AQUATIC ORGANISM PASSAGE MONITORING & ASSESSMENT PROTOCOL (aopMAP)

FIELD MANUAL

Version 4.0

August 1, 2024

Prepared By:

WSP USA Inc.

Natural Waters, LLC

Western Federal Lands Highway Division

NOTES:

Manual Versions – for tracking purposes the Version number indicates the manual update version followed by the corresponding protocol form versions, e.g. Version 1.4 indicates manual version 1 which corresponds with protocol form version 4. This is for workflow tracking only and will be omitted from final version.

Version 4.0 is the first manual update to correspond with the Survey 123 aopMAP protocol.

TABLE OF CONTENTS

GLOSSARY

Active channel: River/stream channel extent corresponding to where water is flowing within the banks just before it spills out into the floodplain, if the channel has an active floodplain. Active channel discharge is the flow rate that forms and controls the shape, size, and patterns of the low flow channel. Active channel extents are typically synonymous with bankfull channel extents. Active channel depth is a measure of the water depth at active channel discharge. Active channel width is the width of flowing water when the water level is at the active channel depth.

Actively Migrating: Channel is highly unstable and actively degrading, such as a headcut in highly erodible soils.

Aggradation: The geologic process by which a streambed is raised in elevation by the deposit of material transported from upstream. (Opposite of degradation.)

Apron: A flat or slightly inclined slab up- or downstream of culvert or weir that provides for erosion protection. A downstream apron may also produce hydraulic characteristics that exclude fish.

Aquatic Organism: Animal growing in, living in, or frequenting water.

Baffle: Wood, plastic, concrete or metal mounted in a series on the floor and/or wall of a culvert

to increase boundary roughness and thereby reduce the average water velocity in the culvert.

Baseflow: Sustained low flow in a river during dry or fair-weather conditions, but not necessarily all contributed by groundwater; includes contributions from interflow and groundwater discharge.

Bed: The bottom of a channel bounded by banks. Also refers to the material placed within an embedded culvert.

Bedload: The part of sediment transport not in suspension consisting of coarse material

moving on or near the channel bed.

Bedrock: Solid rock underlying loose deposits such as soil or alluvium.

Bed Retention Structure: Constructed feature used to hold the channel bed aggregates/materials in place.

Boulder Lag Deposit: Deposition of boulders by fluvial processes.

Bridge: A crossing structure with a combined span (width) greater than 20 ft (6.1 m), measured along the roadway centerline.

Cascade: Tumbling flow with continuous jet-and-wake flow over and around individual large rocks or other obstructions. Cascades may be natural or constructed.

Channel: A natural or constructed waterway that has definite bed and banks that confine water.

Channel Features: Formations of the channel bed and/or in-stream structures that control or typifies the low flow pathway along the system. Channel features can provide grade control, act as aquatic organism passage blockages, or provide a characteristic representation of the channel bed conditions.

Culvert: A conduit or passageway under a road, trail or other waterway obstruction. A culvert differs from a bridge in that it usually consists of structural material around its entire perimeter. A culvert that has a total span (width) of greater than 20 ft (6.1 m), measured along the roadway centerline, is considered a bridge for purposes of the National Bridge Inspection Standards.

Debris: Includes trees and other organic and inorganic detritus scattered about or accumulated near a culvert by either natural processes or human influences.

Degradation: Erosional removal of streambed material that results in a lowering of the bed elevation throughout a reach. (Opposite of aggradation.)

Deposition: Settlement of material onto the channel bed.

Discharge: Volume of water passing through a channel or conduit per unit time.

Dune Ripple: A stream channel geomorphic type that is characteristic of low gradient sand bed channels. Dune-Ripple bed formations are characterized by the formation of cross-channel ripples / small ridges and dunes. Flow depths will be more consistent than in other channel types.

Entrenchment: The vertical containment of a river and the degree to which it is incised in the valley floor.

Evolving and Stable: Channel components have the potential to make but will not degrade the overall function of the structure.

Fish Xing: FishXing (pronounced "fish crossing") is a fish passage analysis tool developed by the United States Forest Service

Floodplain: The area adjacent to the stream constructed by the river in the present climate and inundated during periods of high flow.

Floodprone Width: The width of the active floodplain along the stream channel. Floodprone width is defined as the floodplain width at two times the depth of the active channel.

Gauge Method: The use of stream gauges to determine the estimated flowrate for a storm event

Geomorphology: The study of physical features associated with landscapes and their evolution. Includes factors such as stream gradient, elevation, parent material, stream size, and valley bottom width.

Grade stabilization or Grade control: Stabilization of the streambed elevation against degradation. Usually a natural or constructed hard point in the channel that maintains a set elevation.

Headcut: An abrupt vertical drop in a stream channel bed. Headcuts are unstable knickpoints.

Head-cutting: Channel bottom erosion moving upstream through a stream channel, which may indicate a readjustment of the stream's flow regime (slope, hydraulic control, and/or sediment load characteristics).

Headwall: A wall of masonry or concrete built at the outlet of a drainpipe or culvert with the end of the conduit flush with the outer surface of the wall.

Headwater: The water upstream from a structure or point on a stream.

Headwater depth: The depth of water at the inlet of a culvert.

Hydraulic Toolbox: A stand-alone suite of calculators that performs routine hydrologic and hydraulic analysis and design computations.

HY-8: The HY-8 model is used to determine the upstream headwater depth and culvert barrel flow profile for a variety of different culvert configurations.

Invert: The lowest point of the internal cross section of culvert.

Knickpoint: A sharp change in channel slope that can occur due to geologic features, natural features (logs, tree roots, etc.), headcuts, or over-steepened riffles. Knickpoints can be stable or unstable, depending on the characteristics and durability of the knickpoint feature.

Knickpoint Migration: movement of a part of a river or channel where there is a sharp change in channel slope

Log Sill: Installation of logs to provide temporary grade control of the floodplain or bankfull bench area and prevent migration or cutting of the channel.

Long-term Stable: Channel does not exhibit aggradation or degradation and channel features include permanent structures that are unlikely to move in the long term.

Mid/Side bar: An elevated region of sediment that has been deposited by the flow located in the middle or on the edge of a river.

Mitered structure: When the culvert barrel is cut so it is flush with the embankment slope.

Pipe: A culvert that is circular (round) in cross section.

Pipe arch: A pipe that has been factory-deformed from a circular shape such that the span

(width) is larger than the vertical dimension (rise).

Plane-bed: A near-horizontal surface of sand or gravel.

Point-bar: An alluvial deposit that forms by accretion on the inner side of an expanding loop of a river.

Pool-riffle: A stream geomorphic type that is comprised of an alternating sequence of pools (slow deep water) and riffles (shallow fast water) along the stream channel.

Projecting structure: A structure that protrudes or projects from the surface.

Rational Method: Use of the Rational Equation to determine peak discharge from drainage basin runoff.

Reach: A length of a stream or river, usually suggesting a level, uninterrupted stretch.

Regression Method: Use of Regression Equations to determine estimated flowrate for a storm event

Riffle: The shallowest flowing portion of a stream channel with a riffle-pool morphology. Riffles are characterized by coarser than average channel bed material and shallower / faster flowing water than other areas of the channel.

Riffle Embeddedness: The degree to which riffle cobble, gravel, and boulder substrates are surrounded by fine material (sand and silt), so they cannot be easily dislodged.

Riprap: Large, durable materials (usually rocks; sometimes broken concrete, etc.) used to

protect a stream bank from erosion and other applications.

Rock Sill: Placement of large stones or boulders across the cross-sectional area of a stream valley to provide grade control to the channel, floodplain, and bankfull bench area.

Scour: Localized erosion caused by flowing water.

Short-term Stable: Channel is stable but has evident potential for movement

Step-pool: A regular series of steps, similar to a staircase in the bed of the stream.

Substrate: Mineral and organic material that forms the bed of a stream. In an armored channel, substrate refers to the material beneath the armor layer. Supercritical flow: Occurs when normal depth is less than critical depth; rare for extended reaches in natural streams.

Thalweg: The longitudinal line of deepest water within a stream.

Toe: The break in slope at the foot of a bank where the stream bank meets the bed.

TR-20: TR-20 is a computer program for the generation and routing of runoff hydrographs. Unlike TR-55, which was developed for manual use, the calculations in TR-20 are far too complex and numerous to be of practical use without appropriate computer software.

TR-55: Technical Release 55 (TR-55) presents simplified procedures to calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for floodwater reservoirs. These procedures are applicable to small watersheds, especially urbanizing watersheds, in the United States.

Unstable: Channel exhibits imminent degradation.

Velocity: Time rate of motion; the distance traveled divided by the time required to travel that distance.

Wingwalls: A subordinate lateral wall (as an abutment) or an oblique retaining wall (as of a bridge approach)

Wolman Pebble Count: Documentation of bed material size by taking samples. It requires a person with a metric ruler who walks through the stream, and a note taker who remains on the bank with the field book or survey data sheet. The note taker records the count by size classes or categories.

ABBREVIATIONS

AM	Actively Migrating
AO	Aquatic Organism
AOP	Aquatic Organism Passage
aopMAP	aquatic organism passage Monitoring and Assessment Protocol
BR	Exposed Bedrock
C	Cascade
CMP	Corrugated Metal Pipe
CW	Cold water species
DJ	Debris Jam
DOT(s)	Department(s) of Transportation
EW	Edge of Water
ES	Evolving and Stable
FHWA	Federal Highway Administration
HC	Headcut
HDS	Hydraulic Design Series
HEC	Hydraulic Engineering Circular
LS	Log Sill
LS	Long-term Stable
M.P.	Milepost
MLF	Most Limiting Feature
PLF	Potential Limiting Feature
RC	Rock Cluster
RS	Rock Sill
SS	Short-term Stable
SP	Step Pool
SPP	Structural Plate Pipe
SPPA	Structural Plate Pipe Arch
SB	Streambed
TAC	Top of Active Channel
TEIB	Toe of Interior Bank
TOIB	Top of Interior Bank
TW	Thalweg
WDFW	Washington Department of Fish and Wildlife
USFS	United States Forest Service
U	Unstable
WW	Warm water species
WC	Weir - concrete
WM	Weir - metal
WR	Weir- rock

Introduction

This document presents guidance for conducting the aquatic organism passage Monitoring & Assessment Protocol, (aopMAP at waterway road crossings. The monitoring protocol, aopMAP, was developed for nationwide use on AOP water crossings, applicable to any geographic setting, structure design type, stream flow condition, or aquatic species of interest. aopMAP is an open-source protocol available for use by any transportation agency, partner, or organization with data collection performed primarily using the ESRI Survey 123 platform and cloud-based data collection open for viewing, download and use. However, any transportation agency may choose to integrate aopMAP into their own proprietary system following their own internal requirements for data security. The aopMAP protocols can be readily modified or customized to mee the unique needs of an agency or organization.

Although the discussions, sample diagrams, and images often focus on culverts, the protocol is intended for application to both bridge and culvert water crossings. This protocol is not to be used as design guidance and is not commentary on the applicability or effectiveness of any AOP design guidance. The monitoring protocol presented herein is structured for data collection of all types of AOP designed crossings including United States Forest Service (USFS) and Washington Department of Fish and Wildlife (WDFW) Stream Simulation, Bankfull sizing, and Hydraulic Engineering Circular (HEC)-26, . This manual is not intended to conflict with or replace accepted guidance and procedures adopted by local agencies. When specific monitoring methods are required based upon resource / permitting agency requirements, those methods should be applied. ~~In addition,~~ the asset owner may find long-term asset management benefits in overlaying this approach with agency / permit monitoring requirements, where possible.

This monitoring protocol has been developed to facilitate and standardize data collection at AOP crossings of all types in all settings by utilizing mobile data collection technologies. The protocol is intended to contribute to future research into the effectiveness of AOP designs through the compilation of robust records for constructed AOP installations. The monitoring protocol includes two (2) stages of data collection:

- Stage 1 – As-Built Database Tool
- Stage 2 – Field Monitoring Tool

The general intention of each stage is defined as follows:

Stage 1 – aopMAP As-Built Database Tool is intended to catalogue the available record data for an AOP site, such as design plans or as-built records. The as-built data collection sets the baseline for future monitoring by This step in the process is intended as a desktop exercise, but may require a supplemental field investigation, depending on the level of detail available in the project records. The initial data collection effort is anticipated to take a few hours per crossing, however, that level of effort expectation is highly dependent on the availability and quality of records for a site and the need for a supplemental field visit to complete any gaps in the record. Project sites with the best quality as-built data records may be completed with this stage in under an hour.

Stage 2 – aopMAP Field Monitoring Tool is the primary field data collection tool within the protocol and is intended to determine the aquatic organism passage sufficiency and catalogue the critical features of each AOP water crossing site. The Stage 2 assessment survey is intended for repeated data collection at each site. Use of the protocol helps promote consistency in approach and documentation between repeated monitoring site visits to better track and observe the stability of an installation, identify maintenance needs, deficiencies in passage performance or re-development of possible partial barriers, and observe best practices for future designs and installations. If the Stage 2 assessment determines that a site is not operating as designed / intended, the facility owner could opt to perform remedial repairs to the site, depending on the severity of impairment and individual concerns at a site. Long term, the goal is to develop a time-series of monitoring data sets that can be used to investigate, and inform, studies on the efficacy of AOP installations for different systems, based on physical performance data of constructed crossings.

The Stage 2 assessment is a field measurement exercise that can be performed by two (2) well-trained staff. The Stage 2 assessment is anticipated to take one (1) to four (4) hours per crossing depending on the complexity of the site and familiarity of the assessment protocol. Measurements for Stage 2 are a combination of qualitative observations, simplified measurements, and photo documentation. Necessary equipment for a Stage 2 evaluation is limited to a camera, a survey rod, a measuring tape, a ruler, string line, string level, mounting clips, magnetic hooks, a clinometer, a hand held sight level, and an iPad/Android device. Anticipated equipment commonly used for a Stage 2 evaluation are listed in Table 2 and shown on Figure 1.

Protocol Applicability

The monitoring protocol presented in this document is applicable nationwide and targets roadway water crossings designed or retrofitted with a specific focus on AOP. The monitoring protocol is intended to document passage conditions for all aquatic organisms at all life stages during all flow conditions. The monitoring protocol applies to closed and open bottom culvert installations and bridge installations. The protocol is applicable to new crossing sites, culvert AOP rehabilitations, bridges, and older culvert installations that were built with an AOP focus. This protocol is not intended for the assessment of non-AOP designed water crossings. Water crossings not designed to address aquatic organism passage have different benchmarks for success and would not be appropriately catalogued by use of this protocol. A standard culvert assessment protocol is also available for download to perform structural stability assessment of non-AOP designed water crossings.

This protocol does not target specific organisms or require specific information on fish or other aquatic organisms as part of the data collection. However, identification of aquatic organism species of concern at a particular site, or native aquatic organism populations, will aid in future analysis to evaluate the effectiveness of aquatic organism passage at the crossing. The assessment team may consult with appropriate state and Federal agencies on the identification of specific species of concern at a given site.

Manual Structure

This manual is structured to provide guidance on the workflow of aopMAP, the proposed monitoring protocol. Section headers are structured to follow ~~the~~ section headers in aopMAP data collection surveys. protocol headers and are formatted as “Numeral-Letter_Number”. The “Numeral” portion of the headers correspond to the protocol Stage as follows:

Numeral	Stage
I-	Stage 1 – As-Built Database Tool
II-	Stage 2 – Field Monitoring Tool

The “Letter” portion of the header corresponds to the section of aopMAP. The sections are divided as groupings of correlated data points used to define an aspect of the water crossing. The “Number” portion of the header are the sub-sections of the larger sections.

> An example is the layout of section “II-C” for “Stage 2” “Interior Channel”. This data is grouped into a section as it is collected along the stream channel within the interior of the culvert. Under the section, individual data collection points for “1” – “Structure Information Verification”, “2” – “Typical Interior Channel Characteristics”, etc. are sub-sections. Following this example, the protocol header II.C1 indicates Stage “II” – Stage 2 Field Monitoring Tool, section “C” – Interior Channel and sub-section “1” for Structure Information Verification. The un-numbered data entry lines under the sub-sections are referenced as data entry fields or data points.

The camera image, , indicates that a photograph is required of the specific feature.

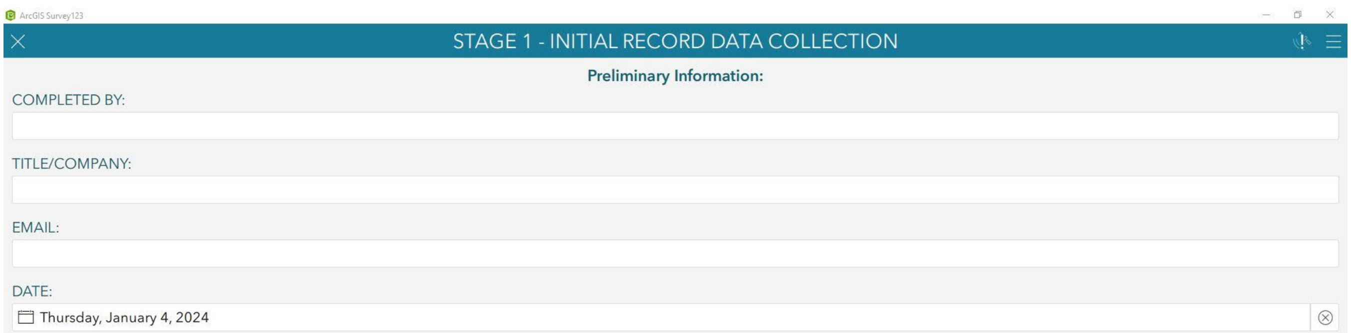
I Stage 1 As-Built Database Tool

The initial data collection stage of the protocol is to document the details of the design and the as-constructed crossing (as-built). The record data compiled at this stage will provide a baseline for comparison of future AOP water crossing measurements. As-built data will be compared to the-field data collected at the AOP crossing in Stage 2. The goal of the comparison is to document changes at the AOP water crossing over time to aid in documenting the effectiveness of the crossing, identifying potential maintenance needs, and documenting best practices at a site for consideration in other design and construction efforts.

This section is intended to be a desktop analysis, but as not all projects may have detailed as-built drawings available, some sites may be limited to design plans and need field visits to completely define the as-built data on the AOP water crossing. The assessor should indicate the source of the baseline data (design based, as-built based, or as-built survey) at each sub-section within the protocol. To complete the initial data record, the assessment team may have to use a combination of sources to collect information.

The following sections provide section by section discussion of the data field included under the Stage 1 As-Built Database Tool stage of the protocol. Each section describes the expected source of information, provides examples of reference measurements (when applicable), and sample photos to define qualitative data collection fields.

Complete the information in the *Preliminary Information* section. Document the name, company and email for the personnel completing the *As-Built Database Tool.*


ArcGIS Survey123

STAGE 1 - INITIAL RECORD DATA COLLECTION

Preliminary Information:

COMPLETED BY:

TITLE/COMPANY:

EMAIL:

DATE:

Thursday, January 4, 2024

Figure 1. Sample Preliminary Info aopMAP

I-A. Design Information

The *Design Information* section provides essential baseline information for the crossing, including the location of the AOP site, age of the installation, and hydrologic and hydraulic data considered in the facility design. Data for “”this section is expected to be found in the AOP water crossing design report. Occasionally, some of the information such as location and design storms may also be found in the design plans, depending on the owner / DOT standards. This protocol does not anticipate that any of the section *I-A. Design Information* can be collected in the field.

I-A1. General Design Information

Information in this section is important for properly defining the location of the AOP water crossing structure and avoid confusion between other nearby structures. Information for the *General Design Information* data field should be available in the design report or in the design/as-built plans. Complete site location data fields for the AOP crossing including *latitude* (Lat.), *longitude* (Long.), the *Route Number* (Route No.) or *Road Name*, and the closest *Mile Post* (MP) number to the nearest 0.1 mile. Latitude and longitude should be expressed in decimal degrees format, if coordinate information, latitude and longitude, are not on the plans they should be located from other sources such as online mapping services.

> For example, a north-western hemisphere site with a latitude of 47 degrees 19 minutes 27.63 second and a longitude of 120 degrees 51 minutes 9.21 seconds would be expressed as lat.: 47.3243 (+ 47 + 19/60 + 27.63/3,600) and long. -120.8526 (-[120 + 51/60 + 9.21/3,600]); where the + latitude references the northern hemisphere and the – longitude references the western hemisphere.

Complete the *Drawing Date* of the AOP water crossing plans. Check the box for *Yes* or *No* to indicate if *As-Built* was available and used to source data. Complete the *Date constructed* to document date AOP water crossing construction was completed. Recording of the month / year is a sufficient level of detail for the completion date of the structure. In the most specific sense, the first day that the stream flows through the structure, via removal of the flow diversion controls, could be considered the completion date; however, it is expected that this level of detail may not be available. If less specific information is known for a structure, a season or just a year of completion may be provided.

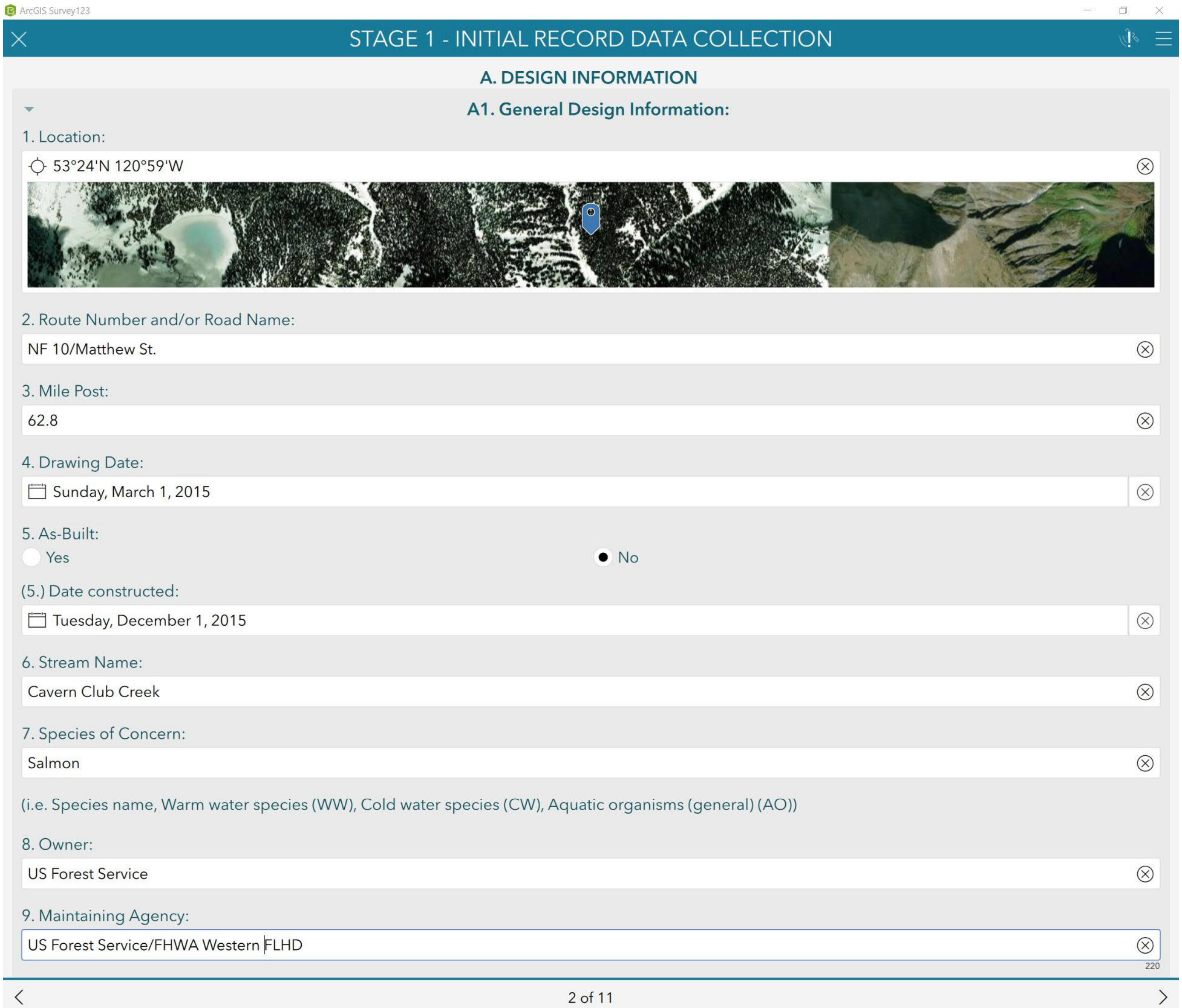
Document the remaining identifying information including the *Stream Name* and S*pecies of Concern*. Stream names are commonly included in design reports and/or design plans. Otherwise, you can find the stream names on USGS Topographic Quadrangle maps, FEMA Flood Insurance Rate maps, Forest Service maps, and several other common sources. If the stream doesn't have a name enter *Unnamed.*

Some AOP structures are designed for a specific species, such as salmonids, while others are intended to generally improved passage for all aquatic organisms native to a system. Use the *Species of Concern* data field to document if an AOP installation was designed to allow passage of a particular species of fish or aquatic organism.

