDAM classified disturbed reaches with similar accuracy as undisturbed reaches.

Streamflow duration indicators can also be affected by disturbances that may not substantially affect streamflow duration (for instance, grading, grazing, recent fire, riparian vegetation management, and bank stabilization); in extreme cases, these disturbances may eliminate specific indicators (e.g., absence of aquatic macroinvertebrates in channels that have undergone recent grading activity). Groundwater pumping, impoundments, and diversions can affect both vegetation and geomorphological indicators (e.g., Friedman et al. 1997). Some long-term alterations or disturbances (e.g., impoundments) can make streamflow duration class more predictable by reducing year-to-year variation in flow duration and/or indicators. Discussion of how specific indicators are affected by disturbance is provided below in Section 3: Data Collection. Assessors should describe disturbances in the "Notes on disturbances or difficult assessment reach conditions" section of the field form.

2.1.7 Multi-threaded systems

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

Section 3: Data Collection

3.1 Conduct desktop reconnaissance

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

Desktop Reconnaissance for:

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

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

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

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

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

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

Local or regional flora lists of species known to grow in the vicinity of an assessment reach may be available to assist with plant identification and helpful for determining a plant's hydrophytic status. Nearby public land managers (such as U.S. Forest Service or the National Park Service) should be consulted to see if they have lists of common riparian plants in the vicinity of the assessment reach. Several online databases can generate regionally appropriate flora lists and/or assist with identification (Table 1), check the SDAM website for updates to the list of references. Note that there are multiple National Wetland Plant List (NWPL) regions that overlap with the region covered by the GP SDAM; consult the appropriate list for your location (see further discussion under 3.8.3 Number of hydrophytic plant species).

Table 1. Examples of online resources for generating local flora lists.

Resource	Geographic coverage
National Wetland Plant List	United States and territories
The Biota of North America Program (BONAP) Vascular Flora Taxonomic Data Center	United States and territories
USDA Plants Database	United States and territories
Consortium of Midwest Herbaria	Illinois, Michigan, Minnesota, and Wisconsin
Lady Bird Johnson Wildflower Center	Continental U.S. (native species only)
Kansas Wildflowers and Grasses	Kansas
Rocky Mountain Herbarium	Montana, Wyoming, Colorado, Utah, Arizona and New Mexico
Minnesota Wildflowers	Minnesota

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

3.2 Prepare sampling gear

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

- This manual and field forms (paper or digital).
- Clipboard, pencils, permanent markers, field notebook.
- Flagging tape.
- Maps and aerial photographs (1:250 scale if possible).
- Global Positioning System (GPS) – used to identify the downstream boundary of the reach assessed. A smartphone that includes a GPS may be a suitable substitute.
- Tape measures – for measuring bankfull channel width and reach length.

- Kick-net or small net and tray – used to sample aquatic macroinvertebrates.
- Hand lens – to assist with plant and aquatic macroinvertebrate identification.
- Digital camera (or smartphone with camera), plus charger. Ideally, use a camera that automatically records metadata, such as time, date, directionality, and location, as part of the EXIF data associated with the photograph.
- Shovel, soil auger, rock hammer, hand trowel, pick or other digging tools to facilitate hydrological observations of subsurface flow.
- Aquatic macroinvertebrate field guides (e.g., *Guide to Aquatic Invertebrates of the Upper Midwest*, Bouchard et al. 2004).
- Vials filled with 70% ethanol and sealable plastic bags for collection of biological specimens, with sample labels printed on waterproof paper.
- Bags or plant press for collecting plant vouchers.
- Hydrophytic plant identification guides (e.g., *Wetland and Aquatic Plants of the Northern Great Plains*, Chadde 2019).
- The U.S. Army Corps of Engineers List of wetland plants for sites to be visited.
- Boots or waders.
- First-aid kit, sunscreen, insect repellant, and appropriate clothing.

Sampling gear that comes into contact with the water (such as nets and boots or waders) should be properly decontaminated to prevent the spread of aquatic invasive species. Stop Aquatic Hitchhikers, an initiative of Aquatic Nuisance Species Task Force sponsored by USFWS provides resources and links.

3.3 Order of operations for completing the GP SDAM field assessment

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

1. Walk Assessment Reach (avoid walking in channel)
   - Confirm assessment reach placement in the field (3.5.1).
   - Measure the bankfull channel width at 3 locations and calculate average to determine assessment reach length and identify reach boundaries (3.5.2). Record average bankfull channel width in Step 2.
   - Record coordinates of downstream reach boundary from center of channel and photograph reach.
   - Begin to note expression and strength of indicators (except bankfull width and aquatic macroinvertebrate indicators).
   - Take photographs at middle and upstream end of reach.
   - Start sketching assessment reach on field form.
2. Record General Reach Site Information on Field Form (3.7.1)
3. Evaluate Indicators (3.8)
   - Collect aquatic macroinvertebrates from reach, starting from downstream end.
   - Identify hydrophytic vegetation taxa and determine presence/absence of upland plants in the channel.
   - Assess the degree to which the riparian corridor has different or more vigorous vegetation than surrounding uplands.
   - Assess the expression and degree of a riffle-pool sequence.
   - Assess the degree of substrate sorting and/or difference of channel substrate material from surrounding uplands.
   - Assess the expression and degree of fine sediment on plants and/or debris.
   - Complete sketch of the assessment reach on the field form.
4. Review Field Form for Completeness
5. Enter Data into Web Application (in office)

3.4 Timing of sampling

Ideally, application of the GP SDAM should occur during the growing season when many aquatic macroinvertebrates are most active, hydrophytes are readily identifiable, and differences in vegetation or growth vigor in the riparian corridor are easier to discern. Assessments may be made during other times of the year, but there is an increased likelihood of specific indicators being dormant or difficult to observe at the time of assessment, especially in northern parts of the GP, where the presence of snow and channel ice during the colder months may also be a factor. However, most of the indicators included in the method persist well beyond a single growing season (e.g., hydrophytic vegetation) or are not dependent on it (e.g., geomorphological indicators), reducing the sensitivity of the method to the timing of sampling.

The protocol may be used in flowing streams as well as in dry or drying streams. However, care should be taken to avoid sampling during flooding conditions and assessors should wait at least one week after large storm events that impact vegetation and sediment in the active stream channel before collecting data to allow aquatic macroinvertebrates and other biological indicators to recover (Grimm and Fisher 1989; Hax and Golladay 1998; Fritz and Dodds 2004). In general, aquatic macroinvertebrate abundance is suppressed during and shortly after major channel-scouring events, potentially leading to inaccurate assessments. Recent rainfall can interfere with measurements (e.g., by washing away aquatic macroinvertebrates). Assessors should note recent rainfall events on the field form and consider the timing of field evaluations to assess each indicator's applicability. Field evaluations should not be completed within one week of significant rainfall that results in surface runoff. Local weather data and drought information should be reviewed before assessing a reach or interpreting indicators. Evaluating antecedent precipitation data from nearby weather stations after each sampling event helps to determine if storms may have affected data collection and informs interpretation of GP SDAM data. The Antecedent Precipitation Tool (APT; U.S. Army Corps of Engineers 2023) can also be helpful for evaluating recent precipitation conditions at a site relative to the 30-year average.

3.5 Assessment reach considerations

3.5.1 Reach placement

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

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

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

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

3.5.2 Reach length

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

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

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

3.5.3 How many assessment reaches are needed?

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

3.6 Photo-documentation

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

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

Photographs that illustrate the following are also strongly recommended:

- Hydrophytic plant identifications, showing diagnostic features and extent within the reach.
- Extent of rooted upland plants in channel.
- Typical riffle-pool sequence, if present
- Particle size and/or stream substrate sorting.
- Disturbed or unusual conditions that may affect the measurement or interpretation of indicators.

3.7 Conducting assessments and completing the field form

3.7.1 General reach information

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

Coordinates

Record the coordinates of the downstream end of the reach from the center of the channel.

Weather conditions

Note current weather conditions (e.g., rain and intensity, sun, clouds, snow). If known, note precipitation within the previous week on the datasheet, and consider delaying sampling, if 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

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

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

- Urban/industrial/residential (buildings, pavement, or other anthropogenically hardened surfaces).
- Agricultural (e.g., farmland, crops, vineyard, pasture).

- Developed open space (e.g., golf course, sports fields).
- Forested.
- Other natural.
- Other (describe).

Bankfull channel width

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

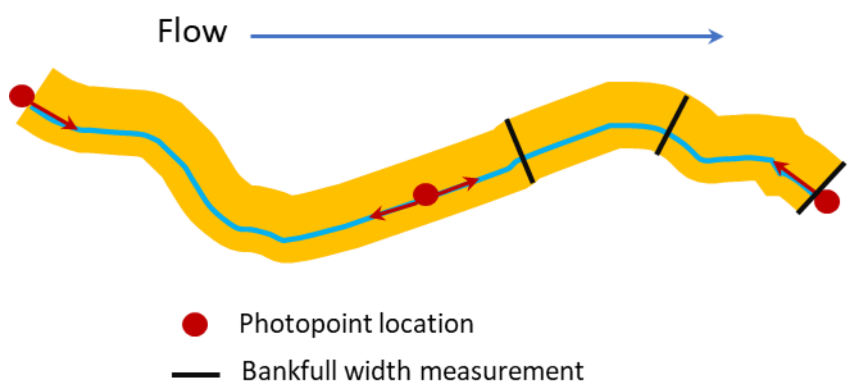


Figure 4. Bankfull measurement and photo point locations.Bankfull is represented by the yellow area and the blue line represents the thalweg of the channel. It is suggested that bankfull width be measured from the downstream end of the reach, but it is not required, as long as the three locations are spread out over one-third of the expected reach length.

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

The bankfull width[2,] is the portion of the channel that contains the bankfull discharge, which is a flow event that occurs frequently (typically every 1.01 to 5 years; David and Hamill 2024), but that does not include larger flood events. The bankfull discharge has an important role in forming the physical dimensions of the channel. For many stream channels, the bankfull elevation (from where bankfull width is measured) can be identified in the field by an obvious slope break that differentiates the channel from a relatively flat floodplain terrace higher than the channel, or a transition from exposed stream sediments or more water and scour tolerant vegetation (e.g., willows) to terrestrial and intolerant vegetation (David et al. 2022). In locations without vegetation, moss growth on rocks along the banks can be an indicator of bankfull height as can breaks in bank slope or changes in substrate composition.

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

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

In larger systems (e.g., drainage area > 0.5 square miles), it may be helpful to compare field measurements to bankfull channel dimensions derived from regional curves relating bankfull dimensions to watershed characteristics. These models may be derived at a national or regional scale (e.g., StreamStats; U.S. Geological Survey 2024) or a local scale (e.g., Texas: Asquith et al. 2020; Wyoming: Foster (2012)). Bieger et al. (2015) provides regional curves for several regions of the continental United States. If observed bankfull dimensions are substantially different from estimated bankfull dimensions derived from regional curves (e.g., more than twice the maximum or less than half the minimum estimates), it may be helpful to re-evaluate bankfull indicators that were used to establish bankfull channel height. Regional curve estimates for bankfull dimensions of small channels (small drainage areas) may be extrapolated outside the range used to develop relationships so such estimates have unknown errors (bias) associated with them and should be used with caution if at all.

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

Describe reach length and boundaries

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

Photo-documentation of reach

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

Disturbed or difficult conditions

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

Figure 6. Examples of difficult conditions that may interfere with the observation or interpretation of indicators. Left: As the San Marcos River progresses through the city of San Marcos in Texas, its banks have been hardened and the natural riparian vegetation has been removed (though there is still aquatic vegetation apparent in the channel itself). The removal of in-stream and riparian zone habitat and addition of urban non-point source discharges may also impact the abundance of aquatic macroinvertebrates and hardened banks may obscure identification of bankfull elevation. Right: Keenan Creek in Wisconsin has been straightened and channelized, affecting naturally occurring stream pattern (e.g., riffle-pool sequence). Image credits: James Treacy.

Observed hydrology

Surface flow

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

Subsurface flow

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

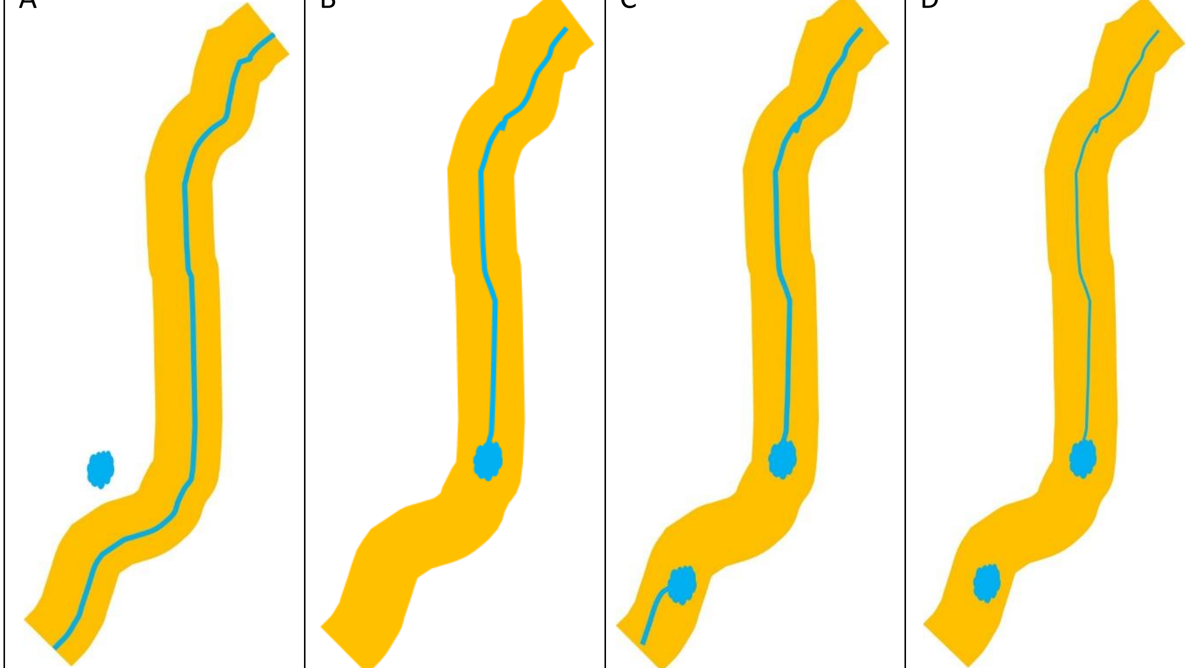
- Flowing surface water disappears into alluvial deposits and reappears downstream. This scenario is common when a large, recent alluvium deposit created by a downed log or other grade-control structure creates a sharp transition in the channel gradient or in valley confinement.
- Water flows out of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