Sample short hand codes provided for this data entry include:

- *WW – Warm Water:* structure designed to consider all warm water aquatic organisms native to the system
- *CW – Cold Water:* AOP structure designed to consider all cold water aquatic organisms native to the system
- *AO – Aquatic Organism:* all other AOP structures

Document the *Owner* of the AOP structure and the *Maintaining Agency*. These may be the same entity, or they may be different. *Figure 2* is a sample of the General Design Information sub-section:


ArcGIS Survey123

STAGE 1 - INITIAL RECORD DATA COLLECTION

A. DESIGN INFORMATION

A1. General Design Information:

1. Location:
53°24'N 120°59'W

2. Route Number and/or Road Name:
NF 10/Matthew St.

3. Mile Post:
62.8

4. Drawing Date:
Sunday, March 1, 2015

5. As-Built:
Yes
No

(5.) Date constructed:
Tuesday, December 1, 2015

6. Stream Name:
Cavern Club Creek

7. Species of Concern:
Salmon

(i.e. Species name, Warm water species (WW), Cold water species (CW), Aquatic organisms (general) (AO))

8. Owner:
US Forest Service

9. Maintaining Agency:
US Forest Service/FHWA Western FLHD

220

2 of 11

Figure 2. Sample General Design Information aopMAP

I-A2. AOP Design Methodology

In this field the user is to check the radial button that best describes the *Methodology* used to design the AOP structure. This information is expected to be found in the design report. The most common methods include *USFS Stream Simulation*, *WDFW Water Crossing Guidelines*, and *FHWA HEC-26*. If a different methodology was used, check *Other* and describe the method.

In addition to the design methodology, document the following design options that were utilized:

Figure 3Culvert embedded (%) is how much a closed bottom culvert invert is buried below the lowest stream bed elevation (thalweg). Some AOP design methodologies require a certain percentage of culvert embeddedness. Document the percentage of the culvert rise that is embedded in the channel. If the embeddedness of the channel varies from the upstream invert to the downstream invert, take the average of the two. If the design does not include an embedded culvert or if the culvert is an open bottom, the percent embedded is 0%.

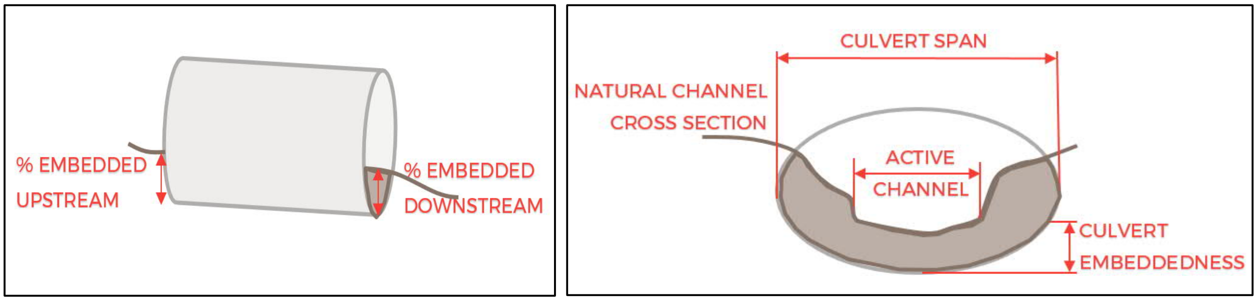


Figure 3: Embeddedness and culvert span to active channel width of the AOP structure

Some design methodologies include a Low *flow channel* in the channel cross section to accommodate baseflow in the channel. Check *yes* or *no* if the AOP design included a low flow channel.

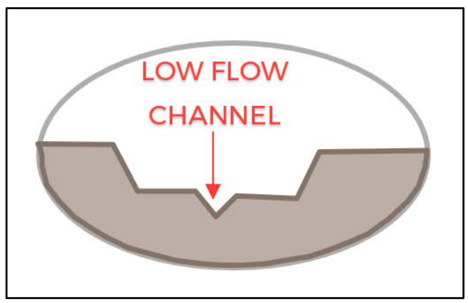


Figure 4: Low flow channel within AOP Structure

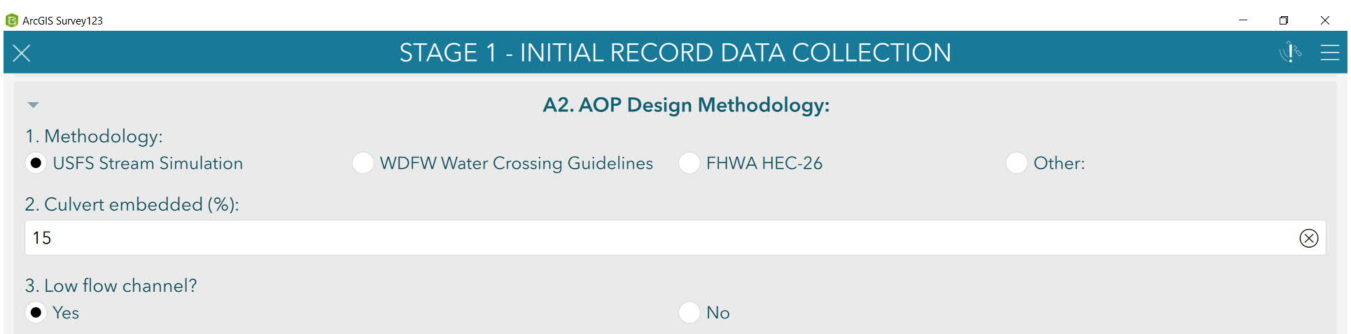


Figure 5. Sample AOP Design Methodology aopMAP

I-A3. Hydrologic Method

Hydrology is the analysis of rainfall-runoff interactions within a watershed to produce flooding flowrates at a point of interest; in this case the AOP water crossing structure. There are various methods for performing a hydrologic analysis that would be evaluated by an engineer or a hydrologist during the design of a stream crossing structure. The user is asked to document this data in the form so that it can be utilized in future comparisons to determine the magnitude of flooding experienced at a culvert site.

Check the radial button under *Method Selection* that best describes which hydrologic method was used to determine the storm flowrates at the AOP water crossing. This information can be found in the design report. Common methods include *stream gauge data, regional or local regression equations*, the USDA *TR-20* Project Formulation Hydrology or *TR-55* Urban Hydrology for Small Watersheds, and the *rational method*. Multiple methods are sometimes used to verify the accuracy of a given method. If a different methodology was used, check *Other* and describe the method.

I-A4. Flowrates

Flowrates are the result of the hydrologic analysis. Stream flowrates are typically found in the design report, they may be referenced as Discharges, Flows, Flowrates, or Q. The data is typically expressed by designers in terms of flood event probability, most commonly as a ___-year flood event. Frequently in the design of AOP structures the 50-year flood event would be considered. In this example, the 50-year flood event is defined as a flood that has a 2-percent chance of occurring in any given year (2% = (1/50-year)). The site designer may have also referred to this data as the Q50, Q_{50}, $Q_{0.02}$, or the 2-percent event; in each case the same flow condition is being referenced. In stream hydrologic studies in the United States the data is generally quantified in units of cubic feet per second or cfs.

The user is asked to enter headwater depths, and flowrates, for the 50-year and 100-year events. Headwater depth is the depth of flow immediately upstream of the culvert for a given storm event. The Headwater depth is measured from the channel bed (or the culvert invert if exposed) at the upstream end of the culvert to the corresponding storm event (e.g. 100-year) water surface elevation.

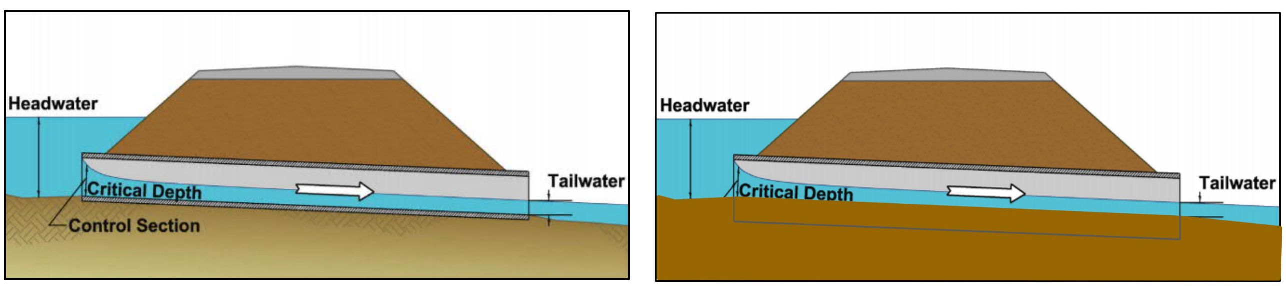


Figure 6: Headwater measurement at a culvert inlet[1] (rt) and at an embedded culvert inlet (lt)

In some cases, flowrate data and headwater depth are shown on profile sheets in design plans. The AOP structure design may not have considered all flow conditions listed in the flowrates section. Document as much information as is available for the given AOP structure. If information is not available leave the data field blank for the unknown flowrates or calculate the missing information.

The *Design Flood Event* is the primary discharge that was considered by the design engineer in the sizing of an AOP facility. The *Design Flood Event* is typically dictated by the local, state, or federal regulations that were utilized in the design of a facility. The *Design Flood Event* may or may not have factored into the ultimate sizing of the AOP crossing but should be documented in the design records.

The *Overtopping discharge* data field is for cataloguing the flow rate for which the headwater rises to the elevation of the road or structure. This data point could be referred to as the incipient overtopping discharge, overtopping discharge, or Q_{OT}

[1] Figure 1.17 from "Hydraulic Design of Culverts", HDS-5 Third Edition, April 2012.

in the records for an AOP facility. The overtopping discharge is not tied to a flood event probability, though one may be stated in the design records.

The user should enter baseflow and low flow discharge information in the *Qbaseflow* and *Qlowflow* data fields. Baseflow discharge represents the everyday / non-storm flow stream conditions within the stream. The low flow discharge represents a minimum flow condition that the designer may have considered in the design of AOP features for the crossing. In many cases the low flow discharge are used in the design process to verify that a minimum flow depth is maintained for AOP. The user should document the low flow condition documented by the designer, if any.

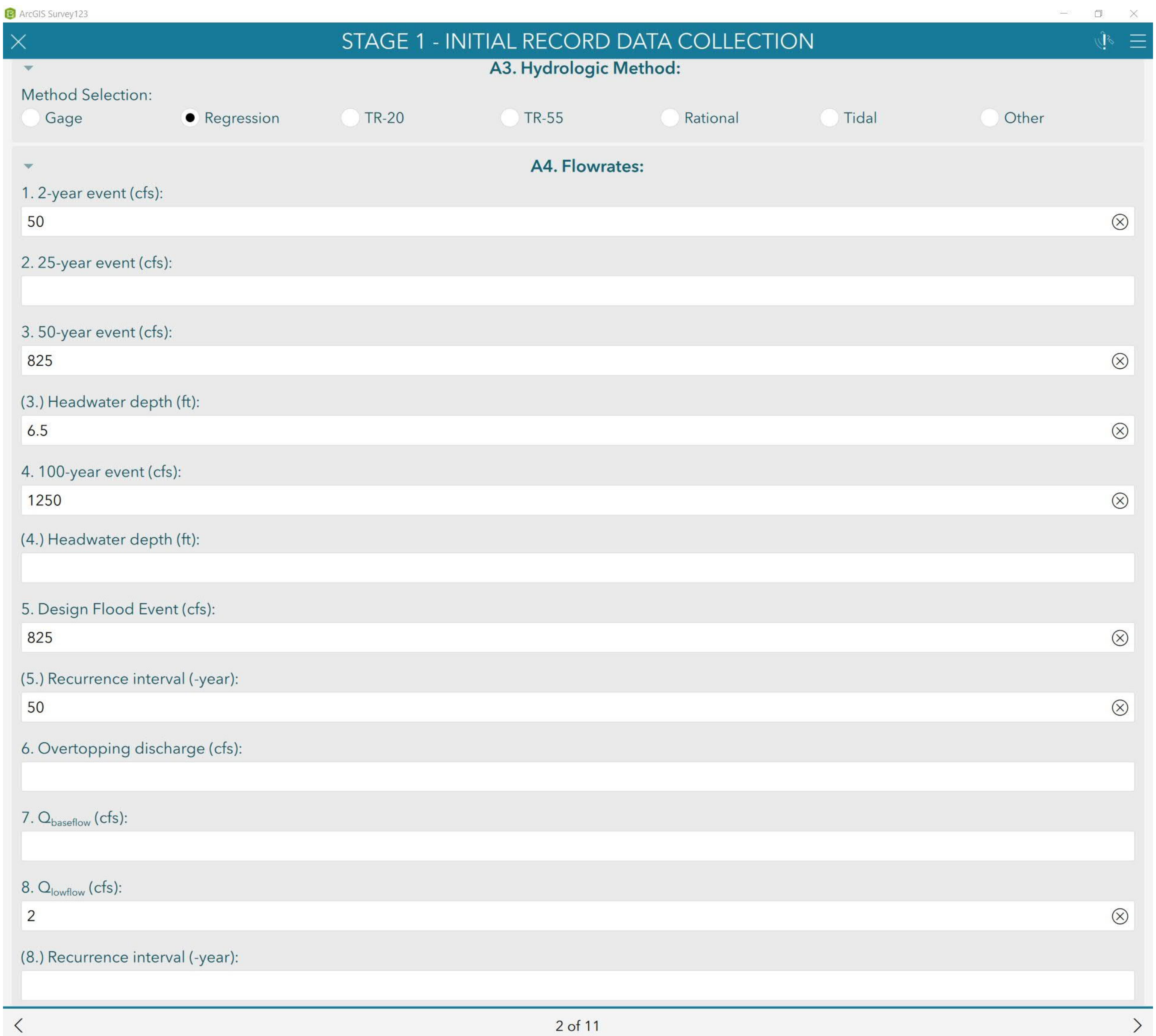


Figure 7. Sample Hydrologic Method and Flowrates aopMAP

I-A5. Hydraulic Basis

Hydraulics is the analysis of how flowrates, discharges or flood flows move in the stream channel. Designers use hydraulic evaluations to determine the depths of flows and velocity (speed) of flows through streams, culverts, and bridges under any flow condition / flow rate. In the design of an AOP structure, a hydraulic study might have been performed to determine forces of storm flows inside the AOP crossing structure or to determine low flow depths and velocities for comparison to a reference condition.

The user is asked to check the radial button that best describes which hydraulics analysis was used to evaluate and design the AOP structure. Common methods of hydraulic analysis include the Army Corps of Engineers' River Analysis System: *HEC-RAS*, the Federal Highway Administration's (FHWA) culvert hydraulics program: *HY-8*, FHWA's SRH-2D hydraulic model, and the Forest Service's fish passage through culverts software: *Fish Xing*. If a different methodology was used, check *Other* and describe the method.

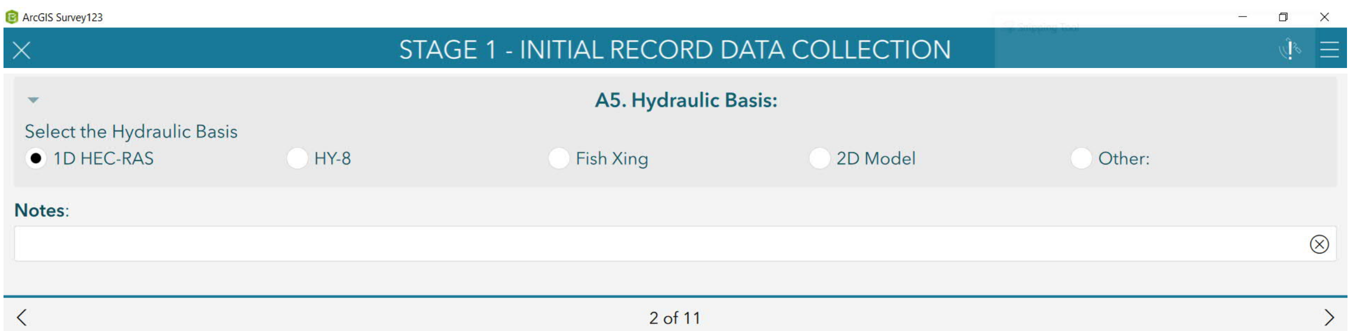


Figure 8. Sample Hydraulic Basis aopMAP

I-B. Structure Information

This section describes the physical characteristics of the AOP structure. Structures are typically culverts but can also be bridges. Structure information can most easily be found in the design or as-built plans but may also be described in the design report.

I-B1. Barrel Shape

Check the radial button that describes the shape of the barrel of the AOP crossing. If the structure is a bridge, select the open bottom option (arch or box) that most closely resembles the shape of the bridge. The user is to select a barrel shape as function of the structural elements of the pipe or bridge only, the influence of bedding material, debris, weirs, baffles or sedimentation is not to be considered as an influencing factor. The user should consider the shape effects of structural modifications such as concrete grouting of a culvert invert that runs the entire length of the pipe. Examples of culvert shapes are shown in *Figure 9*.

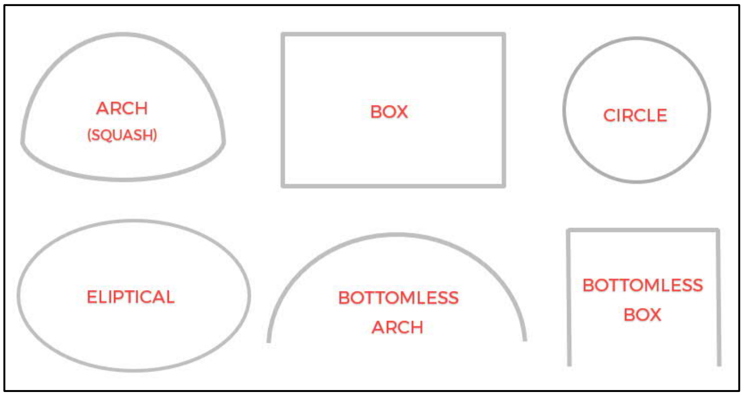


Figure 9. Typical Culvert Shapes

I-B2. Structure Material

Check the radial button that best describes the barrel material. Common abbreviation of pipe materials found on design plans are listed in *Table 1*. Only barrel material should be considered in this selection.

Table 1: Structural Materials and Abbreviations

Aluminum
CAP – Corrugated Aluminum Pipe
ASP – Aluminum Structural Plate

Concrete
RCP – Reinforced Concrete Pipe
PCC – Pre-Cast Concrete

Steel
SSP – Steel Structural Plate
CSP – Corrugated Steel Pipe
CMP – Corrugated Metal Pipe

Smooth Plastic
PVC – Polyvinyl Chloride
HDPE – High Density Polyethylene Pipe

Corrugated Plastic
HDPE – High Density Polyethylene Pipe
CPP – Corrugated High Density Polyethylene Pipe

I-B3. Structure End Treatment

Structure End Treatments are the structural segments at the upstream and downstream ends of the structure. End sections can have sizes, shapes, and characteristics that vary from the interior dimensions of the structure. These variations are commonly observed as flares that widen the openings to provide increased efficiency for flows entering and exiting the structure. End Treatments are not always constructed using the same material as the structure. An example of a commonly used combination includes a steel CMP with concrete headwalls.

Select the appropriate end treatment type for both the inlet and outlet (upstream and downstream) of the AOP structure. *Projecting* ends protrude out of the embankment, *Mitered to slope* ends, also called “sloped”, are angled to match the slope of the embankment, *End Sections* are flared attachments, and *Headwall & wingwalls* are end treatments used to retain roadway embankment and side slopes.

Figure 10: Typical End Treatments[2]: Projecting; Mitered to Slope; End Section; and Headwall/Wingwalls

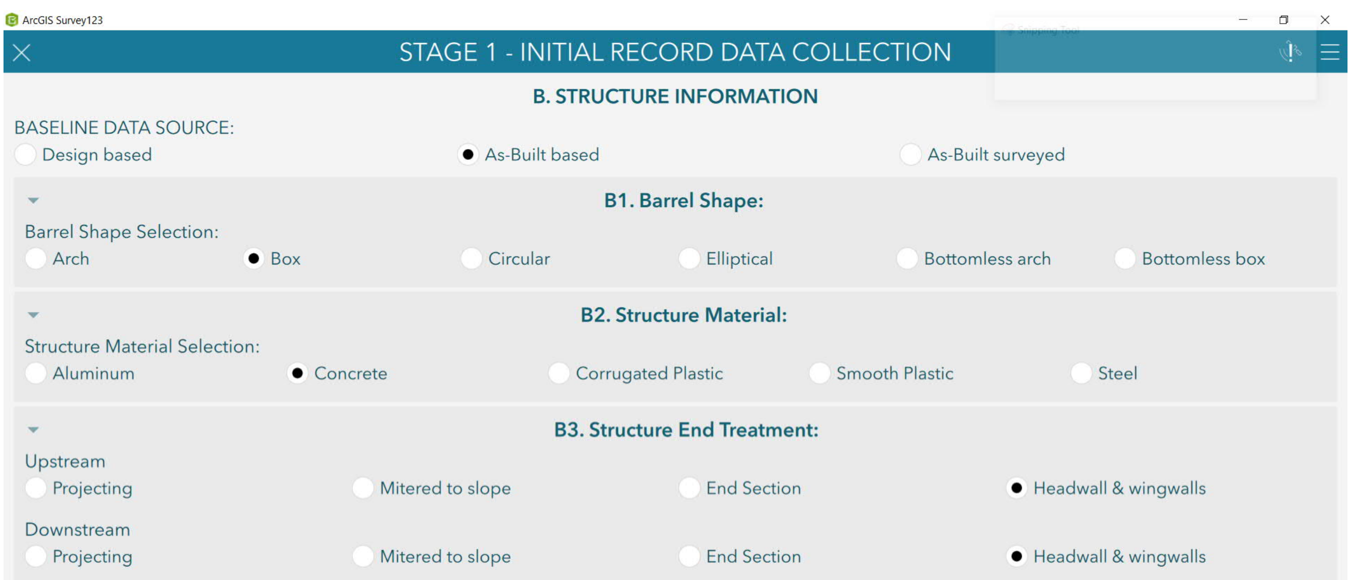


Figure 11. Sample Barrel Shape, Structure Material, and Structure End Treatment aopMAP

I-B4. Structure Dimensions

Document the dimensions and size of the structure. The crown, or low chord, is the highest point on the inside of the structure. The *Rise* is the height of the structure measured from the invert to the crown, or low chord. If a culvert barrel has

[2] Figure 1.8 from "Hydraulic Design of Culverts", HDS-5 Third Edition, April 2012

corrugation, the rise is measured from the inside crest of the corrugations. Please note that this section is concerned with measuring the dimensions of the structure not the interior channel. If the structure is partially buried in the channel, the rise is from the structure invert (not channel invert) to the crown. The exception is bottomless culverts or bridges. In these cases, the invert of the structure is the same as the channel invert and document the average of the inlet and outlet rises. The *span* is the width of the structure measured from inside wall to inside wall. If the structure width varies, as in an arch or elliptical structure, the measurement should be taken at the widest point. The *length* of the structure is measured from the upstream invert to the downstream invert. If the structure is bottomless, the length measurement can be taken from the upstream crown to the downstream crown. The *slope* of the structure is measured from the upstream pipe invert to the downstream pipe invert. For bottomless structures, the slope is measured from the upstream to the downstream crown or low chord of the bridge.