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

The reach sketch should indicate where subsurface flow is evident.

Number of isolated pools

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



A	B	C	D
100% surface flow **100%** surface + subsurface flow **0** isolated pools	**70%** surface flow **70%** surface + subsurface flow **0** isolated pools	**80%** surface flow **100%** surface + subsurface flow **0** isolated pools	**70%** surface flow **70%** surface + subsurface flow **1** isolated pool

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

3.7.2 Assessment reach sketch

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

3.8 How to measure indicators of streamflow duration

Assessments are based on the measurement of eight indicators of streamflow duration. All must be evaluated to determine a flow classification.

Biological indicators

- Total aquatic macroinvertebrate abundance
- Number of hydrophytic plant species
- Presence/absence of rooted upland plants in the streambed
- Differences in vegetation

Geomorphological indicators

- Bankfull channel width
- Riffle-pool sequence
- Particle size or stream substrate sorting
- Sediment on plants or debris

Total aquatic macroinvertebrate abundance, number of hydrophytic plant species, differences in vegetation, riffle-pool sequence, particle size/stream substrate sorting, and sediment on plants or debris are positive indicators of streamflow duration. A greater abundance or strength of these indicators is generally associated with longer duration flows (e.g., Dodds et al. 2004, Burk and Kennedy 2013, Bigelow et al. 2020). For example, hydrophytic riparian corridor vegetation and a stronger riffle-pool sequence are both associated with perennial reaches. The relationship between streamflow duration and bankfull channel width is less straightforward. In general, wider channels are more likely to be perennial and positioned lower in the watershed than narrower non-perennial channels (Lenhart et al. 2023). Rooted upland plants and abundance of ephemeral indicator taxa are negative indicators of streamflow duration. Greater abundance or expression of rooted upland plants in the assessment reach is associated with shorter flow duration classes, as are the presence of taxa determined to be tolerant of ephemeral flow.

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

3.8.1 Bankfull channel width

Bankfull channel width is generally associated with streamflow duration, as wider channels tend to reflect longer-lasting flows. However, this pattern is sometimes reversed in more arid regions and in regions overlying alluvial geology. While this reversed pattern is more common in a region like the Arid West, it may also occur within the GP, particularly near its boundary with the Arid West (parts of New Mexico, Texas, and Wyoming). Bankfull channel width is measured (to the nearest 0.1 m) at three locations during the initial layout of the assessment reach and then averaged, as described in 3.5 Assessment reach considerations. In multi-threaded channels, the width of the entire active channel is measured, based on the outer limits of the OHWM. Wohl et al. (2016) describe the active channel as the portion of the valley bottom distinguished by one or more of the following characteristics:

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

3.8.2 Total aquatic macroinvertebrate abundance

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

A user will choose between three categories for this indicator. Counting of individuals is only required up to ten.

- Total abundance of aquatic macroinvertebrates is zero;
- Total abundance is ≥1 and <10; or
- Total abundance is ≥10.

Sample Collection Instructions

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

Searching is complete when:

- **At least six different locations within the reach have been sampled** across the range of habitat types **and** a minimum of **15 minutes** of effort expended (not including sample sorting to facilitate enumeration), **or**

- **All available habitat in the assessment reach has been completely searched** in less than 15 minutes. A search in dry stream channels with little bed or bank development and low habitat diversity may be completed in less than 15 minutes.

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

Dry channels: Focus the search on areas serving as refuge such as any remaining pools or areas of moist substrate for living aquatic macroinvertebrates, and under cobbles and other larger bed materials for evidence such as caddisfly casings (Figure 8) and snail shells. Exuviae of emergent mayflies or stoneflies may be observed on dry cobbles or stream-side vegetation (Figure 8). In summary, sampling methodology consistent with the Xerces Society's recommendations on using aquatic macroinvertebrates as indicators of streamflow duration (Blackburn and Mazzacano 2012), as developed for the Pacific Northwest SDAM (Nadeau 2015) is recommended. Take care, especially in dry channels, to only collect aquatic species and life stages. Field guides (e.g., Voshell 2002) and identification keys (e.g., Merritt et al. 2019) are recommended, especially if users are unfamiliar with common types of aquatic macroinvertebrates.

When searching dry channels (or dry portions of partially wet channels), be sure to avoid counting terrestrial macroinvertebrates in the streambed. Figure 9 depicts some taxa (especially snails) that may be found near stream channels in the GP, though this list is certainly not exhaustive. If you are unsure whether the invertebrates you encounter are aquatic or terrestrial, collecting a voucher specimen and identifying it in a lab setting or consulting an entomologist is recommended.

Figure 8. Examples of evidence of aquatic macroinvertebrates in dry channels. Left: Caddisfly cases may persist under large cobbles or boulders well after the cessation of flow. Right: Stonefly (Plecoptera) exuvia. Exuviae are left behind when aquatic nymphs or pupae emerge from the stream and go through a final molt to metamorphose to winged adults. Image credits: Raphael Mazor.

Figure 9. Examples of terrestrial macroinvertebrates you may find in a dry channel. Top left: larvae of soldier flies (Stratiomyidae); Top right: garden snail (*Cornu aspersum*) (Image credits: Raphael Mazor); Middle left: Prairie rabdotus (*Rabdotus mooreanus*) (Image credit: David G. Barker CC-BY-NC); Middle right: Decollate snail (*Rumina decollata*) (Image credit: Nicholas Cowey CC-BY-NC); Bottom left: White-lipped globe snail (*Mesodon thyroidus*) (Image credit: Meghan Cassidy CC-BY-SA); Bottom right: White-washed rabdotus (*Rabdotus dealbatus*) (Image credit: Sam Kieschnick CC-BY).