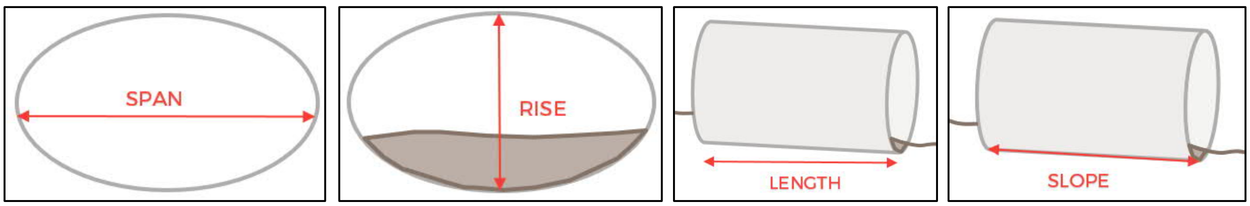


Figure 12: AOP Structural Dimensions

I-B5. Structure Foundation

The *Structure Foundation* is defined as the continuous / solid load bearing component that supports the culvert or bridge. It is important for the user and field assessment team to understand foundation dimensions to more easily identify threats to the stability of the structure due to channel bed evolution, or scour hole development..

Check *yes* or *no* if the AOP structure has an open bottom. Check *yes* or *no* if the AOP structure has includes a foundation. If a foundation is present, document the type and material in the *Notes*. Typical types and materials include cast-in-place concrete, pre-cast concrete, structural metal plate (steel or aluminum), brick and mortar, and stone and mortar. Document the foundation thickness. The foundation is measured from the top of the footer to the bottom of the foundation. Document the depth to footer measuring from the crown of the pipe to the top of the footer at both the inlet and the outlet.

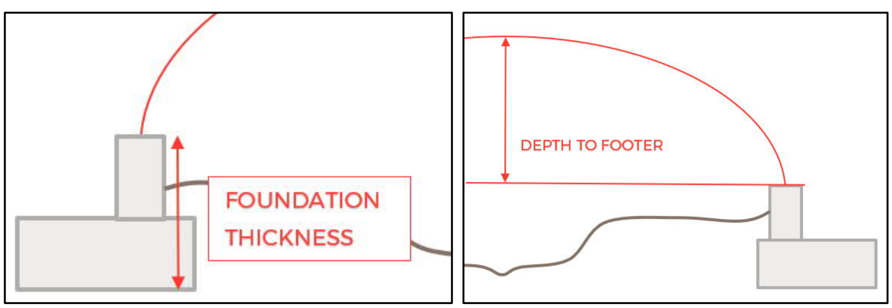


Figure 13: Foundation Dimensions

The user should also document the presence of shallow bedrock at the site and whether the footers are set on / set into the bedrock. The depth to bedrock can vary greatly at a site. Document the depth to the bedrock measured from the crown of the structure to the top of the bedrock at the inlet and the outlet to capture the general bedrock depth. Bedrock will not always be perfectly flat. Take the depth to bedrock to a representative bedrock elevation. If bedrock is not present at a location, leave blank.

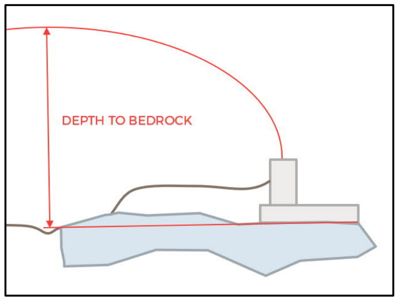


Figure 14: Bedrock Dimensions

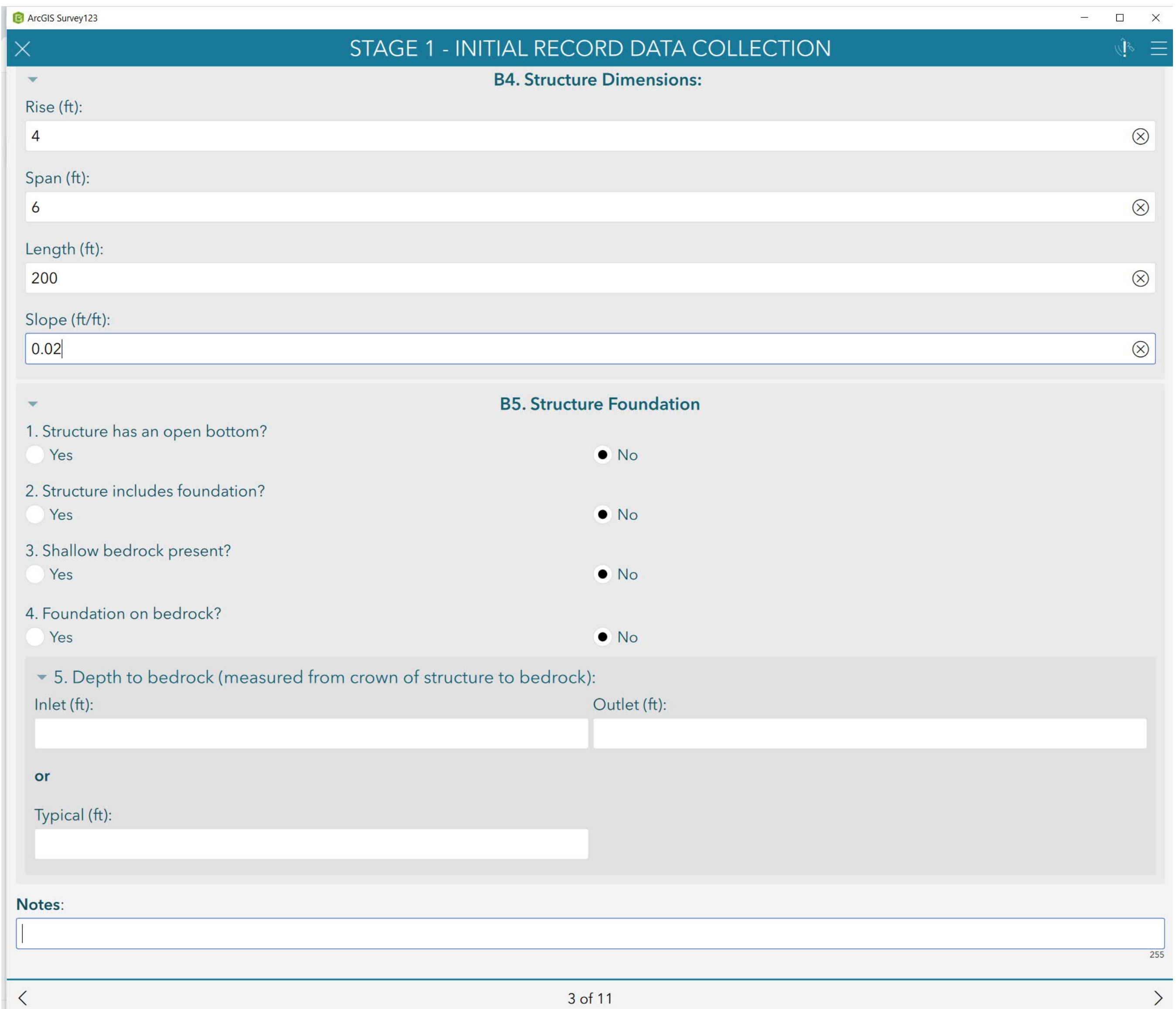


Figure 15. Sample Structure Dimensions and Structure Foundation aopMAP

I-C. Interior Structure Information

The intent of this section is to describe engineered structural components inside the structure. Structure information can most easily be found in the design or as-built plans but may also be described in the design report. Check the *Data Source* used to find the following information.

I-C1. Scour Countermeasures

Scour is the localized erosion of channel bed material caused by fast moving water and tends to occur at the structure inlet and outlet. Scour countermeasures are placed to prevent, delay, or reduce the severity of scouring. Check *yes* or *no* if scour countermeasures are present at the AOP structure. Common scour countermeasures include loose or grouted riprap, gabion mattresses, baffles, retention sills, and concrete or rock aprons.   If a countermeasure is present, document the *width* of the scour countermeasure, which is measured perpendicular to the stream flow and the *thickness* or height of the countermeasure in the *Notes*. document the gradation, or size distribution, of scour countermeasures, as applicable, in the *Notes*. This information is typically found on design plan detail(s) for countermeasure(s).

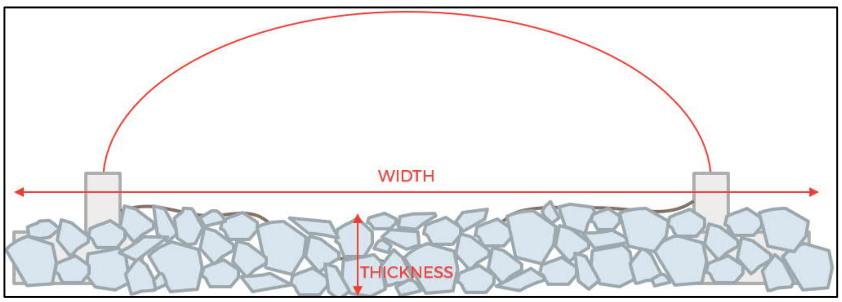


Figure 16: Scour Countermeasures Dimensions

Often, scour countermeasures include a filter to prevent excessive migration of the base soil particles through the voids in the riprap. The two basic types of filters are granular filters and geotextile filters. Document the presence and type of filter material in the *Notes.*

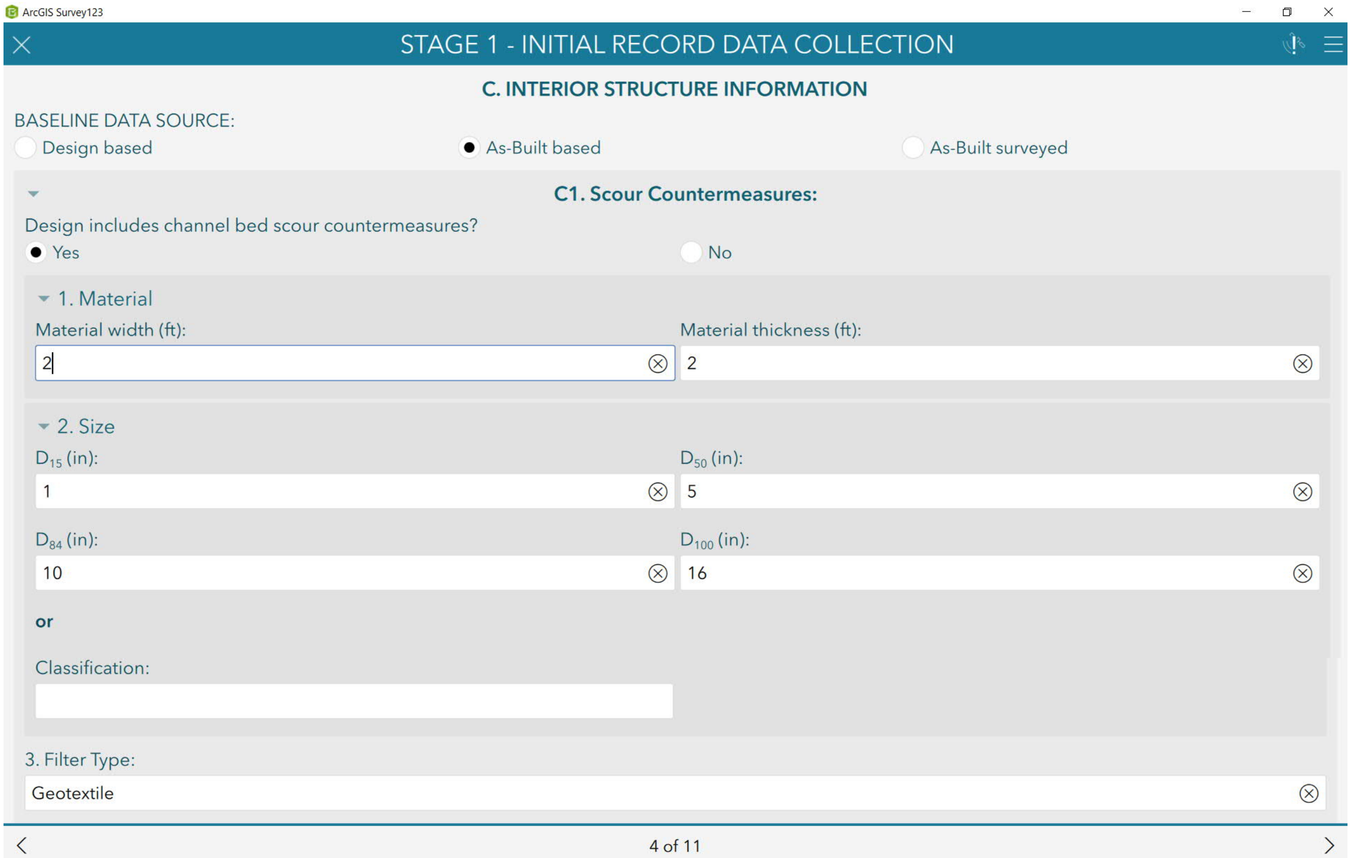


Figure 17. Sample Scour Countermeasures aopMAP

I-C2. Interior Banks

An interior bank is a constructed stream bank located within the AOP structure to mimic the channel cross-section of the reference reach.

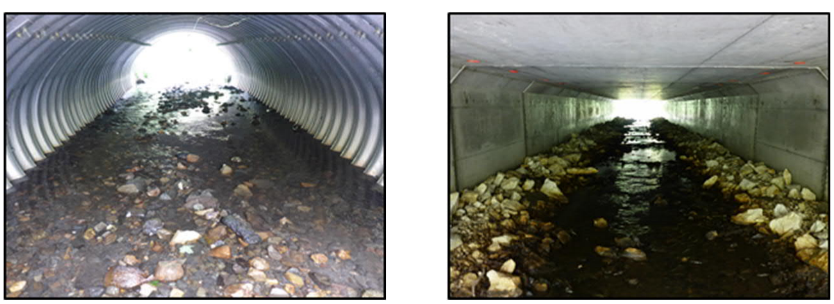


Figure 18: AOP structure without interior banks at Cabot Mack Mnt Rd (left); AOP Structure with interior banks at STP SCRP 8 (right)

Looking downstream, document the width and height of each channel bank. The *width* is measured from the wall of the structure to the inflection point of channel bank and channel side slope. The *height* is measured from the channel thalweg bottom to the channel bank top, the thalweg being the lowest point along the streambed. Document the size gradation of the bank material.

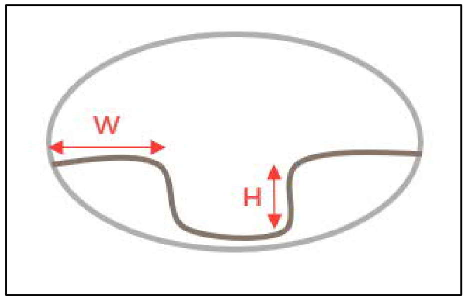


Figure 19: Interior Banks Dimensions

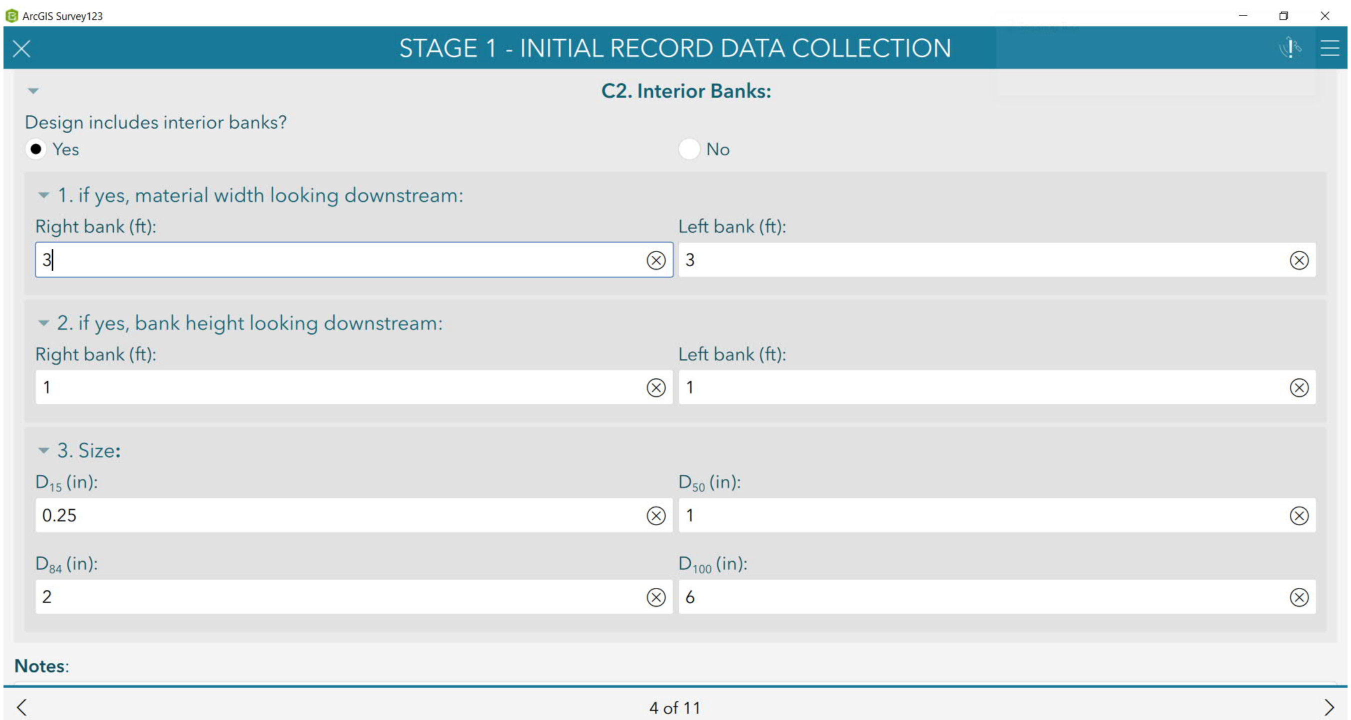


Figure 20. Sample Interior Banks aopMAP

I-D. Channel Information (Upstream and Downstream)

This section provides guidance on compiling relevant geomorphic data for channel, upstream and downstream of AOP crossing. Ideally, the protocol user will be able to find this information from a geomorphic design report for the AOP structure. However, if insufficient detail is otherwise available this data could be collected during the initial field investigation. Check all the *Data Sources* used to find the following information.

I-D1. Channel Slope

Channel slope is obtained from the design report or design profile sheets. If channel slope is not available, preliminary estimates for channel slope can be determined by obtaining topographic data for the AOP site (LiDAR or previous topographic survey data) and creating a profile from a channel centerline. Channel slope can be calculated at various locations by assessing the change in channel elevation compared to distance along the profile. Improved channel slope estimates can be calculated when, or if, an updated survey is performed at the AOP site during a Stage 2 assessment.

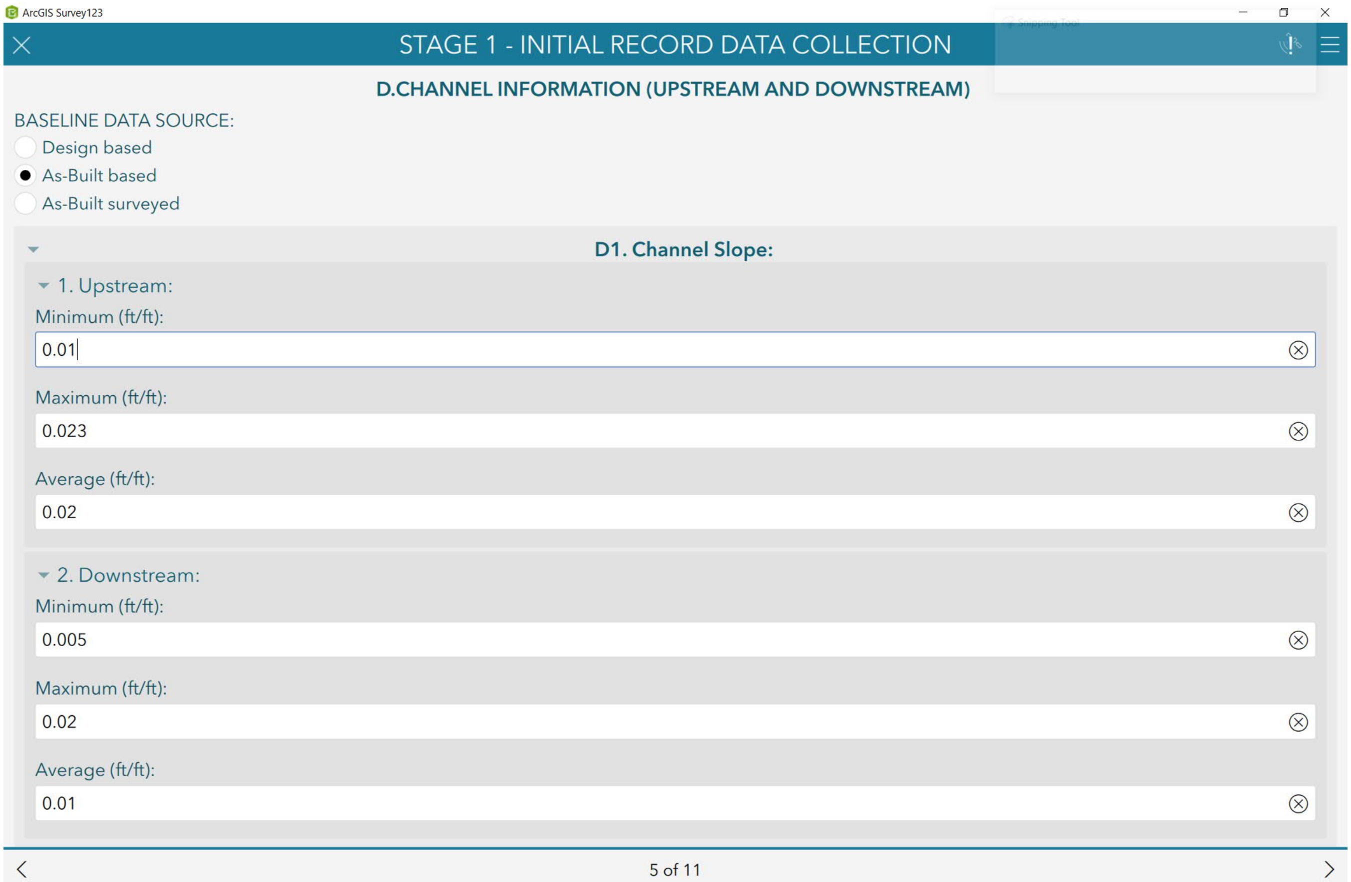


Figure 21. Sample Channel Slope aopMAP

I-D2. Grade Control Type

Grade control features are elements that control the elevation of the channel. Examples of grade control features include log or rock sills, boulder lag deposits, bedrock, utility crossings, lakes, culverts, weirs, and dams *Figure 22*.

Figure 22: Log-sill in Indian Creek, WA (left); Boulder Lag Deposit in Skykomish River, WA (right)

I-D3. Long-Term Degradation Potential

Long-term degradation is defined as the potential general loss of stream bed material at the AOP site during the functional life of the structure. Degradation commonly occurs due to headcut or knickpoint migration through a stream reach that results in an overall deepening, or lowering of bed elevation. The user should differentiate long-term degradation from bed scouring, which is a localized loss of bed material in the form of a scour hole within a limited reach of stream. Bed scouring can result in deep pools but does not generally result in an overall deepening of the channel.

At the As-Built Database Tool stage, long-term degradation potential may be assessed by analysis of stream profile data collected during the project design. A downstream reach with flatter slope and finer material usually indicates a potential for the stream to aggrade, while a steeper and coarser downstream reach usually point to degradation potential (*Figure 23*). Abrupt drops in ground elevation in topographic data are indicative of knickpoints or headcuts. More detailed methods on evaluating the potential for channel degradation are provided by Lagasse et al. (2012)[3]. Field indicators that knickpoint/headcut migration and/or potential degradation have been accounted for in design of AOP crossings include, when the foundation elevation (typically found in as-built drawings) is below the expected depth of total scour, or when a competent grade control structure is present downstream of the crossing.

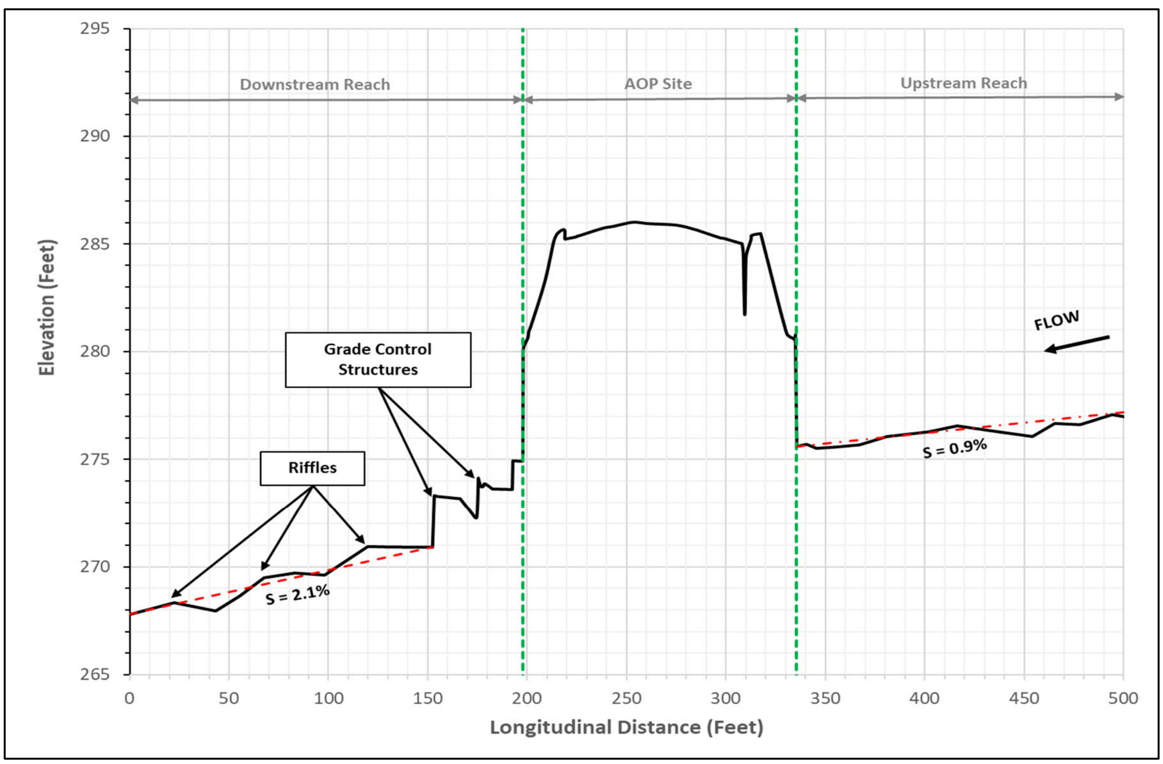


Figure 23: Typical Profile of a Degrading Reach Downstream of an AOP site

---

[3] Lagasse, P.F., Zevenbergen, L.W., Spitz, W.J., and Arneson, L.A. (2012). *Stream stability at highway structures*. Federal Highway Administration Publication No. FHWA-HIF-12-004; Hydraulic Engineering Circular (HEC) 20. United States. Office of Bridge Technology, Washington D.C..

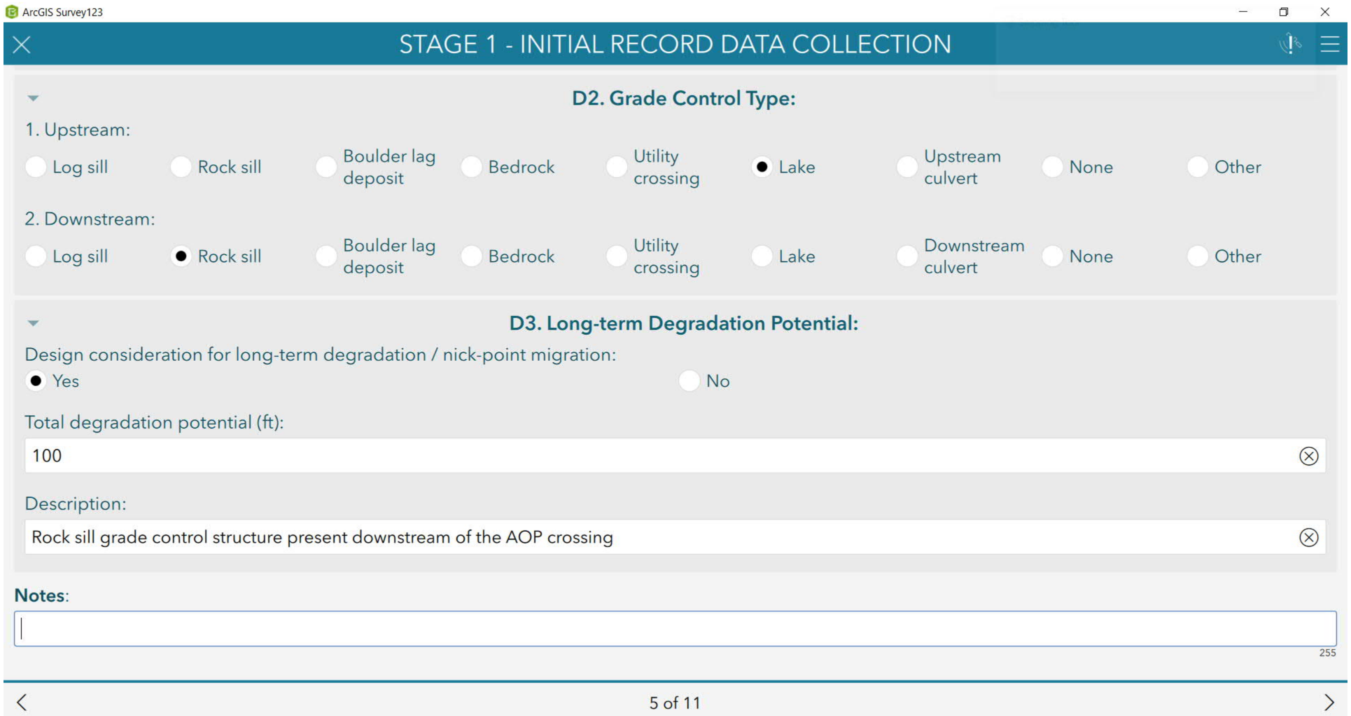


Figure 24. Sample Grade Control Type and Long-Term Degradation Potential aopMAP

I-E. Reference Reach

The reference reach is a segment of channel identified by the AOP designer that is either on the same channel or a similar nearby channel that can be used as a template to aid in designing channel characteristics (e.g., slope, width, shape, particle size gradation) for an AOP project. Collection of reference reach data is not a component of all AOP design methodologies and may not have been performed under certain conditions. The user should anticipate that the AOP structure design team collected and documented comprehensive data on the reference reach in the project design report for USFS Stream Simulation and WDFW Water Crossing Guidelines methodology designs.

I-E1. Was a Reference Reach utilized?

Check *yes* or *no* if a *Reference Reach* was utilized in the design. If a reference reach was not utilized, move on to section *I-F. Interior Channel*, otherwise complete the rest of the section.

I-E2. Reach Location

If a reference reach was utilized as part of the design methodology for an AOP crossing, the user is to document the location of the reference reach relative to the project site. When documenting the location for reference reaches on the same stream as the AOP structure, the user can indicate distance upstream or downstream of the AOP crossing; latitude / longitude, or a geographic marker to allow future assessment teams to find the reference reach location.

Use available data, such as aerial maps or nearby projects, to identify a reach that could be appropriate as a reference reach. The reference reach should ideally be an undisturbed reach that is relatively close to the AOP site. Its characteristics (e.g. drainage area, precipitation, channel slope, etc.) should be similar to those desired at the AOP site.

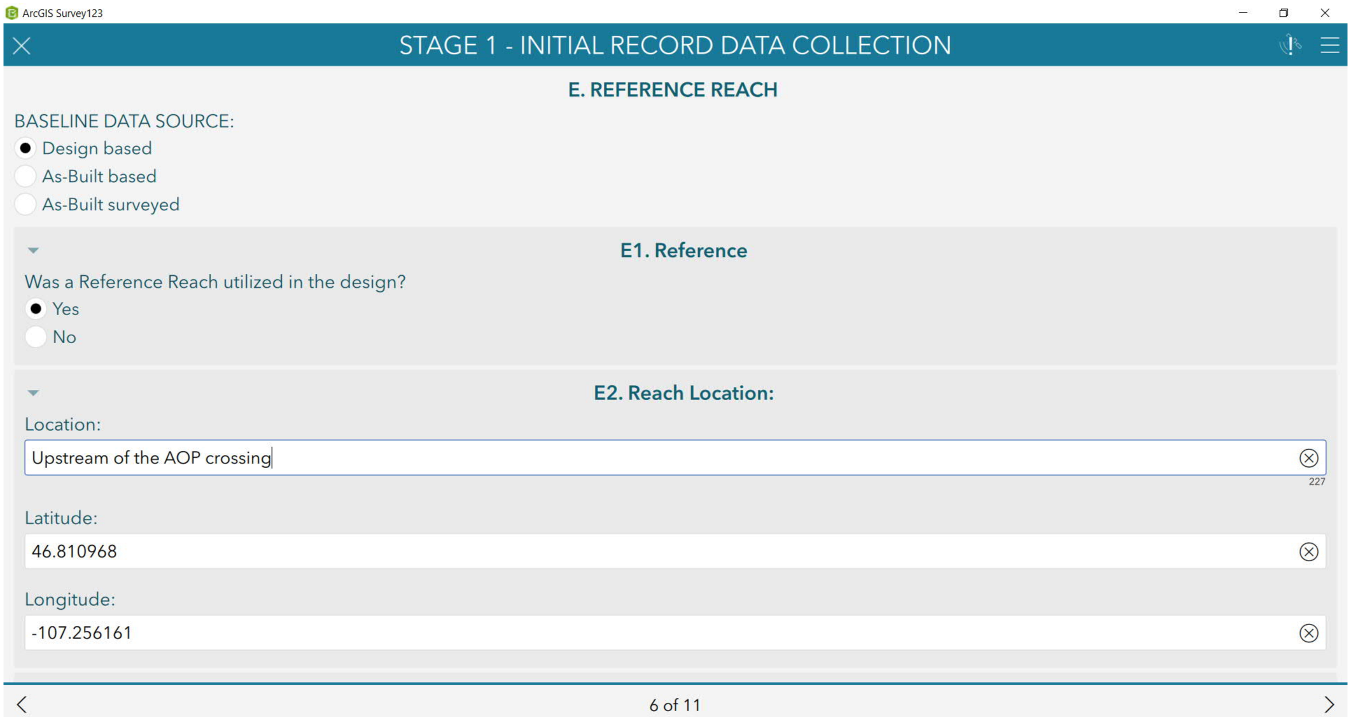


Figure 25. Sample Reference and Reach Location aopMAP

I-E3. Geomorphic Channel Type

This involves assessment of the expected type of channel bed configuration based on the Montgomery and Buffington (1993)[4] stream classification, which includes dune-riffle, riffle-pool, plane-bed, step-pool, cascade and wetland types. At the initial data record stage, the anticipated channel type can be evaluated from the channel slope, bankfull width and depth at the reference reach (sections *I-D1. Channel Slope* and *I-E6. Active Channel Dimensions*) utilizing *Figure 23* of Buffington and Montgomery (2013)[5]. If images of the channel reference reach are available, a visual comparison with the conceptual schematics and typical images of Montgomery and Buffington (1993) may also help determine its type.

4 Montgomery, D.R. and J.M. Buffington (1993). Channel Classification, Prediction of Channel Response and Assessment of Channel Condition. Washington State Department of Natural Resources Report TFW-SH10-93-002.

5 Buffington, J.M., and D.R. Montgomery (2013). Geomorphic Classification of Rivers. In: Schroder, J. (Editor-in-Chief), Wohl, E. (Ed.), Treatise on Geomorphology. Academic Press, San Diego, CA, vol 9, Fluvial Geomorphology, 730-767.

I-E4. Entrenchment

Entrenchment is a stream geomorphic ratio used by geomorphologists to differentiate between streams that have confined / entrenched floodplains and unconfined systems. The degree of channel entrenchment can influence culvert span design.

Entrenchment is a ratio of the width of the floodplain, typically the 100-year top width, to the width of the active channel. Following the Rosgen classification system, an entrenchment ratio of 1.0 to 1.4 indicates an entrenched stream, a ratio greater than 2.2 indicates an unconfined / not entrenched stream, and 1.4 to 2.2 indicates a moderately entrenched stream. If 100-year and active channel top widths are not readily available, topographic data can be utilized to estimate this ratio qualitatively. The protocol user should expect a good reference reach to have a degree of entrenchment equal to the culvert site.

I-E5. Average Channel Slope

The protocol user should document the reference reach average channel slope as the average slope connecting grade control points on the reference reach profile. The user will be able to most effectively determine the average slope from the geomorphic design report reference reach summary or from measurements off the geomorphic longitudinal profile.

If the user does not have available geomorphic survey data, preliminary estimates for channel slope can be determined by first obtaining topographic data for the AOP site (LiDAR or previous topographic survey data) and creating a profile from a channel centerline. The average channel slope can then be calculated through the reach by assessing the change in channel elevation compared to distance along the profile. Improved channel slope estimates can be calculated by performing an as-built geomorphic survey.

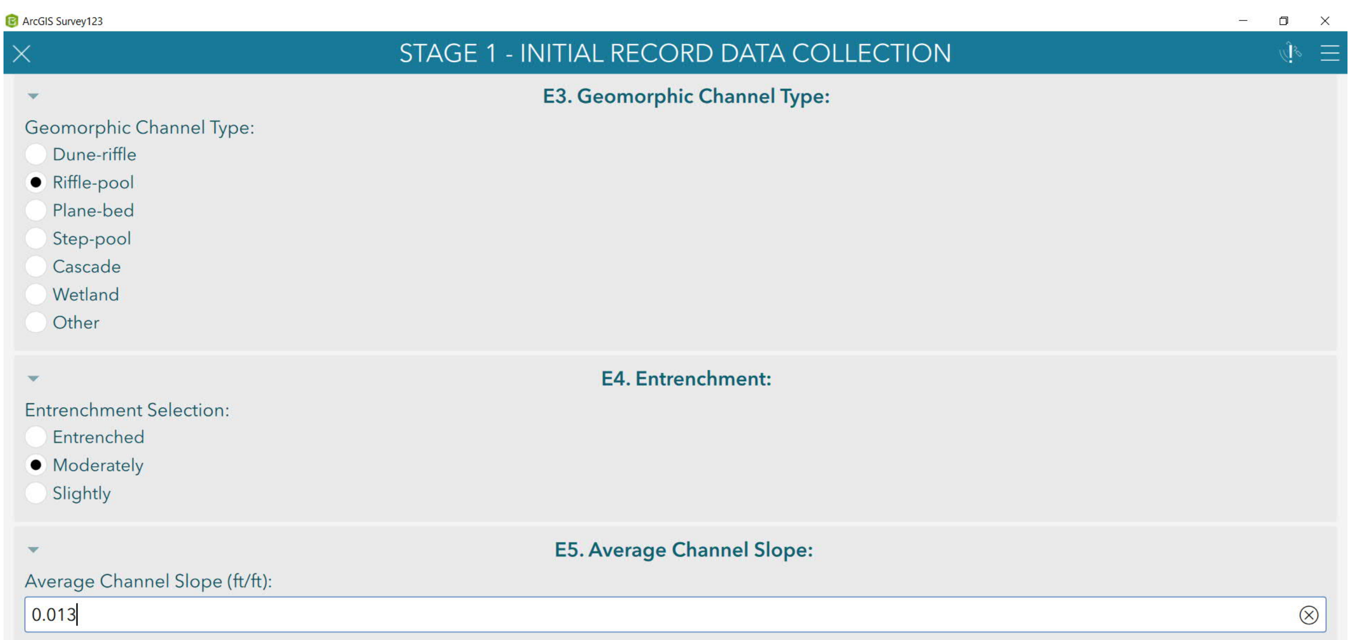


Figure 26. Sample Geomorphic Channel Type, Entrenchment and Average Channel Slope aopMAP.

I-E6. Active Channel Dimensions

The active channel width and depth at the reference reach may be evaluated by cross-sections extracted from pre-existing topographic data, such as LiDAR and/or previous surveys or may be included in the basis of design report. The average active flow depth may be estimated by applying the trapezoidal rule of integration on the extracted cross-section using the water surface elevation which corresponds to the estimated active channel width.

I-E7. Riffle Sizing and Spacing

When the reference reach exhibits a pool-riffle or dune-riffle morphology, the spacing between successive riffles may be determined from a longitudinal profile extracted from pre-existing topographic data with finer spatial resolution than the riffle spacing (Figure 23). The riffle spacing corresponds to the distance between successive peaks in the ground profile. The riffle length (along the stream profile) may be determined from the profile if there is grain size information which would be indicative of a riffle. If pebble counts have been previously conducted at the riffle location, the characteristic grain sizes (e.g., D_{50}, D_{16}, D_{84} and D_{100}) at the riffle may be used to estimate the riffle length. It is recommended to verify these estimates during Stage 2 of the AOP site monitoring.

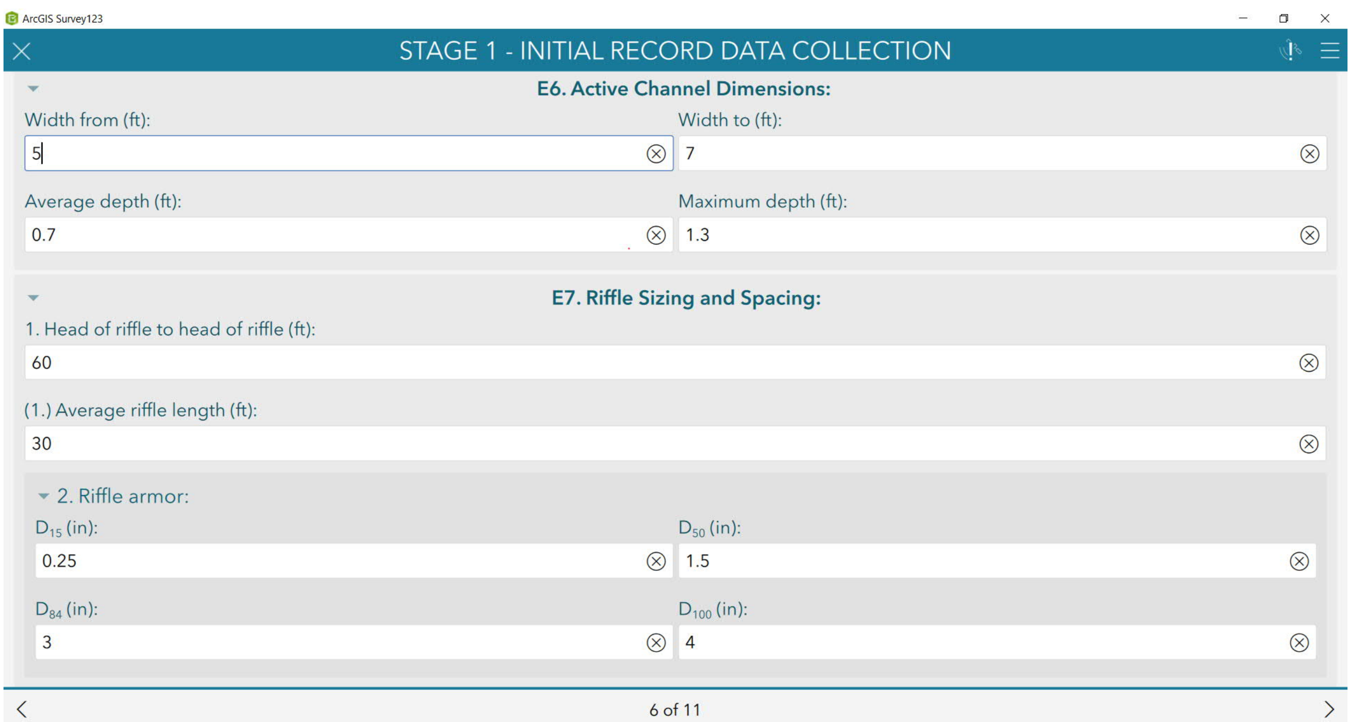


Figure 27. Sample Active Channel Dimensions and Riffle Sizing and Spacing aopMAP.

I-E8. Depositional Characteristics

Information on the amount and characteristic grain sizes (e.g., D_{50}, D_{16}, D_{84} and D_{100}) of bedload may be available from previously collected pebble counts at the site. When a USGS gage (or other available gages that may be privately or publicly owned) is near the AOP site, depositional information may also be found in the gage field data set.