3.8.3 Number of hydrophytic plant species

For the GP SDAM, hydrophytes are defined as those with a Facultative Wetland (FACW) or Obligate (OBL) wetland indicator status in the National Wetland Plant List (U.S. Army Corps of Engineers 2020).

The GP region encompasses multiple NWPL regions, including all or large parts of the Great Plains, Midwest (MW), and Northcentral Northeast (NCNE) (Figure 10). Indicator status for certain species may differ between regions; therefore, it is important to consult the correct list when determining indicator status. For example, stinging nettle (*Urtica dioica*), a common, widespread herb often found growing in riparian zones, is FACW in the MW but only Facultative (FAC) in the GP and NCNE.

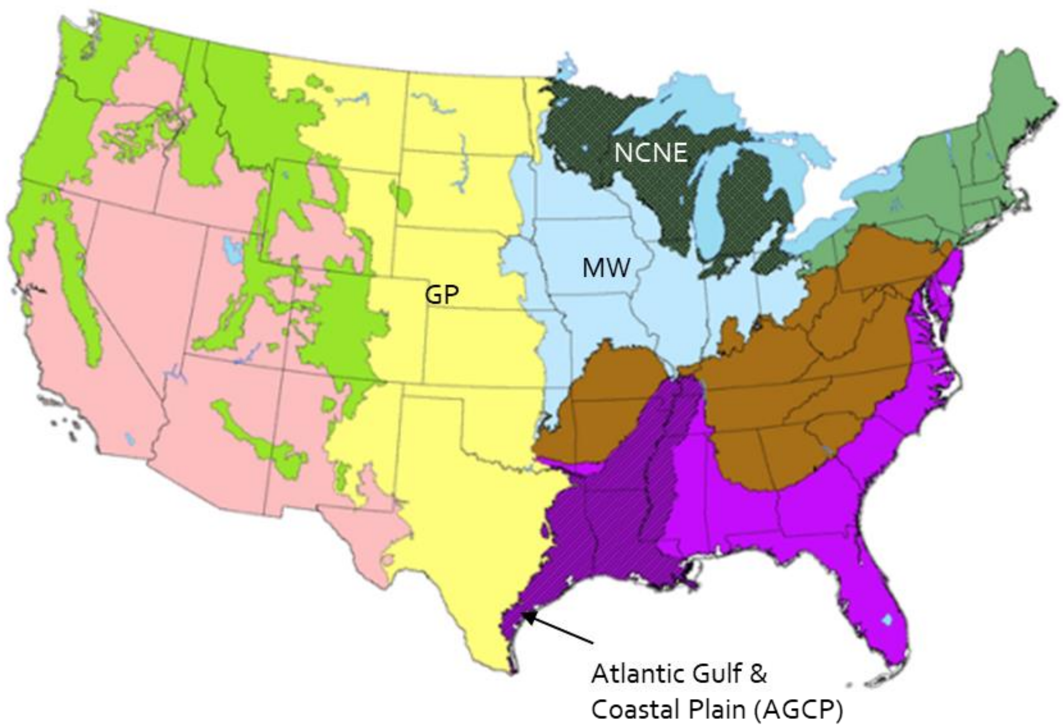


Figure 10. National Wetland Plant List (NWPL) regions that overlap with the GP SDAM region.

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

- Isolated individuals, or small patches covering only a small portion of the total assessment area (e.g., < 2%) and only found in one location (as opposed to plants sparsely distributed throughout the reach). Hyperlocal hydrologic conditions may support the growth of hydrophytes in otherwise unsuitable stream reachs. In more arid regions, this can occur at road crossings, where road runoff increases water availability to vegetation (Figure 11).
- Long-lived species exclusively represented by seedlings or plants less than one-year old. A large flood may promote the growth of hydrophytes in streams that are normally too dry to sustain them (Figure 12).

- Old specimens clearly in decline. This scenario may be a sign of major long-term reductions in water availability due to changes in water use practices or to extreme and/or persistent drought (Figure 13).

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

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

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

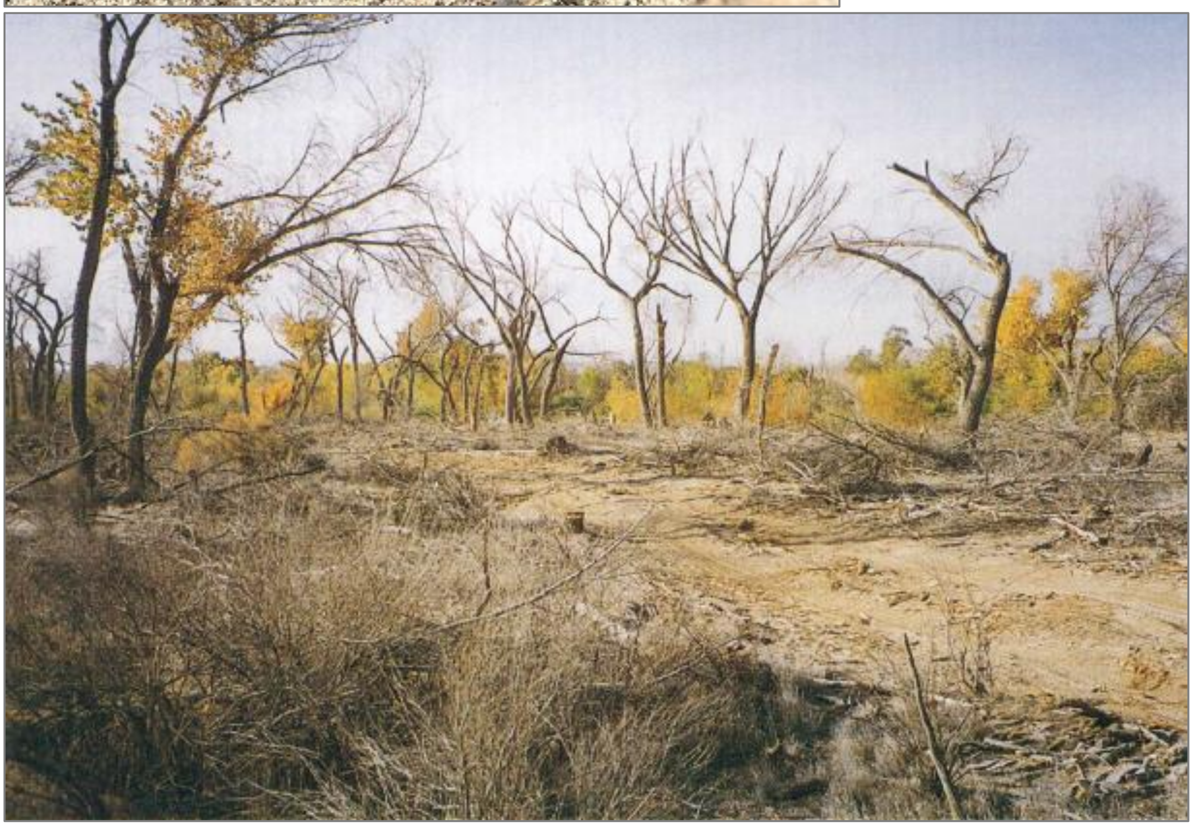


Figure 13. Water-stressed riparian trees near Oro Grande on the Mojave River. Reproduced from Lines (1999).