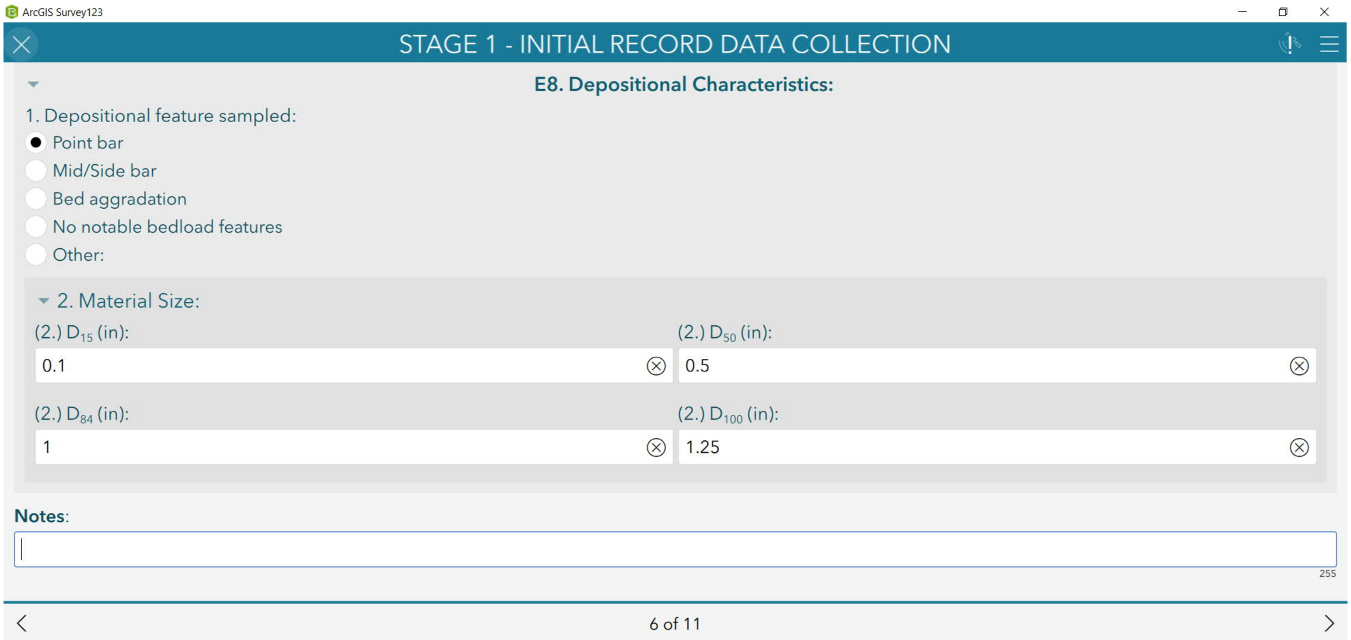


Figure 28. Sample Depositional Characteristics aopMAP

I-F. Interior Channel

The intent of this section is to describe the characteristics of the channel located inside of the AOP structure. Channel information can be found in the design or as-built plans and described in the design report. Check all the *Data Sources* used to find the following information.

I-F1. Channel Geomorphic Type

Check the radial button that best describes the *geomorphic channel type* of the channel interior to the structure. Follow the methodology described in section *I-E3. Geomorphic Channel Type.*

I-F2. Average Channel Slope

Document the slope of the channel interior to the structure. The *slope* should be taken from the upstream channel flowline to the downstream channel flowline. For bottomless culverts, this should be the same as the structure slope documented in I-B4. *Structure Dimensions.*

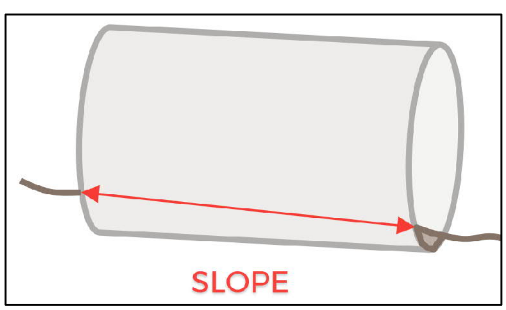


Figure 29: AOP Interior Channel Slope

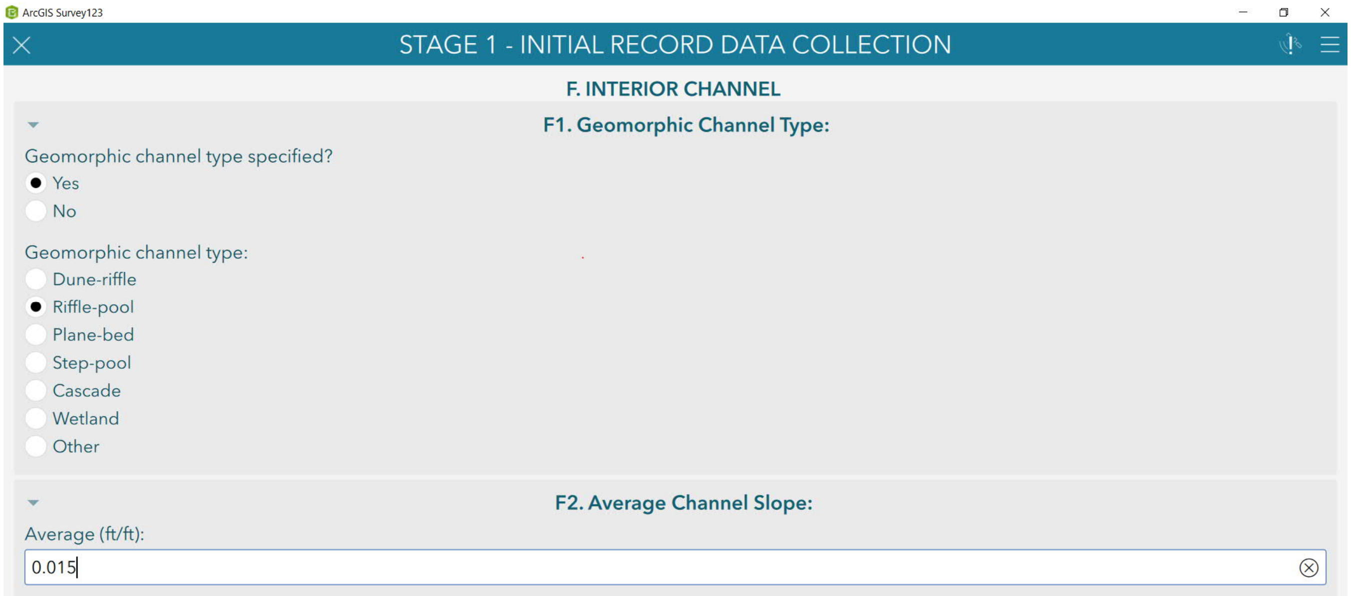


Figure 30. Sample Geomorphic Channel Type and Average Channel Slope aopMAP

I-F3. Constructed Bed Material Depth

The streambed material in the AOP structure is expected to be sized. Some designs have only one layer of completely mixed streambed materials. In some designs two layers are engineered, the top layer provides the mobile bedload and the bottom layer provides the immobile bedload. Document the constructed streambed depth and material gradation. This information is expected to be found on the plans or as-built details. Also note if there is an engineered base layer and document its depth and material gradation. The total depth should be the top layer depth plus the base layer depth.

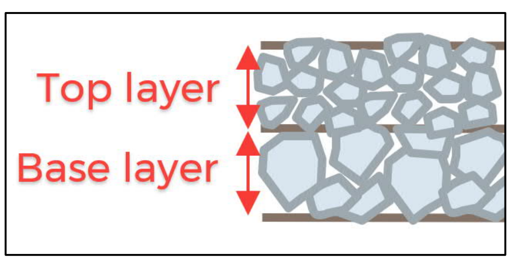


Figure 31: Streambed Material Dimensions

Document if any of the bed material is placed on bedrock.

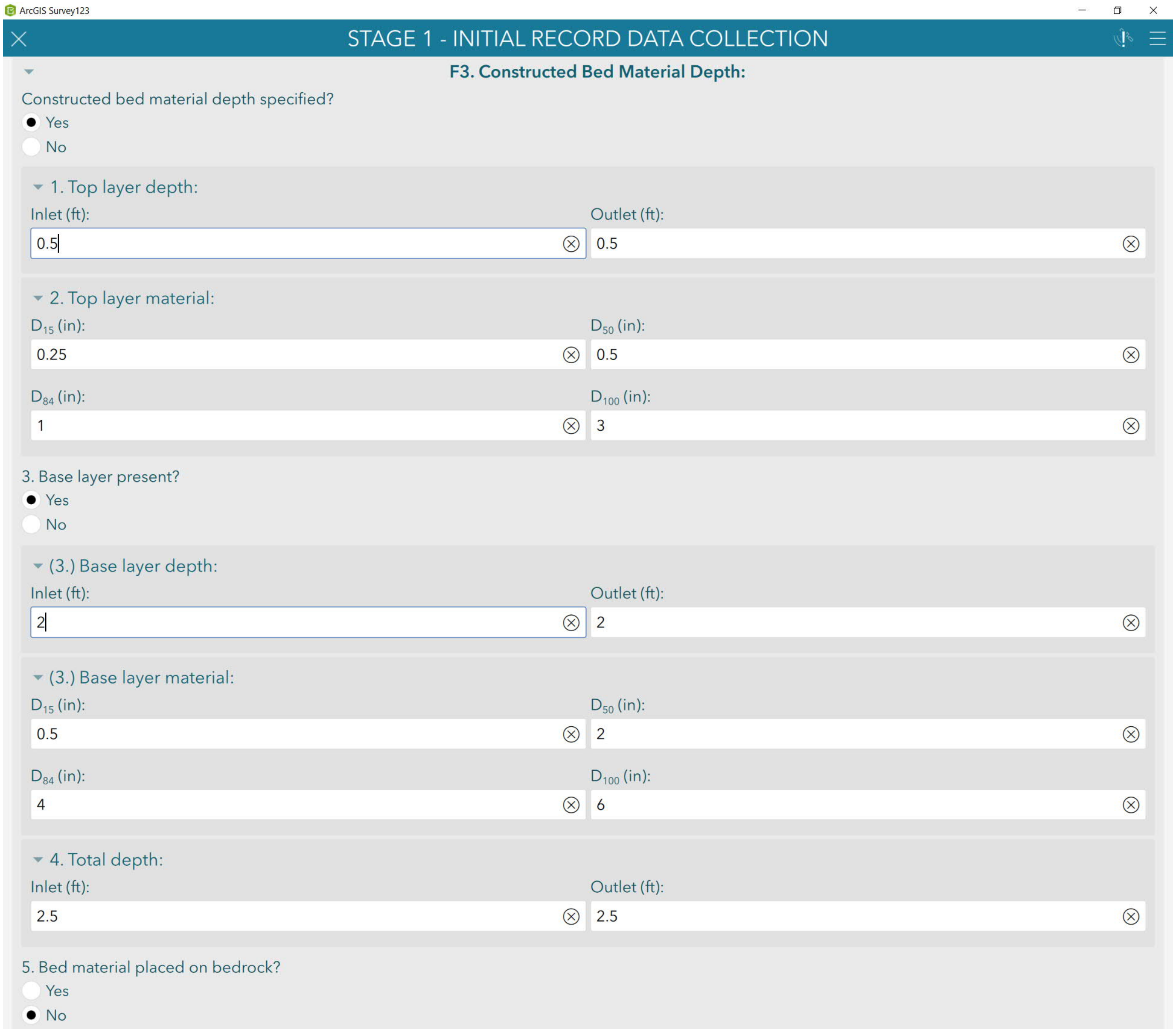


Figure 32. Sample Constructed Bed Material Depth aopMAP

I-F4. Riffle Sizing and Spacing

Document the *riffle size* measured from head of riffle to head of riffle and *riffle length* of the channel interior to the structure. Follow the methodology described in section *I-E7. Riffle Sizing and Spacing*.

I-F5. Channel Large Roughness Features

Channel Large Roughness Features are structures such as large boulders, concrete baffles, etc. that protrude significantly above the channel bed in a manner that obstructs and alters flow paths. An assessor would be able to view these structures as causing alterations in flow path, turbulent eddies, and stagnation zones. A designer may have included these features in

AOP structures to increase bed stability, maintain low flow channels, provide resting areas for aquatic organisms, and increase hydraulic diversity.

Typical ways of creating roughness include baffles, which are series of mounts on the floor of the structure, typically made of wood, plastic, concrete, or metal. Boulder clusters are another method used to create roughness. Check *yes* or *no* if *large roughness features* are present inside the structure. If large roughness elements are present in the structure, check the button that best describes their location in the structure. Examples of large roughness features are shown in *Figure 33*. Document the typical diameter of the features. For baffles this is equal to the length of an individual baffle, for boulder clusters this is equal to the diameter of the boulders. Document the number of elements present throughout the length of the AOP structure.

Figure 33: Random boulders at Porcupine Creek, WI (left); Baffles on channel margin[6] (center); Baffles in pattern[7] (right)

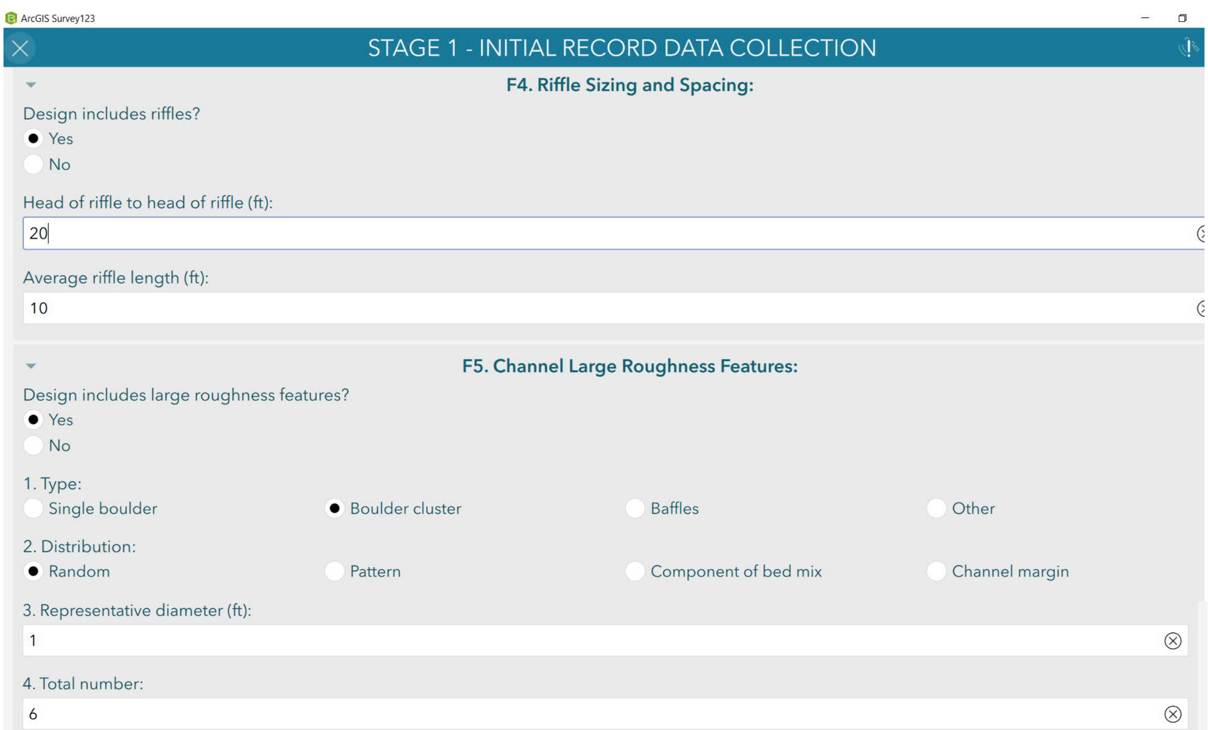


Figure 34. Sample Riffle Sizing and Spacing and Channel Large Roughness Features aopMAP

[6] Figure 5.7 from "Hydraulic Design of Culverts", HDS-5 Third Edition, April 2012

[7] Figure 5.6 from "Hydraulic Design of Culverts", HDS-5 Third Edition, April 2012

I-F6. Bed Stability Features

Sills and weirs are typically single baffles that extend across the width of the structure or channel but do not extend above the surface of the streambed, i.e. they are flush with the channel bed not protruding above as shown in *I-F5. Channel Large Roughness Features*. Sills and weirs are typically made from riprap or boulders; baffles are typically made from steel, concrete, or wood. Check *yes* or *no* if there are *bed stability structures* located inside or immediately upstream or downstream of the AOP structure. If stability features are present, document their location and check all the boxes that apply: *upstream*; *downstream*; and *inside*. Document the number of stability features located inside the AOP structure. Document the *structure material*: rock, steel, concrete, and logs are examples of typical stability feature materials.

Figure 35: Rock sill at Middle Vinegar Creek

Document the typical dimensions of the stability structure. The *thickness* is the depth of the feature, the *width* is the upstream to downstream dimension, the *extent* is the dimension perpendicular to the flow, and the *spacing* is the distance between structures measured from upstream side to upstream side. When features have non-uniform sides, such as with boulders or logs, measures should be taken from the effective face of the feature. If there is only one structure the spacing is n/a. For rock features, document the particle size gradation.

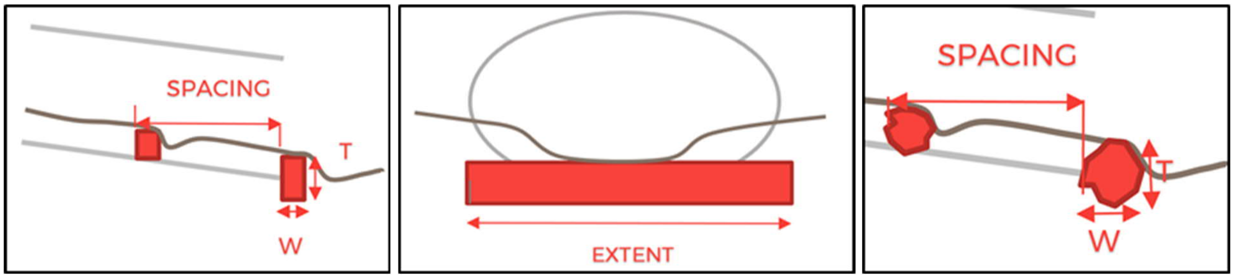


Figure 36: Bed Stability Feature Dimensions

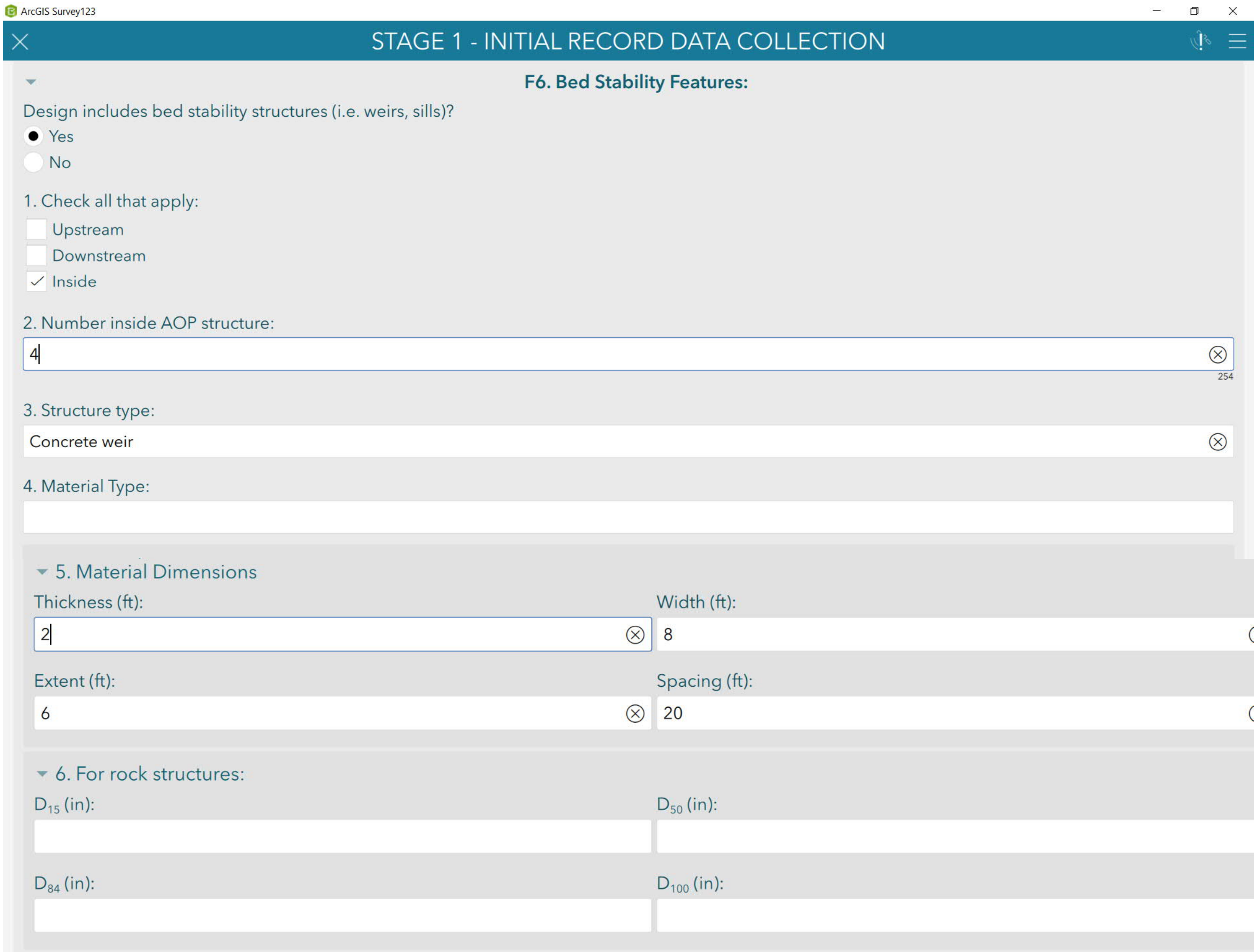


Figure 37. Sample Bed Stability Features aopMAP

I-F7. Subsurface Grade Control Structures

Subsurface grade control structures are similar to bed stability features but instead of finishing flush with the channel bed they are buried. The intent of the subsurface grade control is to hold the bed material in place. Data inputs for subsurface grade control structures are the same as inputs for bed stability features. Follow the methodology described in section *I-F6. Bed Stability Features*.