For this indicator, identify hydrophytic plant species growing within the channel or up to one half-channel width from the channel of the assessment reach that do not have unusual or odd distribution patterns. Hydrophytes growing at greater distances from the channel may be supported by local water sources not related to streamflow in the assessment reach. A user will choose between two categories for this indicator, as shown below. Once three taxa are identified, counting can stop; however, where the user may not be confident in all identifications, more species should be assessed, if possible.

In general, focusing on the most dominant species in the reach is efficient. Take photos of each plant species, focusing on diagnostic features and photos that illustrate the abundance and environmental context where the species grows. Where practical, voucher material (e.g., flowers, leaves, etc.) may be collected and preserved (e.g., in a plant press) for later identification.

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

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

Common questions about identifying hydrophytes

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

Do Facultative (FAC) or Facultative Upland (FACU) status plants count?
No. Although some applications of the NWPL treat FAC or FACU plants as hydrophytes, they do not count towards this indicator for the GP SDAM. For instance, some important, high-profile riparian species are FAC in some or all of the NWPL regions applicable to the Great Plains, such as American sycamore (*Platanus occidentalis*; GP NWPL region), Eastern cottonwood (*Populus deltoides*; all applicable NWPL regions), green ash (*Fraxinus pennsylvanica*; GP NWPL region), and box elder (*Acer negundo*; all applicable NWPL regions). This exclusion in no way lessens the ecological importance or conservation value of these plants, but rather indicates their relative tolerance for drier conditions than FACW or OBL species.

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

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

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

What if a hydrophytic plant species covers <2% of the assessment area (channel width plus ½ channel width on both sides of the channel x reach length) and is represented only by seedlings and/or dead/dying individuals?
Do not consider the species among the number of hydrophyte plant species present in the reach. The species with such distributions can be photographed and noted for additional information on the reach.

3.8.4 Presence/absence of rooted upland plants in streambed

Few plants can tolerate the conditions they would experience on the streambed of a reach with relatively long flow duration. Prolonged inundation, soil saturation, and shear stress create an inhospitable environment for most upland plants, preventing their establishment or perseverance. Thus, the presence of upland plants in the streambed indicates that flows have insufficient frequency, duration, or severity to limit these species. For the GP SDAM, upland plants in the context of this indicator are those with FAC, Facultative Upland (FACU) and Upland (UPL) indicators on the most recent NWPL. Species not listed in the NWPL (No Indicator; NI) are also considered upland plants.

When assessing this indicator, the focus should be on plants rooted in the streambed (Figure 15); plants growing on any part of the bank or on upland islands within the OHWM should not be considered. A user will indicate whether upland plants are present or absent from the reach and identify them on the field form.

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

3.8.5 Differences in vegetation

Streams with longer streamflow durations tend to support a distinct riparian vegetation community that includes more hydrophytic species compared to surrounding uplands. Even streams of shorter duration may allow upland species found in the riparian corridor to grow more vigorously in and or near the channel than in surrounding uplands. It is important to note in the context of this indicator, an 'upland' species does not have the same definition as in 3.8.3 Number of hydrophytic plant species and

3.8.4 Presence/absence of upland plants in streambed indicators. For this indicator, an 'upland' species is not defined by its NWPL indicator status but rather by its location relative to the channel. For example, cottonwoods (*Populus deltoides*, which are FAC and would be considered 'upland' plants for other indicators) found only in the riparian corridor along the length of the assessment reach, but not in the uplands outside of the riparian corridor, would receive a strong score for this indicator (see Table 2).

When assessing this indicator, consider the entire length of the reach, and choose the score from Table 2 that best characterizes the predominant condition; photos that demonstrate the scoring guidance are shown in Figure 16. High levels of distinctness in either composition or vigor results in a higher score. In settings where upland vegetation cannot be assessed due to development in the surrounding area, consider the upland vegetation growing in comparable areas outside the reach. In settings where the riparian corridor has been eliminated due to wildfire or management activities (e.g., channel clearing, mowing), the preferred option is to conduct the assessment after the vegetation has recovered. When a delay is not an option and the riparian corridor is devoid of vegetation, a score of zero is appropriate.

This indicator is derived from the New Mexico Hydrology Protocol (NMED 2020). As with other indicators derived from the New Mexico Hydrology Protocol, "moderate" scores (i.e., 2) are intended as an approximate midpoint between the extremes of "poor" and "strong". Half scores (i.e., 0.5, 1.5, and 2.5) midway between the scores shown in Table 2 are appropriate to allow the assessor flexibility to characterize this indicator more continuously.

Table 2. Scoring guidance for the Differences in Vegetation indicator.

Score	Evidence of perennial flows	Guidance
0	Poor	No compositional or density differences in vegetation are present between the streambanks and adjacent uplands.
1	Weak	Vegetation growing along the reach may occur in greater densities or grow more vigorously than vegetation in the adjacent uplands, but there are no dramatic compositional differences between the two.
2	Moderate	A distinct riparian vegetation corridor exists along part of the reach. Riparian vegetation is interspersed with upland vegetation along the length of the reach.
3	Strong	Dramatic compositional differences in vegetation are present between the stream banks and adjacent uplands. A distinct riparian corridor exists along the entire reach. Riparian, aquatic, or wetland species dominate the length of the reach.

Figure 16. Examples illustrating scoring levels for the Differences in Vegetation indicator. (0): The vegetation along the reach is similar in composition and vigor to surrounding uplands; (1) While the plant community composition is similar, the riparian vegetation is growing with more vigor; (2) The riparian corridor is a mix of upland (e.g., *Phegopteris connectilis*) and hydrophytic (e.g., *Alnus* spp.) vegetation while hydrophytic vegetation is absent from the surrounding uplands (3) The streambanks are dominated by hydrophytes (e.g., *Eleocharis palustris*, *Schoenoplectus pungens*) that are absent in adjacent uplands.