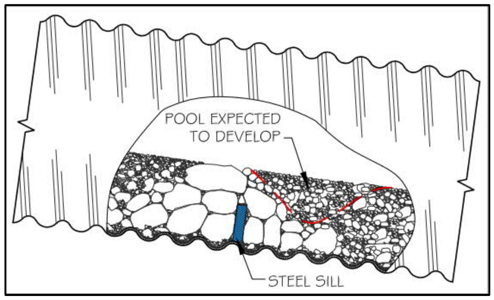
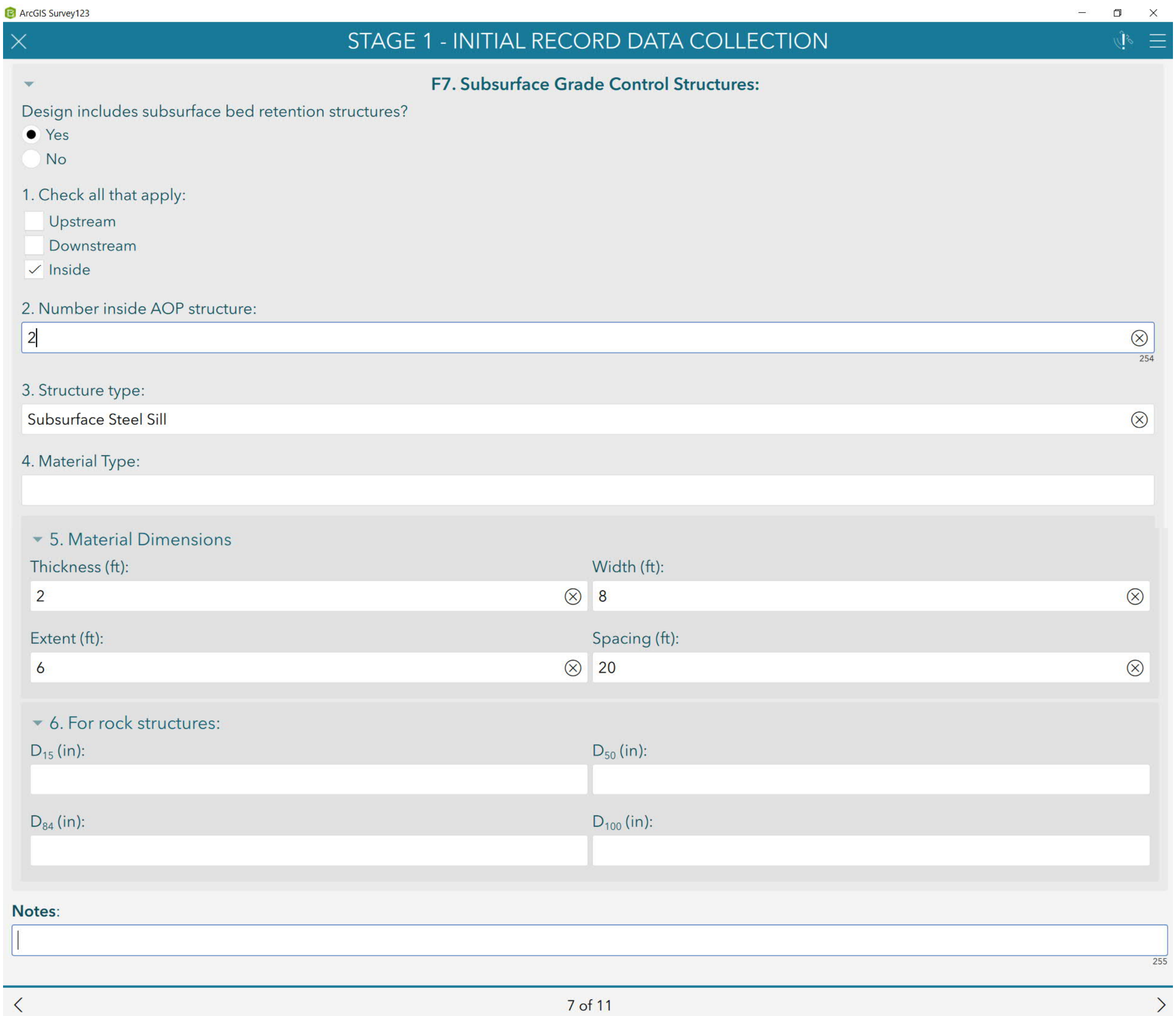


Figure 38: Subsurface Structures: Subsurface steel sill.



ArcGIS Survey123

STAGE 1 - INITIAL RECORD DATA COLLECTION

F7. Subsurface Grade Control Structures:

Design includes subsurface bed retention structures?

- (●) Yes
- ( ) No

1. Check all that apply:

- [ ] Upstream
- [ ] Downstream
- [x] Inside

2. Number inside AOP structure:

2

254

3. Structure type:

Subsurface Steel Sill

4. Material Type:

5. Material Dimensions

Thickness (ft):	Width (ft):
2	8
Extent (ft):	**Spacing (ft):**
6	20

6. For rock structures:

D_{15} (in):	D_{50} (in):
D_{84} (in):	D_{100} (in):

Notes:

255

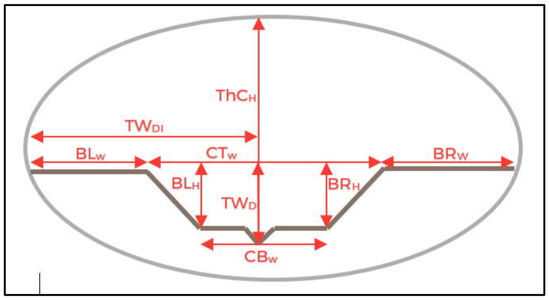
7 of 11

Figure 39. Sample Subsurface Grade Control Structures aopMAP.

I-G. Interior Structure Cross-Sectional Data

The intent of this section to document a detailed cross-section of the channel interior to the structure. To capture changes in the channel over the length of the culvert, cross-sections are taken at the upstream bounds, downstream bounds, and center of the structure at a minimum. When measuring, begin river-left while facing downstream and measure across the structure to river-right. In some cases, cross-sections can be found in the design plans or as-builts, in many cases, field measurements will need to be taken. Check all the *Data Sources* used to find the following information.

Cross sections are intended to capture the small nuances of a channel as shown in the photograph below.



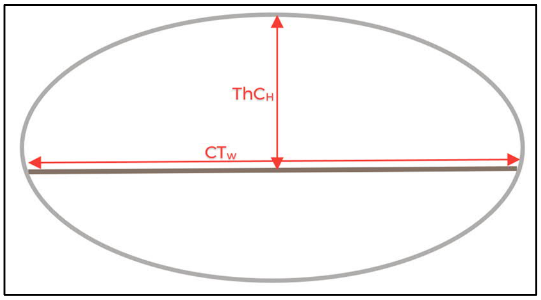


Figure 40: Cross-Section measurements with channel (lt) and without (rt)

Each measurement point is assigned a standard description.

BL_W – *Bank Left Width*: The width of the left bank measured from the side of the AOP structure to the top of bank.

BL_H – *Bank Left Height*: The height of the left bank measured from the toe of slope to the top of bank.

TW_{DI} – *Thalweg Distance*: The distance of the centerline of the thalweg to the left side of the AOP structure.

TW_D – *Thalweg Depth*: The depth of the lowest point in the thalweg to the average top of bank elevation.

ThC_H – *Thalweg Depth from Crown*: The distance from the crown of the AOP to the lowest point in the thalweg.

BR_W – *Bank Right Width*: The width of the right bank measured from the side of the AOP structure to the top of bank.

BR_H – *Bank Right Height*: The height of the right bank measured from the toe of slope to the top of bank.

CT_W – *Channel Top Width*: The width of the channel measured from the left top of bank to the right top of bank.

CB_W – *Channel Bottom Width*: The width of the channel measured from the left toe of slope to the right top of slope.

To duplicate the cross-section measurements in the future, the location of field measured cross-section needs to be documented. Measure the distance from the upstream face of the structure to the location of the culvert and document *length from upstream face of structure* on the data form. Also document the *elevation of crown* at the cross section location on the data form. This can be determined by noting the upstream invert elevation of the AOP plus the rise of the AOP minus the distance from upstream face time the slope of the AOP.

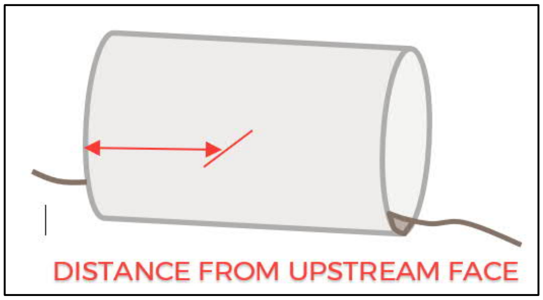


Figure 41: Measurements of cross-section locations in AOP structure

I-G1 – G5. Interior Structure Cross Sections

The protocol user is to use these sections to document stream channel cross-sections at the upstream, downstream, and middle of interior of the structure. The measurements for upstream and downstream cross-sections should be taken inside the culvert within 5-ft of the inlet / outlet.

If the assessor observes that there are notable variations in the shape of the interior channel that are not well defined by the upstream, downstream, and middle cross-sections; the user can define additional interior cross-sections to capture these variations. For example, if bedrock is present for a portion of the interior channel, a cross-section should be documented at the bedrock location and at a non-bedrock location.

ArcGIS Survey123

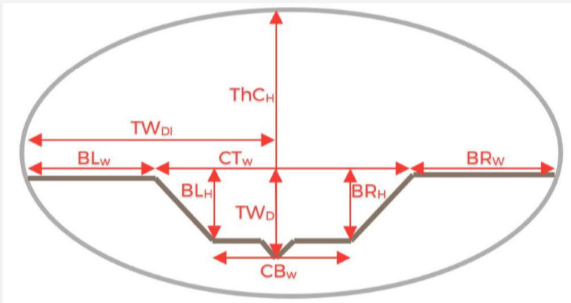
STAGE 1 - INITIAL RECORD DATA COLLECTION

G. INTERIOR STRUCTURE CROSS-SECTION DATA

BASELINE DATA SOURCE:

- ○ Design based
- ● As-Built based
- ○ As-Built surveyed

Description Plot:



(measured from river-left to river-right while facing downstream)

Description Abbreviations:

BL$_W$ - Bank Left Width BL$_H$ - Bank Left Height
TW$_{DI}$ - Thalweg Distance TW$_D$ - Thalweg Depth
ThC$_H$ - Thalweg Depth from Crown
BR$_W$ - Bank Right Width BR$_H$ - Bank Right Height
CT$_W$ - Channel Top Width CB$_W$ - Channel Bottom Width

G1. Interior Structure Upstream Cross-Section / Typical Section:

Check if Typical Section

- ● Yes
- ○ No

Bank Left

Width (ft)	Height (ft)
2	1

Thalweg

Distance (ft)	Depth (ft)	Depth from Crown (ft)
5	0.5	5.5

Bank Right

Width (ft)	Height (ft)
2	1

Channel Top

Width (ft)

5

Channel Bottom

Width (ft)

3

Length from upstream face of structure (ft):

0

Elevation of Crown (ft):

210.5

Figure 42. Sample Interior Structure Upstream Cross-Section / Typical Section aopMAP

I-H. Construction Information

Construction information, such as as-built drawings and design reports, can help with better understanding or evaluating the condition of infrastructure near the AOP site. This information should be solicited from the owner of the infrastructure at the AOP site. Elevations of the infrastructure or channel at the time of construction are important to discern changes when comparing to the design report or plans. In many cases, changes can happen during construction which may differ than what is in the plans or design report. Having a baseline of what the site looks like immediately after construction will assist in understanding how the site changes over time.

Check *yes* or *no* if the structure was built to the *original plan or design*. Modifications will be noted on as-built plans. If known, *describe the changes and why they were made*.

Check *yes* or *no* if the record drawing shows *backfill* was utilized to obtain final grades of the design.

The following information requires knowledge of the construction and can be obtained from the builder, construction assessor, or construction project manager. Check *yes* or *no* if roughness features were placed. Check *yes, no,* or *unknown* if during construction the streambed material was *thoroughly mixed* before placement, if the streambed *gradation* was per design requirements, the streambed was installed with just a *tamper*, if the streambed was installed with a *tamper and a water jet*, if the *bank features* were constructed per design, and if the *low flow channel* was constructed. Document the *construction costs.*

ArcGIS Survey123

STAGE 1 - INITIAL RECORD DATA COLLECTION

H. CONSTRUCTION INFORMATION

1. Was the structure built to original plan/design?
- ○ Yes
- ● No

(1.) If no, describe changes and why they were made during construction (if known):

Unknown

248

2. Backfill placed:
- ● Yes
- ○ No

3. Roughness features placed:
- ● Yes
- ○ No

4. Streambed material thoroughly mixed:
- ○ Yes
- ○ No
- ● Unknown

5. Streambed gradation per design:
- ● Yes

9 of 11

ArcGIS Survey123

STAGE 1 - INITIAL RECORD DATA COLLECTION

6. Bed compacted with tamper:
- ○ Yes
- ○ No
- ● Unknown

7. Bed compacted with tamper and water jet:
- ○ Yes
- ○ No
- ● Unknown

8. Bank features constructed per design:
- ● Yes
- ○ No
- ○ Unknown

9. Low flow channel constructed:
- ● Yes
- ○ No
- ○ Unknown

10. Construction Costs:

Unknown

248

9 of 11

Figure 43. Sample Construction Information aopMAP

I-I. Maintenance History

I-I1. Largest Documented Storm Event Since Construction

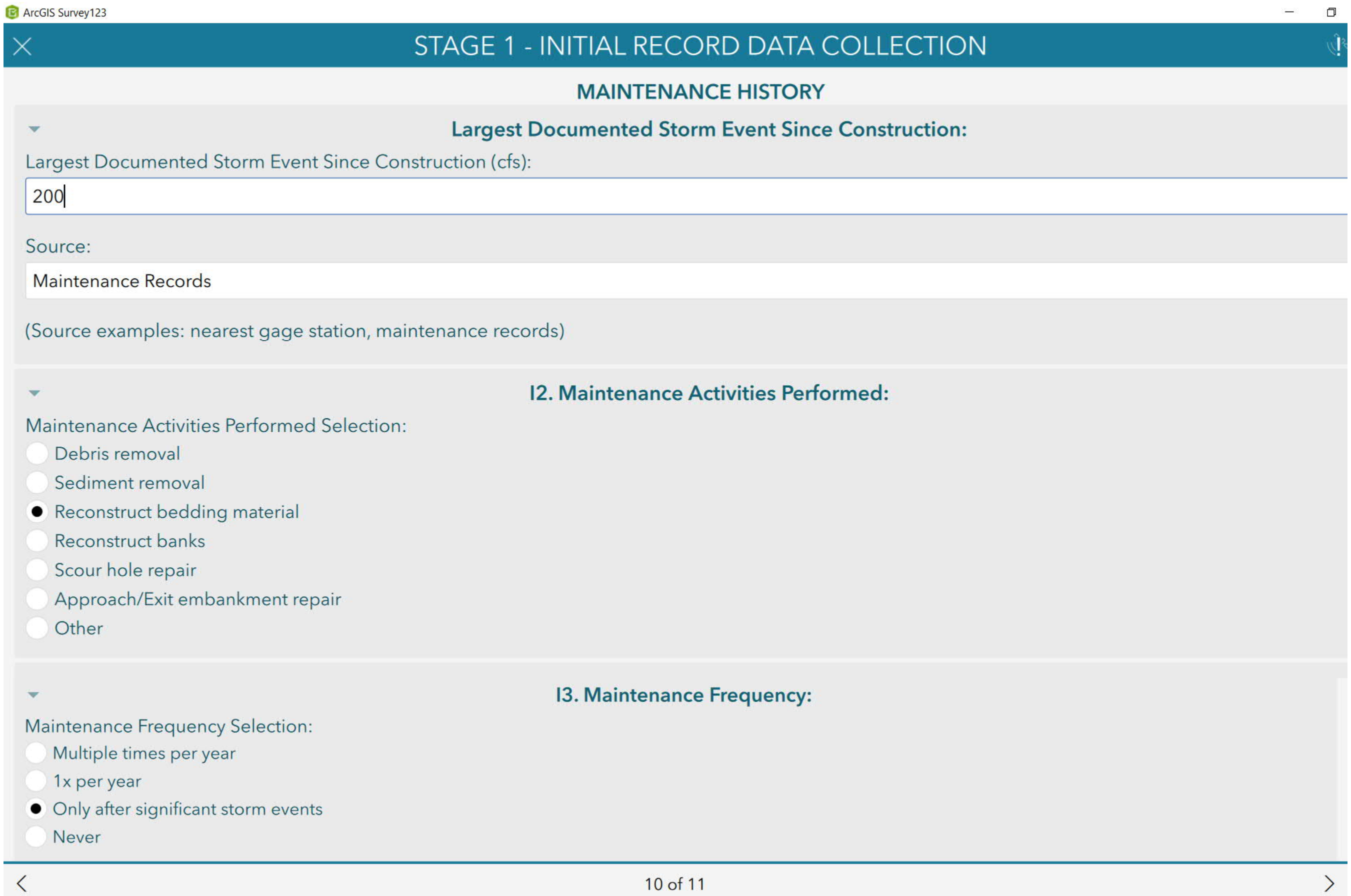
The largest documented storm event is helpful to determine if the site has had a flow event which is capable of changing the stream geomorphology (e.g. slope, cross section, bed material, etc.) since construction of an AOP structure. Information on the largest documented storm event, including the date and an estimate of the flow discharge, is typically acquired from maintenance records kept by the AOP structure owner. If a USGS stream gage (or other available gages that may be privately or publicly owned) is nearby, the largest storm event may be found in the gage record.

I-I2. Maintenance Activities Performed

Typical maintenance activities at an AOP structure are provided in the data form, which may include: debris or sediment removal, reconstructing the channel bed within the structure, repairs to the banks or the roadway embankments near the structure after potential erosion by the stream flow and the repair of scour holes. Information on the type of the maintenance activities conducted at an AOP structure is most typically acquired from the structure maintenance records. Maintenance personnel should be contacted to determine if there is documentation of these or other activities at the AOP site.

I-I1. Maintenance Frequency

Maintenance activities would typically be performed either at predetermined time intervals or after significant storm events, when erosion, scour, aggradation, or debris clogging is observed. Information on the frequency of the maintenance activities conducted at an AOP structure is most typically acquired from the structure maintenance records. Maintenance personnel should be contacted to determine if there is documentation of these or other activities at the AOP site.



ArcGIS Survey123

STAGE 1 - INITIAL RECORD DATA COLLECTION

MAINTENANCE HISTORY

Largest Documented Storm Event Since Construction:

Largest Documented Storm Event Since Construction (cfs):

200

Source:

Maintenance Records

(Source examples: nearest gage station, maintenance records)

I2. Maintenance Activities Performed:

Maintenance Activities Performed Selection:

- Debris removal
- Sediment removal
- Reconstruct bedding material
- Reconstruct banks
- Scour hole repair
- Approach/Exit embankment repair
- Other

I3. Maintenance Frequency:

Maintenance Frequency Selection:

- Multiple times per year
- 1x per year
- Only after significant storm events
- Never

10 of 11

Figure 44. Sample Maintenance History aopMAP

I-J. Monitoring History

Past inspection reports of the AOP site should contain information regarding the condition of any pertinent structural elements. These reports may also include information regarding channel conditions and changes over time. Maintenance personnel should be contacted to determine if there is documentation of monitoring history at the AOP site.

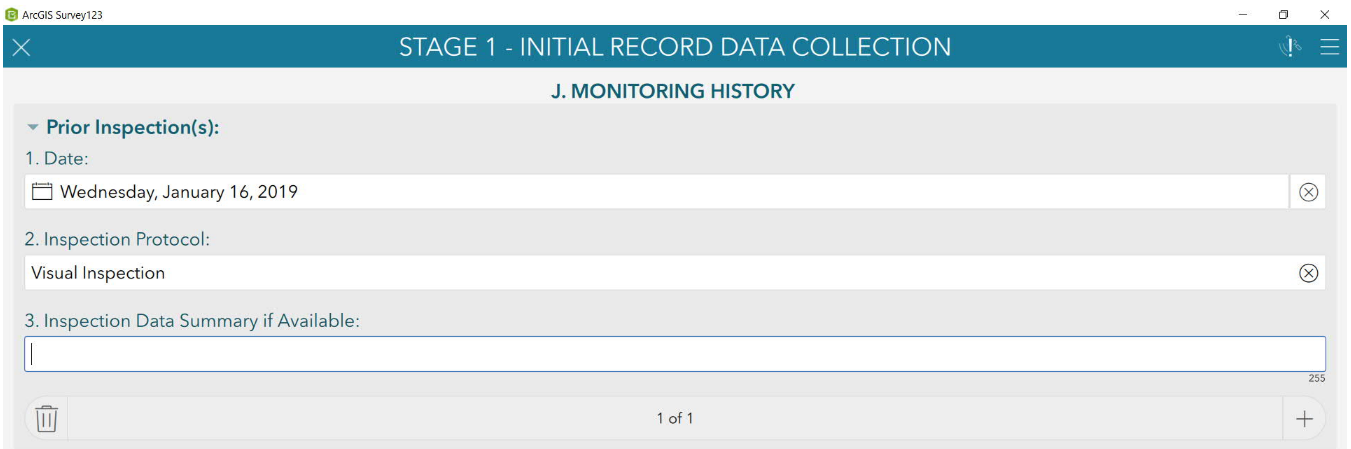


Figure 45. Sample Monitoring History aopMAP

II. Stage 2 – Field Monitoring Tool

The Stage 2 – Field Monitoring Tool is the primary data collection tool within the protocol for post-construction monitoring. The Stage 2 assessment is intended for repeated data collection at each site to allow for asset owners to observe the stability of an installation, identify maintenance needs, and observe best practices for future installations. Similarly, a time-series of data sets from repeated measurement will aide future researchers in defining the effectiveness of different AOP installations based upon the documented physical performance of constructed crossings.

The Stage 2 assessment is a field measurement exercise that can be performed by Engineering staff or well-trained maintenance staff. A Stage 2 assessment takes between one (1) and four (4) hours per structure, depending on the complexity of the structure / channel bed and familiarity of the assessment team with the protocol. Measurements for the Stage 2 are a combination of qualitative observations, simplified measurements, and photo documentation. Anticipated equipment commonly used for a Stage 2 evaluation are listed in Table 2.

Table 2. Stage 2 Assessment Field Equipment List

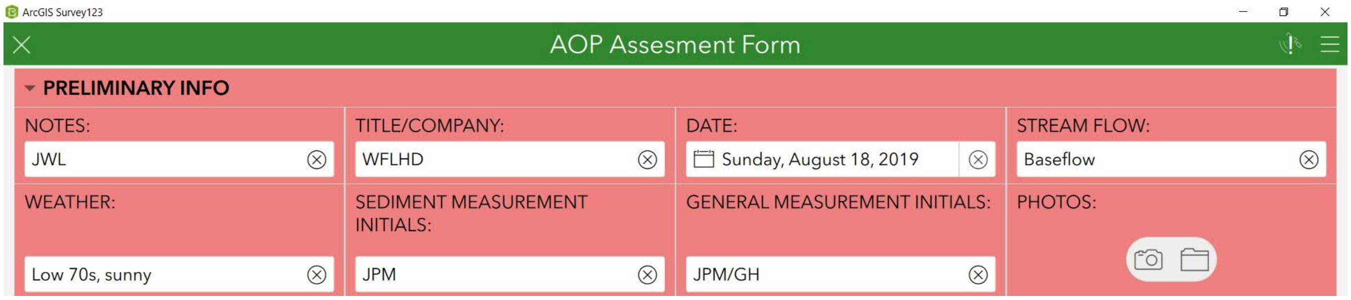
✓	Camera & Spare Batteries / Photo Storage	✓	25-foot Fiberglass Survey Rod – for High Clearance Culverts
✓	Minimum 50-ft Measuring Tape	✓	25-foot measuring tape
✓	String Level & String	✓	Plastic Ruler (inch and mm measurement)
✓	Waders	✓	Clinometer (Optical or Digital)
✓	Mounting Clips	✓	iPad/Android Device
✓	Magnetic Hooks (for Steel Barrel Culverts/RCP Steel Bolts)	✓	Flash Light / Headlamp/Polarized Sunglasses
✓	Pocket Rod (6-ft height) – for Low Clearance Culverts	✓	Hand Level / 6-ft Level
✓	**GPS Unit (optional)**	✓	Laser Level (optional)

Figure 46. Stage 2 Assessment Field Equipment

If the Stage 2 assessment determines that a site is not operating as designed or intended, the facility owner could progress to a more detailed Stage 3 assessment or opt to perform remedial repairs to the site, depending on the severity of impairment and individual concerns at a site.

Data collection for the Stage 2 assessment is to be preceded by a Walk-Through-Assessment (WTA). This will allow the inspecting team to first collect visual observations within the 200-foot long reach upstream and 200-foot long reach downstream of the AOP structure. Once these observations are collected, the inspection team may commence data collection following the downstream-to-upstream order.