3.8.6 Riffle-pool sequence

A riffle is a zone with a relatively high channel slope gradient, shallow water, and high flow velocity and turbulence. In smaller streams, riffles are defined as areas of a distinct change in gradient where flowing water can be observed. The bottom substrate material in riffles contains the largest particles that are moved by bankfull flow (bedload). A pool is a zone with relatively low channel slope gradient and deep water that moves at a low velocity and with minimal turbulence. Fine textured sediments generally dominate the bottom substrate material in pools. A repeating sequence of riffles and pools can be readily observed in most perennial systems, though the form of this sequence can differ based on gradient and bed material (riffle-run or ripple-pool in low gradient and sand bed systems, or step-pool in higher gradient systems). Riffle-run (or ripple-run) sequences in low gradient systems are often created by in-channel woody structures such as roots and woody debris. No matter the form, these features can be observed even in dry channels by closely examining their local profile and patterns of

sediment deposition (at least for streams with coarser bed material). Score the indicator using the guidance in Table 3. Scoring guidance for the Riffle-Pool Sequence indicator.
This indicator is derived from the New Mexico Hydrology Protocol (NMED 2020). As with other indicators derived from the New Mexico Hydrology Protocol, "moderate" scores (i.e., 2) are intended as an approximate midpoint between the extremes of "poor" and "strong". Photos that demonstrate the scoring guidance are shown in Figure 17. Half scores (i.e., 0.5, 1.5, and 2.5), midway between the scores shown in Table 3 are appropriate to allow the assessor flexibility to characterize this indicator more continuously.

Table 3. Scoring guidance for the Riffle-Pool Sequence indicator.

Score	Evidence of perennial flows	Guidance
0	Poor	No riffle-pool sequences observed.
1	Weak	Mostly has areas of pools or of riffles.
2	Moderate	Represented by a less frequent number of riffles and pools. Distinguishing the transition between riffles and pools is difficult to observe.
3	Strong	Demonstrated by a frequent number of structural transitions (e.g., riffles followed by pools) along the entire reach. There is an obvious transition between riffles and pools.

Figure 17. Examples illustrating scoring levels for the Riffle-Pool Sequence indicator. (0): No structural definition is apparent throughout the reach; (1) The reach is largely comprised of pools and transitions to other structures infrequent or not distinct; (2) More structural definition is apparent, but distinctions are subtle, (3) A sequence of structures is present throughout the reach and transitions between them are obvious.

3.8.7 Particle size or stream substrate sorting

Well-developed streams that have eroded through the soil profile often have substrate materials dominated by larger sediment sizes, such as coarse sand, gravel, and cobble, relative to floodplain sediments and adjacent soils. Finding similar sediment sizes in the stream bed and the adjacent stream side area may indicate that stream channel-forming processes have not been consistent enough to cut into the soil profile as typically seen in intermittent and perennial streams. The bed in ephemeral channels is often soil, having the same or similar texture as areas adjacent to the channel, and often having differentiated soil horizons.

This indicator can be evaluated in two ways:

1) In channel versus outside channel: Determine if the sediment texture on the bed of the channel is similar to sediment texture adjacent to the channel (e.g., on banks or adjacent floodplain). If this is the case, then there is evidence that erosive forces have not been active enough to down

cut the channel and support an intermittent or perennial system. Stormflow runoff resulting from human development can form incised ephemeral or intermittent channels; however, these channels often show little to no coarsening of the substrate.

2) Substrate sorting: Look at the particle size distribution on the channel bed, are there substrate differences between the bedforms identified in Section 3.8.6 Riffle-pool sequence? For lower gradient channels dominated by sand substrate, the user may need to identify sorting across coarse versus fine sand.

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

Score the indicator using the guidance in Table 4. Photos that demonstrate the scoring guidance are shown in Figure 18.

This indicator is derived from the New Mexico Hydrology Protocol (NMED 2020). As with other indicators derived from the New Mexico Hydrology Protocol, "moderate" scores (i.e., 1.5) are intended as an approximate midpoint between the extremes of "poor" and "strong". Half scores (i.e., 0.75, 2.25), midway between the scores shown in Table 4 are appropriate to allow the assessor flexibility to characterize this indicator more continuously.

Table 4. Scoring guidance for Particle Size/Streambed Sorting indicator.

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

Figure 18. Examples illustrating scoring levels for the Particle Size/Stream Substrate Sorting indicator. Top left photo: Dry channel in Texas where the in channel particle size of material is similar to surrounding uplands (score of 0); Top right photo: This Montana stream shows signs of increased sorting in the middle of the channel, with slightly larger particles than low flow channels or surrounding uplands (score of 1.5); Left photo: Particle sizes in this North Dakota channel are much larger compared to surrounding uplands and a high level of sorting can be seen in the riffle in the middle of the photo (score of 3).

3.8.8 Sediment on plants or debris

The transportation and processing of sediment is a main function of streams. Therefore, evidence of fine sediment on plants or other debris in the channel, streambank, and/or floodplain may be an important indicator of persistent flow. Note that sediment production in stable, vegetated watersheds is considerably less than in disturbed watersheds. For this indicator, look for silt/sand accumulating in thin layers on debris or rooted aquatic vegetation in the runs and pools, as well as along the channel fringes, banks, and adjacent floodplain. Be aware of upstream land-disturbing construction activities, which may contribute greater amounts of sediments to the channel and can confound this indicator. Note these activities on the field form if these confounding factors are present. Score the indicator using the guidance in Table 5.

This indicator is derived from the New Mexico Hydrology Protocol (NMED 2020). As with other indicators derived from the New Mexico Hydrology Protocol, “moderate” scores (i.e., 1) are intended as an approximate midpoint between the extremes of “poor” and “strong”. Half scores (i.e., 0.25, 0.75, and 1.25), midway between the scores shown in Table 5 are appropriate to allow the assessor flexibility to characterize this indicator more continuously.

Table 5. Scoring guidance for the Sediment on Plants or Debris indicator.

Score	Evidence of perennial flows	Guidance
0.0	Poor	No fine sediment is present on plants or debris.
0.5	Weak	Fine sediment is isolated in small amounts along the stream.
1.0	Moderate	Fine sediment found on plants or debris within the stream channel, although it is not prevalent along the stream. Mostly accumulating in pools.
1.5	Strong	Fine sediment found readily on plants and debris within the stream channel, on the streambank, and within the floodplain throughout the length of the stream.

3.9 Additional notes and photographs

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

Section 4: Data Interpretation and Using the Web Application

The GP SDAM relies on a random forest model to make classifications; therefore, the EPA has developed a free, open-access web application that runs the model for each assessment reach and is required to return a flow classification. This application allows assessors to input data from assessments, including ordinal scores and non-ordinal information like number of aquatic macroinvertebrates. In addition, users have the option to produce a PDF report, which may be included as documentation of SDAM results.

The web application walks users through three steps in analyzing data from an SDAM. First, the user selects the desired regional SDAM (either by entering coordinates, clicking on a map, or selecting from a drop-down list). The coordinates field of the web application uses decimal degrees format of the World Geodetic System of 1984 (WGS84) datum. Then the user enters field data on each indicator required for the selected SDAM. At this point, the user can run the model and obtain the resulting classification. The third step, report production is optional. Users may enter additional information about the assessment (such as date of the site visit, notes, and photos of indicators) and produce a PDF report. No data entered into the web application is stored or submitted to the EPA or other agencies. A link at the top of the web application goes to Supporting Materials including User Manuals, Field Forms, Training Videos and more.