Complete the information in the *Preliminary Info* section. Delegate and document with initials which field personnel are taking notes, estimating sediment measurements, and taking general measurements. It is preferred that the sediment measurements are completed by a single person at a given site, so that there is consistency in the D_{50} selection process throughout the survey allowing for a more valid comparison between different collected features. Document the *stream flow* and *weather.* Take photographs of the overall site.


ArcGIS Survey123

AOP Assesment Form

PRELIMINARY INFO

NOTES:	TITLE/COMPANY:	DATE:	STREAM FLOW:
JWL	WFLHD	Sunday, August 18, 2019	Baseflow
WEATHER:	SEDIMENT MEASUREMENT INITIALS:	GENERAL MEASUREMENT INITIALS:	PHOTOS:
Low 70s, sunny	JPM	JPM/GH	

Figure 47. Sample Preliminary Info aopMAP

II-A. Design Information

As in the Stage 1 As-Built Database Tool section, the design information section provides essential information on the location of an AOP site, the age of the installation, and baseline hydrologic and hydraulic data considered in the facility design. Information in this section is important for defining the location of a structure; to avoid improper cataloguing and confusion between different structures in similar areas. Information for the *Design Information* data field is expected to be available in the AOP design report or on the design/as-built plans. Record the location by either using the GPS point or manually entering the *GPS Latitude* and *GPS Longitude*. Complete the additional location data for the AOP structure including the road *route number* or *road name*, the closest *mile post* number to the nearest 0.1 miles, and the *stream name*. Follow the methodology described in section *I-A1. General Design Information*.

II-B. Downstream Channel Information

This section will document the condition of the downstream channel from the downstream face of the culvert to 200-feet downstream.

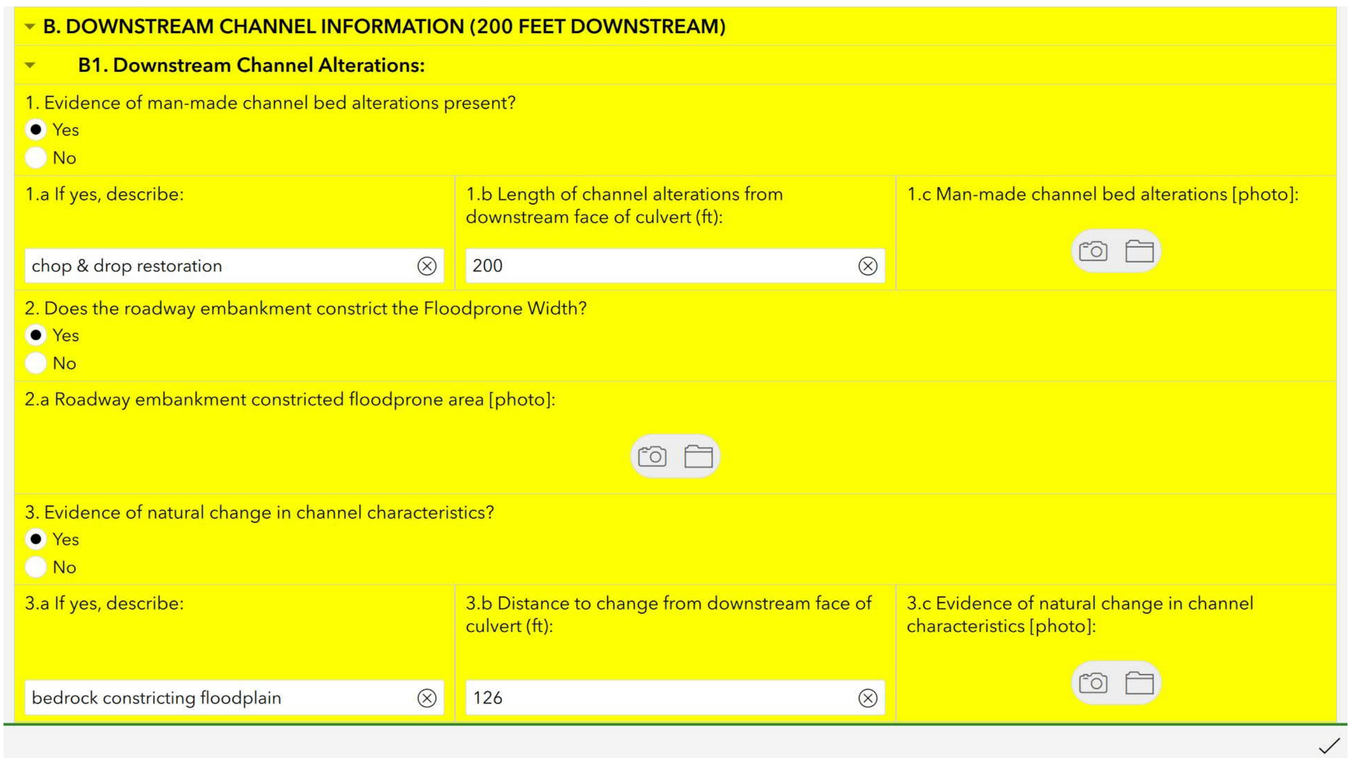
II-B1. Downstream Channel Alterations

Check *yes* or *no* if man-made channel bed alterations are present in the downstream channel. Example of alterations include reconstructed channel and channel armoring. If man-made alterations are present, describe the alteration and estimate the length of the alteration from the downstream face of the culvert. The length of the alteration should be measured from the downstream face of the culvert to the downstream end of the alteration. If the channel alteration continues beyond the 200-foot study area, document the length as *> 200-ft*. Take photographs of man-made channel bed alterations.

Check *yes* or *no* if the roadway embankment constricts the downstream floodplain. Take photographs of floodplain encroachment.

Check *yes* or *no* if naturally occurring changes in channel bed characteristics are present in the downstream channel. Example of natural changes include change in geomorphic channel type, change in channel slope and bed material, or change in floodplain characteristics. If natural changes are present, describe the change and estimate the distance to the beginning of the change from the downstream face of the culvert. Take photographs of the changes in channel characteristics.

Figure 48. Man-made "chop & drop" fallen trees on Logger Brook (left), roadway embankment constricting downstream floodplain on Molly Brook (center), and channel naturally constricted downstream by bedrock on Molly Brook (right)



B. DOWNSTREAM CHANNEL INFORMATION (200 FEET DOWNSTREAM)

B1. Downstream Channel Alterations:

1. Evidence of man-made channel bed alterations present?
- (●) Yes
- ( ) No

1.a If yes, describe:	1.b Length of channel alterations from downstream face of culvert (ft):	1.c Man-made channel bed alterations [photo]:
chop & drop restoration	200	

2. Does the roadway embankment constrict the Floodprone Width?
- (●) Yes
- ( ) No

2.a Roadway embankment constricted floodprone area [photo]:

3. Evidence of natural change in channel characteristics?
- (●) Yes
- ( ) No

3.a If yes, describe:	3.b Distance to change from downstream face of culvert (ft):	3.c Evidence of natural change in channel characteristics [photo]:
bedrock constricting floodplain	126	

Figure 49. Sample Downstream Channel Alterations aopMAP

II-B2. Typical Downstream Channel Characteristics

Check the radial button that best describes the *geomorphic channel type* of the downstream channel. Follow the methodology described in section *I-E3. Geomorphic Channel Type.*

Check the radial button that best describes the *channel bed classification* of the downstream channel. Check all that apply. *Table 3* describes the size of each substrate type to aid in identification. The channel bed material assessment should not consider large roughness features or channel bank material.

Table 3: Bed Material Sizes

Bed Material Type	Size (in)	Equivalent Size
Clay	<0.02	smaller than sand (cohesive when squeezed between fingers)
Silt	<0.02	smaller than sand (slippery when rubbed between fingers)
Sand	0.02 – 0.1	Salt – peppercorn
Gravel	0.1 – 2	Peppercorn – baseball
Cobble	2 – 10	Baseball – volleyball
Boulder	> 10	Greater than a volleyball

Document the *average channel slope* for the downstream channel. Measurements can be collected in the field using instruments (e.g., level and staff, inclinometer and tape, etc.). It requires at least two field staff to measure slope. One person will be taking the measurements with a hand-held clinometer (optical or digital) (1), the other person will be downstream holding a reference target (2), typically a survey or pocket rod. The eye height of the staffer reading the sight level should be measured and marked on the target (3). Measurements are taken by standing with the field staffs' feet and the reference target base at the water surface. The average reach slope should be characterized over the longest possible stretch of stream in each reach, the length may be limited by line of sight, shifts in channel types, major confluences, or other factors. A common stream channel feature should be used at the upstream and downstream points of the measurement, typically the head of a riffle, top of a step, or other similar grade features are utilized. General observations can be made regarding relative slope differences throughout the reach, as well. These measurements and observations will be validated with survey data in Stage 3.

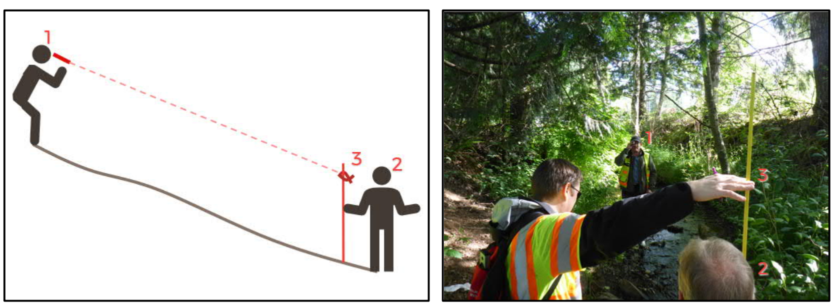


Figure 50: Measuring Channel Slope. Field staffer marks the eye height of person reading level on the pocket rod at Little Skookum (right)

B2. Typical Downstream Channel Characteristics:

1. Geomorphic Channel Type:
Dune-ripple / Riffle-pool (selected) / Plane-bed / Step-pool / Cascade / Wetland / Other:

2. Channel Bed Classification (check all that apply):
Clay / Silt / Sand (checked) / Gravel (checked) / Cobble (checked) / Boulder / Bedrock

3. Average Channel Slope (ft/ft) {Conversion: TAN(Degrees) = ft/ft}
0.009

Figure 51. Sample Downstream Channel Characteristics aopMAP

II-B3. Downstream Channel Depositional Characteristics

Identifying bedload characteristics will help identify if the channel is transport-limited, identified by aggradational features, or supply-limited, identified by a lack of depositional features. Check *yes* or *no* if there is a depositional feature downstream. There will typically be a depositional feature; the exception are systems that are backwatered or otherwise completely submerged. Document the type of *feature* sampled. *Feature types* include side bars, mid-channel bars, point bars – inside bend, depositional bars – channel wide deposition, pocket deposition – small depositional feature behind boulders/logs. Take photographs of the depositional features.

Document the *downstream channel depositional material size* by estimating the D_{50} or median particle size and D_{100} or largest particle size of the channel bed material. When measuring particle sizes, the median axis is taken as the particle size. In other words, don't measure the longest or the shortest axis, measure the middle length to estimate the particle size.

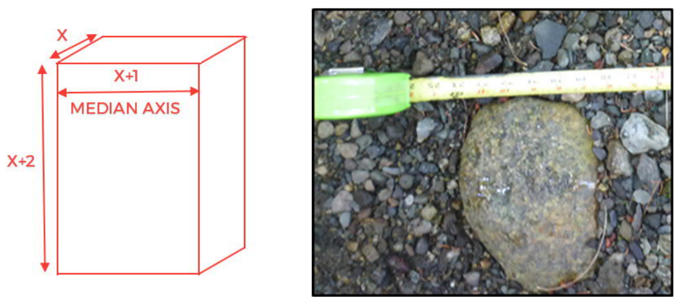
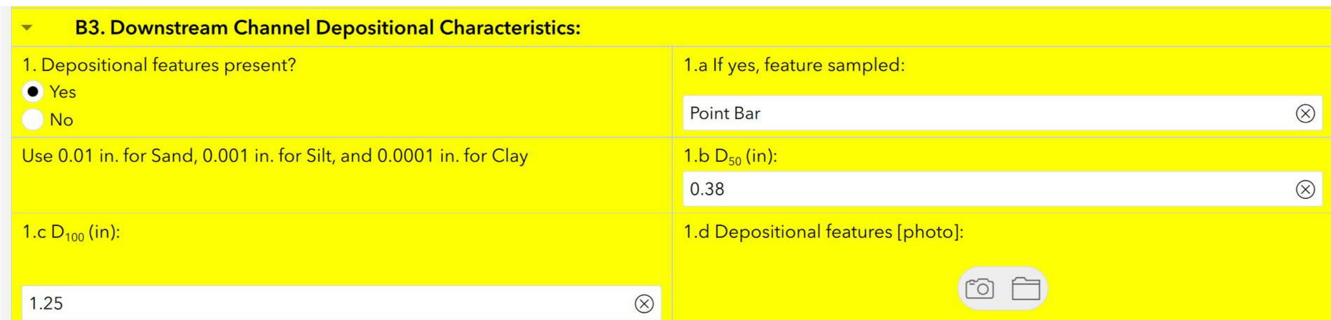


Figure 52: Particle Median Axis Diagram (left); measuring the median axis of a cobble at Halls Brook (right)

Deposited material measurements are to be consistently performed by the same individual during the assessment of a site. Since the protocol asks the field team to visually estimate size characteristics, such as D_{50}, it is expected that different people would come to different conclusions. This protocol anticipates that the bias's in size estimation by an individual field team member will be consistent from observation to observation. As the protocol ultimately relies on a comparative evaluation of bed material and bedload material characteristics, the individual accuracy of sediment size estimates is anticipated to be as critical as the overall precision of the estimates.

If the bed material is determined to be gravel, cobble, or boulders, use the *FHWA Hydraulic Toolbox Sediment Gradation Analysis* tool to determine the bed material gradation. Take photographs of material with ruler.

Figure 53. Side bar (left) and measuring depositional size on Saxine Creek (right)



B3. Downstream Channel Depositional Characteristics:

1. Depositional features present? ● Yes ○ No	1.a If yes, feature sampled: Point Bar
Use 0.01 in. for Sand, 0.001 in. for Silt, and 0.0001 in. for Clay	1.b D_{50} (in): 0.38
1.c D_{100} (in): 1.25	1.d Depositional features [photo]:

Figure 54. Sample Downstream Channel Depositional Characteristics aopMAP.

II-B4. Downstream Channel Features

A *Potential Limiting Feature (PLF)* is any channel feature, man-made or natural, that may be an impediment to AO passage. It is not intended that the field personnel make an absolute judgement call on whether the feature is an obstruction, but if there is the potential there could be an impediment, the feature should be documented. For example, the PLF in one reach may be a 6-foot vertical bedrock drop. The PLF in another reach may be fast moving-shallow riffle. The assessment teams are to identify and collect PLF data at every reach assessed, unless no limiting feature is located, for example, a low gradient stream systems that consist of flowing wetlands or a backwatered system where the entire reach is a pool. The assessment protocol is reliant on a comparative evaluation of PFL features, if, for example, a downstream PFL is not identified due to a confluence with a larger stream immediately downstream of the culvert, the upstream PFL will be relied upon and must be collected.

Check the radial button that best describes if the downstream channel *feature* is typical or a potential limiting feature (PLF). Document all unique features. For example, if a channel has a constructed rock sill followed by a cascade and then a debris jam, all three features should be recorded. If a downstream channel has multiple, similar features, for example a reach of step-pools, a typical step-pool should be measured as representative. Take photographs of each typical or potential limiting feature.

Document the feature *type*. Typical examples of features could be constructed rock sill, natural step-pools, debris jams, log sills, or bedrock outcrops. Feature types and descriptions are listed in Table 4.

Table 4: Potential Limiting Feature Types

Feature Type	**Abbreviation**	**Description**
Rock Sill	RS	Man-made rock structure that completely spans the stream channel
Rock Cluster	RC	Naturally forming rock structure that completely spans the stream channel

Log Sill	LS	Man-made or naturally forming log structure that completely spans the stream channel. If naturally forming, include debris jam (LS/DB)
Bedrock	BR	Exposed bedrock
Weir – concrete	W_C	Man-made concrete weir that completely spans the stream channel
Weir – metal	W_M	Man-made metal weir that completely spans the stream channel
Cascade	CA	Man-made or naturally forming tumbling flow over disorganized large rocks
Pool	P	Man-made or naturally forming pool
Headcut	HC	Naturally forming abrupt vertical drop in a stream channel bed
Debris Jam	DJ	Trees and other organic/inorganic detritus
Low Gradient	LG	Dune-Ripple bed formation in sand bed channels
Riffle	R	Man-made or naturally forming flow over coarse bed material and shallower / faster flowing water

Document the *origin* of the feature by noting whether it is man-made (M) or naturally occurring (N).

Document the *stability* of the feature. There are five potential stability classifications. When permanent grade controls, such as competent bedrock or lakes, are present, the channel reach may be considered as long-term stable. On the contrary, the channel may be characterized as short-term stable when grade is controlled by temporary features, such as log sills, that may be mobilized during larger storms, or structures, such as dams, weirs and culverts, that may be removed. A complete list of feature stabilities and descriptions are listed in *Table 5* with photo examples in Figure 55.

Table 5: Feature Stabilities

Stability Type	**Abbreviation**	**Description**
Long-term Stable	LS	Channel does not exhibit aggradation or degradation. Channel features include permanent structures such as rock sills and bedrock that are unlikely to move in the long term.
Evolving and Stable	ES	Channel components have the potential to move but will not degrade the overall function of the structure. For examples include riffle material that moves but is being replaced or a log drop that has the potential to rot but in a system with many trees and root wads that will likely replace the log.
Short-term Stable	SS	Channel has evident potential for movement, such as a sturdy debris jam that cannot be replaced and once gone may degrade the overall function of the channel.
Unstable	U	Channel exhibits imminent degradation, such as a headcut or a weak debris jam.
Actively Migrating	AM	Channel is highly unstable and actively degrading, such as a headcut in highly erodible soils.

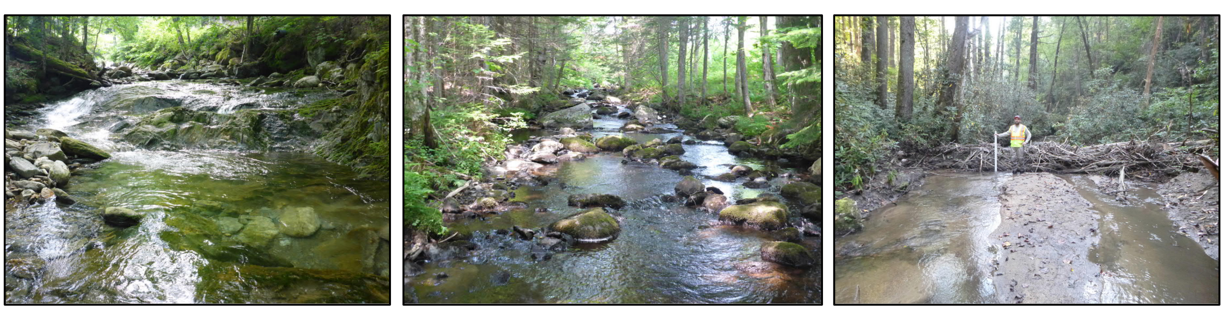


Figure 55. Long-term Stable – bedrock cascade on White River (left-top), Evolving and Stable – boulder clusters on Halls Brook (center-top), Short-term Stable – debris jam on Tottery Pole Creek (right-top), Short-term Stable – hand-stacked stone dam near campsite on Walnut Creek (left-bottom), Unstable – weak debris jam holding a 3-ft headcut on Tributary to St. Lewis River (center-bottom), and Actively Migrating – actively moving headcut with eroding bed and banks on Desolation Creek (right-bottom)

Document the *GPS Latitude* and *GPS* Longitude using the GPS point button or manually entering the coordinates. Document the *location* of the feature by measuring from the downstream face of the culvert to the highest vertical point of the feature, i.e. the head of the riffle or upstream side of the rock sill. Document the *length* of the feature along the channel alignment, i.e. upstream to downstream length.

Document the cross-section dimensions of the channel feature. There are three components of the cross-section that should be measured and documented. The first is the *width of flow* (1) and average *depth of flow* (2) at the time of the inspection. The second is the *width of active channel* (3) and *average depth of active channel* (4). The active channel can be identified using ordinary high-water mark indicators, such as a clear natural line impressed on the bank, shelving, changes in the character of soil, changes in vegetation, the presence of litter and debris. The third is the *floodprone width* (5) and *floodprone depth* (6). The floodprone width is the width taken at two times to maximum active channel depth. If the maximum depth of the channel is 16-inches, measure the width of the floodplain at a channel depth of 32-inches.

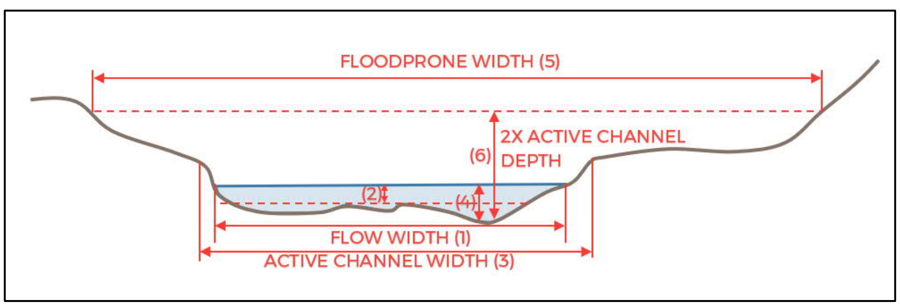


Figure 56. Downstream Channel Cross Section Components

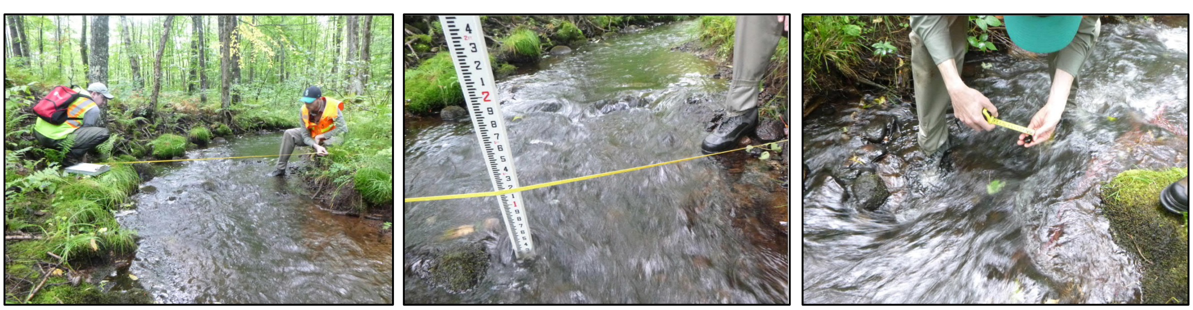


Figure 57. Documenting a typical channel cross-section at the head of riffle at Pre-emption Creek: measuring active channel width (left), active channel depth (center), and feature material (right)

Check *yes* or *no* to select if the feature material is bedrock. If the feature material is not bedrock, document the characteristic *feature material size* by estimating the D_{50} or median particle size and D_{100} following the methodology described in section II-B3. Downstream Channel Depositional Characteristics. The characteristic bed material should be the material of the bedform feature measured. In the example of Pre-emption Creek, a riffle head was chosen for the typical cross section; therefore the material of the riffle is documented as the characteristic bed material.