4.1 Outcomes of GP SDAM classification

As described in 1.1 The SDAM for the Great Plains, application of the SDAM can result in one of six possible classifications:

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

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

In some cases, the pattern of indicators is associated with multiple classes, and the GP SDAM model cannot assign a single classification with high confidence. However, the GP SDAM model may be able to rule out an ephemeral classification with high confidence or a perennial classification with high confidence. In the former case, the outcome is at least intermittent, meaning that there is a high likelihood that the stream is either perennial or intermittent, but not ephemeral. In the latter case, the outcome is less than perennial, meaning that there is a high likelihood that the stream is either intermittent or ephemeral, but not perennial. In both cases the two classes (i.e., perennial vs. intermittent and intermittent vs. ephemeral) cannot be distinguished with confidence. In some instances, this information may be sufficient for management decisions, although additional assessment may be warranted. Two outcomes, at least intermittent and less than perennial, were rare in the GP SDAM development data set; less than 2% of the time for both classifications. The needs more information outcome is possible and generally occurs when no classification can be made with confidence, but this did not occur in the GP SDAM development data set.

4.2 Applications of the GP SDAM outside the intended area

The GP SDAM is intended only for application to the GP region shown in Figure 2. The online web application allows the user to apply the protocol to reaches outside the GP; however, classifications resulting from these applications are for informational purposes only. For example, it may be helpful to assess reaches with more than one regional SDAM near regional boundaries. Reports generated from such applications are accompanied by warnings.

4.3 What to do when a more specific classification is needed

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

When a more specific classification is needed:

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

4.3.1 Review historical aerial imagery

Considerations for aerial imagery

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

In many parts of the GP, sequences of aerial imagery can provide information about streamflow duration. Google Earth's time slider and USGS Earth Explorer offer a convenient method of reviewing historical imagery, particularly for areas where trees do not obscure channels (however, Google Earth time slider may not have accurate image dates). If surface water is observed in all interpretable images across multiple years (especially during dry seasons), this may provide evidence that the reach is likely perennial. If surface water is never observed, even when other nearby intermittent streams show water, the consistent absence of surface water may provide evidence that the reach is likely ephemeral (particularly if images are captured during the wet season or after major storm events). If surface water is present in some images and dry in others, the stream may be intermittent. The evidence for perennial flow is strong if the images with surface water occur in the dry season and do not coincide with recent storm events. It is also important that users consider whether conditions as reflected by historical imagery are congruent with current conditions. For example, due to groundwater withdrawals, a stream that once flowed perennially may now have ephemeral flow; therefore, images from 15-20+ years ago might not be indicative of current flow conditions.

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

Perennial reach: South Loup River at Arnold, Nebraska

7/2006: Flowing | 5/2012: Flowing | 4/2017: Flowing

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

9/1997: Pools only | 12/2003: Pools only | 10/2014: Discontinuous flow

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

6/2005: Dry | 10/2011: Dry | 10/2016: Dry

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

4.3.2 Conduct additional assessments at the same reach

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

4.3.3 Conduct assessments at nearby reaches

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

4.3.4 Conduct reach revisits during regionally appropriate wet and dry seasons

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

4.3.5 Collect hydrologic data

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

Section 5: References

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Appendix A. Glossary of Terms

Term	Definition
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 GP SDAM indicators are measured.
Aquatic macroinvertebrates	Invertebrate organisms that require aquatic environments for parts or all of their life cycle and are visible without the use of a microscope (i.e., > 0.5 mm body length). Includes bottom dwelling or benthic macroinvertebrates.
Bank	The side of an active channel, typically associated with a steeper side gradient than the adjacent channel bed, floodplain, or valley bottom.
Bankfull elevation	The elevation associated with a shift in the hydraulic geometry of the channel and the transition point between the channel and the floodplain. In unconstrained settings this is the height of the water in the channel just when it begins to flow onto the floodplain.
Bankfull width	Width of the stream channel at bankfull elevation.
Braided system	A stream with a wide, relatively horizontal channel bed over which during low flows, water forms an interlacing pattern of splitting into numerous small conveyances that coalesce a short system downstream. Same as multi-threaded system.
Canal	An artificial or formerly natural waterway used to convey water between locations, possibly in both directions. Same as ditch.
Catchment	An area of land, bounded by a drainage divide, which drains to a channel or waterbody. Synonymous with watershed.
Channel	A feature in fluvial systems consisting of a 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	Channels that flow only in direct response to precipitation. Water typically flows at the surface only during and/or shortly after large precipitation events, the streambed is always above the water table, and stormwater runoff is the primary water source.

Exuviae	The shed exoskeletons of arthropods typically left behind when an aquatic larva or nymph becomes a winged adult. Singular: exuvium.
FAC	Facultative plants. They are equally likely to occur in wetlands and non-wetlands.
FACU	Facultative upland plants. They usually occur in non-wetlands but are occasionally found in wetlands.
FACW	Facultative wetland plants. They usually occur in wetlands but may occur in non-wetlands.
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.
Hydrophyte	Plants that are adapted to inundated conditions found in wetlands and riparian areas.
Hyporheic	The saturated zone under a river or stream, including the substrate and water-filled spaces between the particles.
Indicator	For the SDAM GP, indicators are rapid, generally field-based measurements that are used to predict streamflow duration class.
Instar	A phase between two periods of molting in arthropods (i.e., insects).
Intermittent	Channels that contain sustained flowing surface water for only part of the year, typically during the wet season, where the streambed may be below the water table and/or where the snowmelt from surrounding uplands provides sustained flow. The flow may vary greatly with stormwater runoff.
Larva	An immature stage of an insect or other invertebrates. Several insects have aquatic larval stages, such as mayflies, stoneflies, and caddisflies. Immature salamanders are sometimes also described as larvae. Plural: larvae.
Low-flow channel	In braided systems, the main channel with the lowest thalweg elevation. In intermittent or ephemeral reaches, the low-flow channel typically retains flow longer than other channels.
Macrophyte	Aquatic plants.
Multi-threaded system	A stream with a wide, relatively horizontal channel bed over which during low flows, water forms an interlacing pattern of splitting into numerous small conveyances that coalesce a short system downstream. Same as braided system.
NI	Plants that have no assigned wetland indicator (e.g., FACW, FACU) in a specific National Wetland Plant List region.
OBL	Obligate wetland plants. They almost always occur in wetlands.

Ordinary high-water mark (OHWM)	The line on the shore established by the fluctuations of water and indicated by physical characteristics, such as a clear natural line impressed on the bank, shelving, changes in the character of the soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas. See 33 CFR 328.3. An OHWM is required to establish lateral extent of U.S. Army Corps of Engineers jurisdiction in non-tidal streams. See 33 CFR 328.4.
Perennial	Channels that contain flowing surface water continuously during a year of normal rainfall, often with the streambed located below the water table for most of the year. Groundwater typically supplies the baseflow for perennial reaches, but the baseflow may also be supplemented by stormwater runoff and/or snowmelt.
Pool	A depression in a channel where water velocity is slow and suspended particles tend to deposit. Pools typically retain surface water longer than other portions of intermittent or ephemeral streams.
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 upland ecosystems.
Rooted upland plants	Plants rooted in the streambed that have wetland indicator statuses of FAC, FACU, UPL, and NI
Runoff	Surface flow of water caused by precipitation or irrigation over saturated or impervious surfaces.
SAV	Submerged aquatic vegetation. This class is treated the same as OBL in current versions of the National Wetland Plant List.
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.
Tributary	A stream that conveys water and sediment to a larger waterbody downstream.
UPL	Upland plants. They almost always occur in non-wetlands.
Uplands	Any portion of a drainage basin outside the river corridor.
Valley width	The portion of the valley within which the fluvial channel is able to migrate without cutting into hill slopes, terraces, or artificial structures.
Watershed	An area of land, bounded by a drainage divide, which drains to a channel or waterbody. Synonymous with catchment.

Appendix B. Field Form

Great Plains 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 prior week):	**Coordinates at downstream end (decimal degrees):** Lat (N): Long (E): Datum:
Surrounding land-use within 100 m (check one or two): □ Urban/industrial/residential □ Agricultural (farmland, crops, vineyards, pasture) □ Developed open-space (e.g., golf course) □ Forested □ Other natural □ Other: ______________________________________	**Describe reach boundaries:**	
Mean bankfull channel width (m): _________ (Indicator 1) ______ _______ _______	**Reach length (m):** 40x width min 40 m max 200 m	**Site photographs**: Enter photo ID or check if completed. Top down: _________ Mid down: ___________ Mid up: ___________ Bottom up: ___________
Disturbed or difficult conditions (check all that apply): □ Recent flood or debris flow □ Stream modifications (e.g., channelization) □ Diversions □ Discharges Notes on disturbances or difficult site conditions:	□ Drought □ Vegetation removal/limitations □ Other (explain in notes) □ None	
Observed hydrology: ______ % of reach with surface flow ______ % of reach with sub-surface or surface flow ______ # of isolated pools	Comments on observed hydrology:	

Site sketch:

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

	Notes about mean bankfull channel width:

2. Total aquatic macroinvertebrate abundance

Collect aquatic macroinvertebrates from at least 6 locations in the assessment reach and determine total abundance using the following categories:

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

- ☐ Total abundance of aquatic macroinvertebrates is zero.
- ☐ Total abundance is ≥1 and <10.
- ☐ Total abundance is ≥10.

Notes on total aquatic macroinvertebrate abundance:

3. Number of hydrophytic plant species

Record up to 3 hydrophytic plant species (FACW or OBL in the appropriate regional wetland plant list, depending on location) within the assessment area: **within the channel or up to one half-channel width outside the channel**. Explain in notes if species has an odd distribution (e.g., one individual or small patch, 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.

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

Check if applicable: ☐ No vegetation in assessment area

Species	Odd distribution?	Notes	Photo ID

Notes on hydrophytic vegetation:

4. Presence/absence of rooted upland plants in streambed

Evaluate the reach for rooted upland plants (i.e., plants rated as FAC, FACU, UPL, NI, or not listed in regionally appropriate regional National Wetland Plant List) in the streambed.

Mark the appropriate box for rooted upland plants.

☐ Rooted upland plant individuals are present in the streambed.

☐ Rooted upland plant individuals are absent in the streambed.

Upland species	Notes	Photo ID

Notes on presence/absence of rooted upland plants in streambed**:**

5. Differences in vegetation

____ **(0-3)** *Half scores (0.5, 1.5, 2.5) are allowed.*	Compare the composition and density of plants growing on the banks and riparian areas to plants in the adjacent uplands. For this indicator, upland vegetation is not defined by its wetland indicator status but by its location relative to the channel. 0 (Poor) No compositional or density differences in vegetation are present between the streambanks and adjacent uplands. 1 (Weak) Vegetation growing along the reach may occur in greater densities or grow more vigorously than vegetation in the adjacent uplands, but there are no dramatic compositional differences between the two. 2 (Moderate) A distinct riparian vegetation corridor exists along part of the reach. Riparian vegetation is interspersed with upland vegetation along the length of the reach. 3 (Strong) Dramatic compositional differences in vegetation are present between the stream banks and adjacent uplands. A distinct riparian corridor exists along the entire reach. Riparian, aquatic, or wetland species dominate the length of the reach.
Notes on differences in vegetation:	

6. Riffle-pool sequence

____ **(0-3)** *Half scores (0.5, 1.5, 2.5) are allowed.*	Evaluate the prevalence of riffles, pools, and other microhabitats in the streambed. 0 (Poor) No riffle-pool sequences observed. 1 (Weak) Mostly has areas of pools or riffles. 2 (Moderate) Represented by a less frequent number of riffles and pools. Distinguishing the transition between riffles and pools is difficult to observe. 3 (Strong) Demonstrated by a frequent number of structural transitions (e.g., riffles followed by pools) along the entire reach. There is an obvious transition between riffles and pools.
Notes about riffle-pool sequence:	

7. Particle size or stream substrate sorting

____ (0-3) *Half-scores (0.75, 2.25) are allowed.*	Evaluate the extent of substrate sorting. Compare substrate on the channel bed to the banks and adjacent floodplain. Look for sorting within the channel bed (e.g., along bars and islands). 0 (Poor) Particle sizes in the channel are similar or comparable to particle sizes in areas close to but not in the channel. Substrate sorting is not readily observed in the channel. 1.5 (Moderate) Particle sizes in the channel are moderately similar to particle sizes in areas close to but not in the channel. Various sized substrates are present in the channel and are represented by a higher ratio of larger particles (gravel/cobble). 3 (Strong) Particle sizes in the channel are noticeably different from particle sizes in areas close to but not in the channel. There is a clear distribution of various sized substrates in the channel with finer particles accumulating in the pools, and larger particles accumulating in the riffles/runs.
Notes about substrate sorting:	

8. Sediment on plants or debris

____ (0-1.5) *Half scores (0.25, 0.75, 1.25) are allowed.*	Evaluate the extent of fine sediment on plants or debris within the stream channel, streambank, and floodplain. 0 (Poor) No fine sediment is present on plants or debris. 0.5 (Weak) Fine sediment is isolated in small amounts along the stream. 1 (Moderate) Fine sediment found on plants or debris within the stream channel, although it is not prevalent along the stream. Mostly accumulating in pools. 1.5 (Strong) Fine sediment found readily on plants and debris within the stream channel, on the streambank, and within the floodplain throughout the length of the stream.
Notes about sediment on plants or debris:	

Photo log

Indicate if any other photographs taken during the assessment:

Photo ID	Description

Additional notes about the assessment:

Model classification:

☐ Ephemeral

☐ At least intermittent

☐ Intermittent

☐ Less than perennial

☐ Perennial

☐ Needs more information