Document the *WSE total drop* and *downstream pool depth* of the PLF. The *WSE total drop* is measured from the top of the water surface above the feature to the top of the water surface below the feature. The *downstream pool depth* is measured downstream of the PLF by measuring from the deepest point of the pool to the water surface.

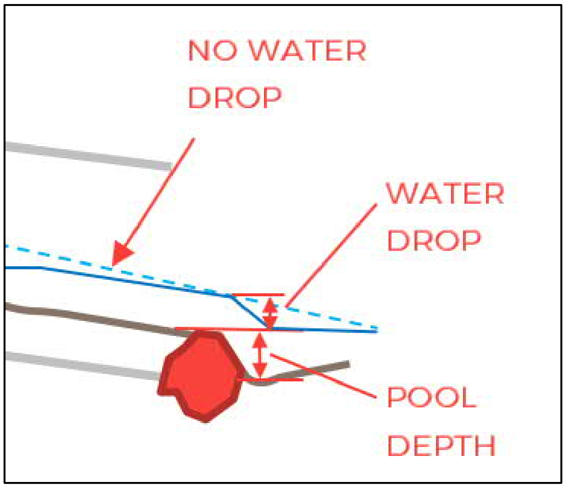


Figure 58. Diagram of water drop over a feature and pool depth downstream of feature.

Figure 59. Measuring the WSE total drop and downstream pool depth at the features on Pre-emption Creek: Man-made rock sill with a single water surface drop in the downstream channel (left) and a natural cascade with multiple water surface drops in the upstream channel (right)

In some cases, the water drop will be a single measurement over the feature, but in other cases, there may be multiple drops over one feature. For example, a bedrock feature that has an overall drop of 3-feet but has micro-topography with drops and pools so that there are smaller individual drops, such as shown in Figure 60. Document the *WSE drop height* and *pool depth at drop* and take photographs for each individual drop.

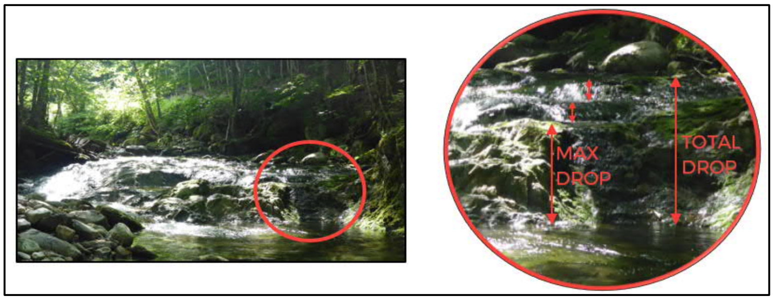


Figure 60. Feature with varying maximum drop and total drop on White River bedrock cascade

B4. Downstream Channel Features:

CHANNEL FEATURES

Abbreviations:
ID: TYP - typical; PLF - Potential Limiting Feature;
Type:P - Pool; LG - Low Gradient; RF - Riffle; CA - Cascade; RS - Rock Sill; RC - Rock Cluster; LS - Log Sill; BR - Bedrock; W_ (C-concrete, M-metal) - Weir; HC - Headcut, DJ - Debris Jam
Origin: N - Natural; M - Man-made
Stability: LS - Long-term Stable; ES - Evolving and Stable; SS - Short-term Stable; U - Unstable; AM - Actively Migrating

ATTRIBUTES

Feature ID: (●) TYP ( ) PLF	Type: ( ) P ( ) LG (●) RF ( ) CA ( ) RS ( ) RC ( ) LS ( ) BR ( ) WC ( ) WM ( ) HC ( ) DJ
Origin: (●) N ( ) M	Stability: (●) LS ( ) ES ( ) SS ( ) U ( ) AM

GPS Point

GPS Latitude:	GPS Longitude:
Location (distance from culvert) (ft): 100	Length (ft):
WSE Total Drop (ft): 0.5	Width of Flow at Inspection (ft): 7.7
Average Depth of Flow at Inspection (ft): 0.3	Width of Active Channel (ft): 16.3
Average Depth of Active Channel (ft): 1.2	Floodprone Width (ft): 24
Floodprone Depth (ft): 2	Is the Feature Material Bedrock? ( ) Yes (●) No ( ) Yes (●) No

Figure 61. Sample Downstream Channel Features aopMAP

II-B5. Channel Scour

As explained in section *I-C1. Scour Countermeasures*, scour is the localized erosion of channel bed material caused by fast moving water and tends to occur at the structure inlet and outlet. Observed scour could include exposed footers or foundations, undercutting of the abutments, pools forming along the walls or on the bottom of the AOP structure. Scour at the inlet is often due to a poor approach of the channel. Check *yes* or *no* if there is observed *scour* and describe the location and severity. Take photographs of the channel scour.

Figure 62. Scour hole downstream of rock sill at culvert exit at Pre-Emption Creek (left) and Observed scour at the entrance to Tributary to Schafer Creek (right)

B5. Channel Scour:

1. Scour at outlet?
- (●) Yes
- ( ) No

1.a if yes, describe:

Scour pool d/s of rock sill

PHOTOS:

Figure 63. Sample Channel Scour aopMAP

II-B6. Downstream Channel Large Roughness Feature

Document the downstream channel *large roughness features.* Follow the methodology described in section *I-F5. Channel Large Roughness Features.*

B6. Downstream Large Roughness Features:

Observed large roughness features?
- (●) Yes
- ( ) No

1. Type:
- [x] Single boulder
- [ ] Boulder cluster
- [ ] Rootwads
- [ ] Other

2. Distribution:
- (●) Random
- ( ) Pattern
- ( ) Component of bed mix
- ( ) Channel margin

3. Representative diameter/length (ft):

1.5

3.a Typical Spacing (ft):

5

3.b Total number:

10

3.c Large roughness feature [photo]:

Figure 64. Sample Downstream Large Roughness Features aopMAP

II-C. Interior Channel

II-C1. Structure Information Verification

Check *yes* or *no* verifying the *structure type and material*, *number of barrels*, *end treatments*, *dimensions*, and *foundation* are consistent with those documented in the Stage 1 As-Built Database Tool section *I-B. Structure Information.*

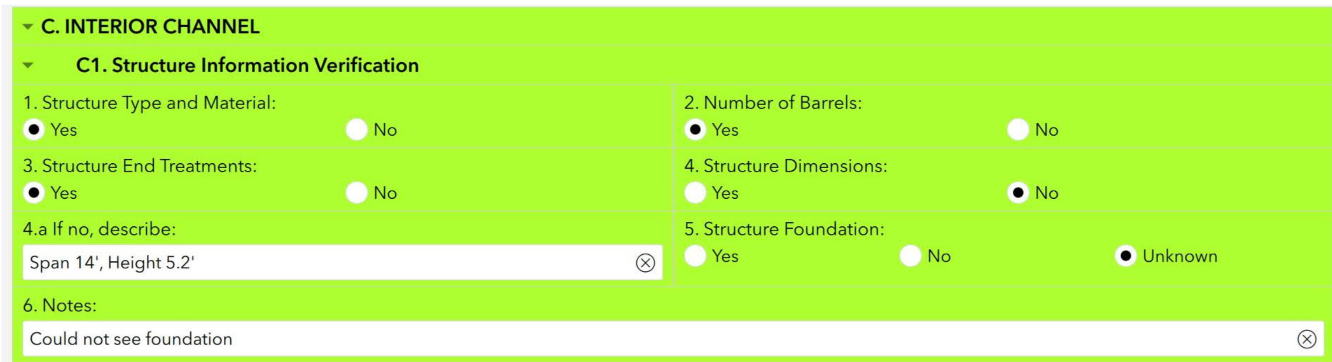

C. INTERIOR CHANNEL
C1. Structure Information Verification
1. Structure Type and Material: (•) Yes ( ) No
2. Number of Barrels: (•) Yes ( ) No
3. Structure End Treatments: (•) Yes ( ) No
4. Structure Dimensions: ( ) Yes (•) No
4.a If no, describe: Span 14', Height 5.2'
5. Structure Foundation: ( ) Yes ( ) No (•) Unknown
6. Notes: Could not see foundation

Figure 65. Sample Structure Information Verification aopMAP

II-C2. Typical Interior Channel Characteristics

Check the radial button that best describes the *geomorphic channel type* of the interior channel. Follow the methodology described in section *I-E3. Geomorphic Channel Type.*

Check the radial button that best describes the *channel bed classification* of the interior channel. Follow the methodology described in section *II-B2. Typical Downstream Channel Characteristics.*

Document the *average channel slope* for the interior channel. Follow the methodology described in section *II-B2. Typical Downstream Channel Characteristics.*

II-C3. Interior Channel Depositional Characteristics

Document the interior channel *depositional features.* Follow the methodology described in section *II-B3. Downstream Channel Depositional Characteristics.*

II-C4. Interior Channel Features

Document the interior *channel features.* Follow the methodology described in section *II-B4. Downstream Channel Features.*

II-C5. Exposed Structure

Document the *overall stability* of the *interior channel*. Follow the methodology described in section *II-B4. Downstream Channel Features.*

Exposed structures within the AOP structure occurs with both closed bottom and open bottom culverts or bridges. Exposed structures that would normally be buried may indicate an unstable channel. Check *yes* or *no* if *exposed structures* are observed at the AOP structure. An example of an exposed structure in a closed bottom culvert is the culvert itself. An example of an exposed structure in an open bottom culvert or bridge is bedrock or an exposed utility crossing. If they are observed, check the radial button that best describes what *percentage* of the bottom surface area of the AOP structure is exposed structure. For example, if the entire observed bottom of a closed bottom AOP structure or the entire observed bottom of an open bottom AOP structure is bedrock, the percentage of exposed bottom area is 100%. If an encased sewer is exposed for a portion of the culvert, estimate the total surface area of the bottom of the AOP structure and what percentage of that is exposed encasement. Document their location and check all the boxes that apply: *upstream*; *middle*; or *downstream*. Take photographs of the exposed structure.

If exposed footings are observed, document the *exposed height* of the footer for river-right and river-left looking downstream and the observed *length exposed*. Check *yes* or *no* if the *footing has been undermined* and the *length* of undermining and *location*, i.e. river-right at the AOP structure outlet. Note, some metal arch culverts will have exposed concrete where the metal fits into the footer. This is not an exposed footer. Include any notes about the observed scour that might be important; including risk of AOP structure failure. Document scour and exposed structure observations with photographs.

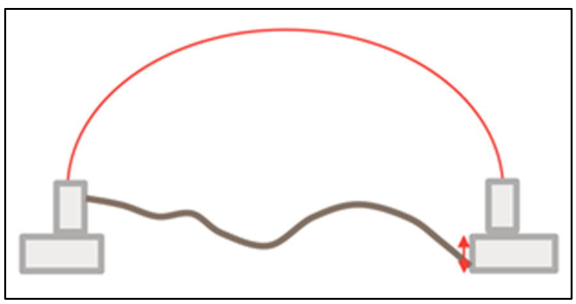
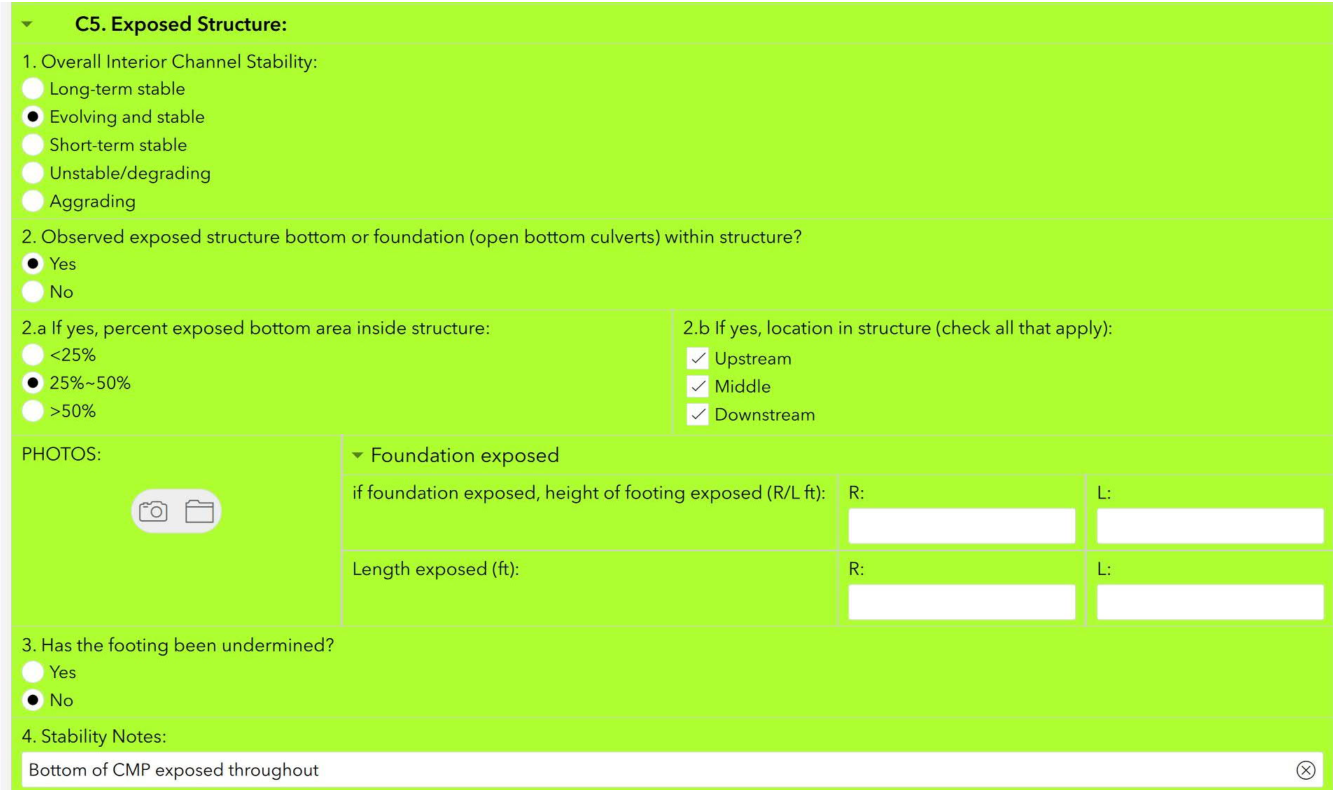


Figure 66: Diagram of exposed spread footer measurement

Figure 67: Exposed concrete spread footer measurement (left)[8], exposed metal spread footer (center)[9], and metal arch culvert on concrete footings with no exposed spread footer at White River

[8] Figure 6.9 from "Hydraulic Design of Culverts", HDS-5 Third Edition, April 2012

[9] Figure 7.7 from "STREAM SIMULATION: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings" August 2008


C5. Exposed Structure:

1. Overall Interior Channel Stability:
- ○ Long-term stable
- ● Evolving and stable
- ○ Short-term stable
- ○ Unstable/degrading
- ○ Aggrading

2. Observed exposed structure bottom or foundation (open bottom culverts) within structure?
- ● Yes
- ○ No

2.a If yes, percent exposed bottom area inside structure:
- ○ <25%
- ● 25%~50%
- ○ >50%

2.b If yes, location in structure (check all that apply):
- ☑ Upstream
- ☑ Middle
- ☑ Downstream

PHOTOS:

Foundation exposed

if foundation exposed, height of footing exposed (R/L ft):	R:	L:
Length exposed (ft):	R:	L:

3. Has the footing been undermined?
- ○ Yes
- ● No

4. Stability Notes:

Bottom of CMP exposed throughout

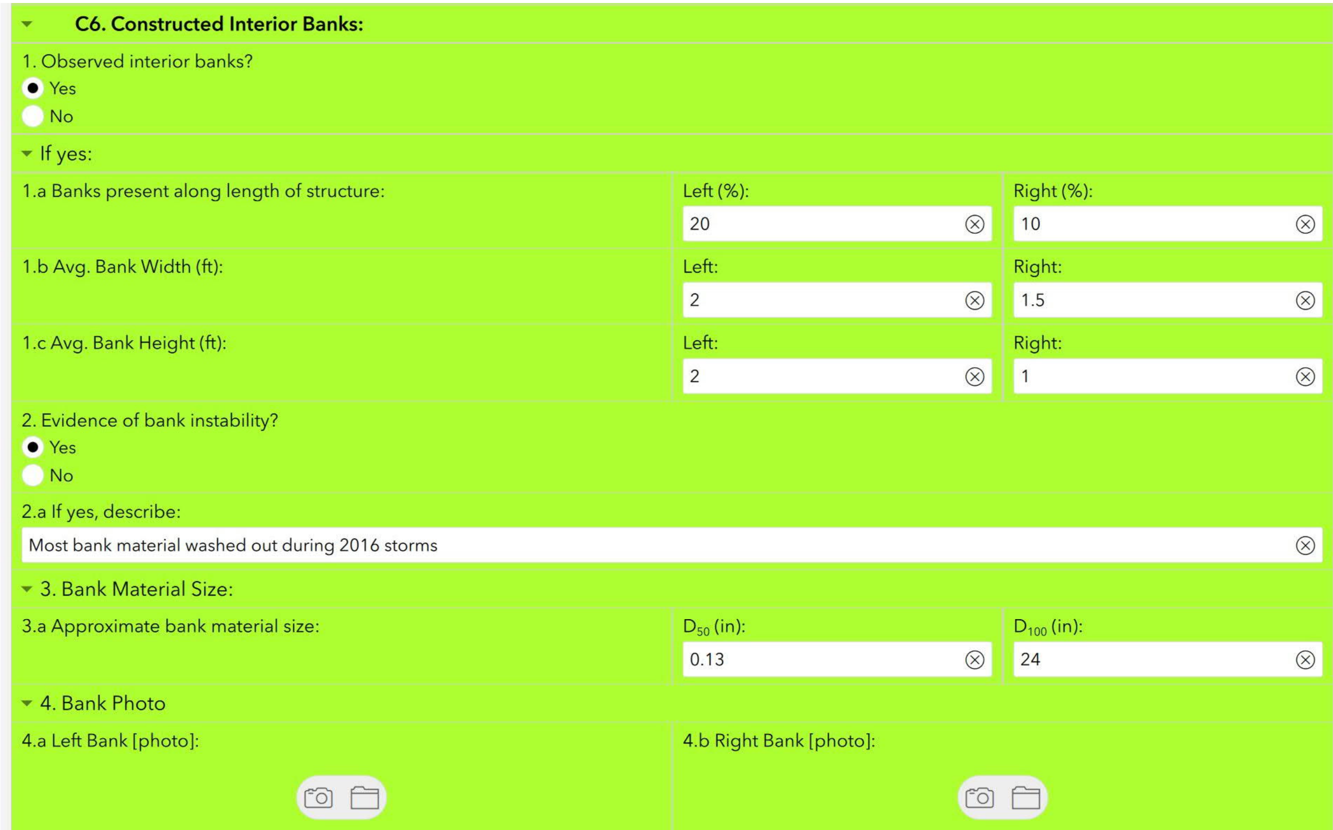
Figure 68: Sample Exposed Structure aopMAP

II-C6. Constructed Interior Banks

Check *yes* or *no* if *interior banks* are present at the AOP structure. Interior banks are constructed streambank features interior to the AOP water crossing. Interior banks may have been noted in the project as-built but are not present during the field inspection due to erosion or instability caused during major floods. If interior banks are present, estimate the percent of culvert with interior bank present along both river-left and river-right (left and right are determined while looking downstream). If the interior banks are present for the entire length of the AOP structure, the percentage is 100%. Investigation into the potential erosion of interior banks could include looking for on-site markers such as bank elevation lines painted on the structure walls, as shown in the middle photo of figure 48.

Figure 69: Interior banks along 100% AOP structure on Potash Brook (left) interior banks along 30% of left bank on Pre-emption Creek (center), and no interior banks on Mill Creek (right)

Document the average *bank width* and *bank height* for both the left and right banks following the methodology described in section *I-C2. Interior Banks*. Check *yes* or *no* if there is evidence of *bank instability* within the AOP and describe the situation. Document the *approximate bank material size* by estimating the D_{50} and D_{100} following the methodology described in section *II-B2*. Take photographs of the left and right interior banks.



C6. Constructed Interior Banks:

1. Observed interior banks?
(•) Yes
( ) No

If yes:

1.a Banks present along length of structure:	Left (%): 20	Right (%): 10
1.b Avg. Bank Width (ft):	Left: 2	Right: 1.5
1.c Avg. Bank Height (ft):	Left: 2	Right: 1

2. Evidence of bank instability?
(•) Yes
( ) No

2.a If yes, describe:
Most bank material washed out during 2016 storms

3. Bank Material Size:

3.a Approximate bank material size:	D_{50} (in): 0.13	D_{100} (in): 24

4. Bank Photo

4.a Left Bank [photo]:

4.b Right Bank [photo]:

Figure 70. Sample Constructed Interior Banks aopMAP

II-C7. Flow Observations

Observe the low flow channel in the AOP structure. Check *yes* or *no* whether the flow concentrates along the AOP structure wall. Document the overall percentage of structure *wall length with flow*, and *which side* the flow is observed on while looking downstream. If the flow covers the entire bottom of the culvert, do not count that as concentrated flow along AOP structure wall unless the thalweg runs along the wall.

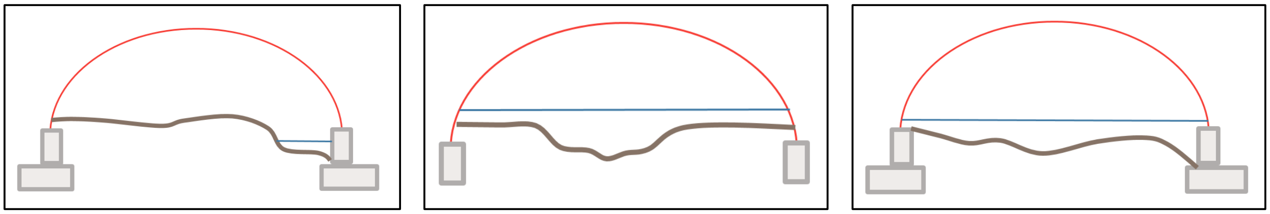


Figure 71: Flow Observations: Flow concentrated along wall (left and right), flow not concentrated along wall (center)

Figure 72: Flow Observations: Flow concentrated left wall at Marsh Brook (left), along both walls (split flow) at Saxine Creek (center), along both walls (alternating) at Tributary to Shafer Creek (right)

C7. Flow Observations:

1. Observed concentrated flow along wall?	1.a If yes, percent of wall length with flow:	1.b Which side of structure:
● Yes	○ <25%	○ Left
○ No	● 25%~50%	○ Right
	○ >50%	○ Both (split flow)
		● Both (alternating)

Figure 73. Sample Flow Observations aopMAP

II-C8. Interior Channel Large Roughness Feature

Document the interior channel *large roughness features*. Follow the methodology described in section *I-F5. Channel Large Roughness Features.*

Figure 74: Large Roughness Features: Single, random boulders at Porcupine Creek (left) and bedrock, channel margin at Tottery Pole Creek (right)

II-D. Interior Structure Cross-Sectional Data

Complete the interior structure cross-sectional data following the methodology described below. Cross sections should be taken at the same location as in section *I-G. Interior Structure Cross-Sectional Data*. To duplicate the cross-section measurements in the future, the location of field measured cross-section needs to be documented. Measure the distance from the upstream face of the structure to the location of the culvert and document *length from upstream face of structure.* Also measure the distance from the cross-section line level to the crown of the structure and document the *reference height to crown/low chord of structure* on the data form.

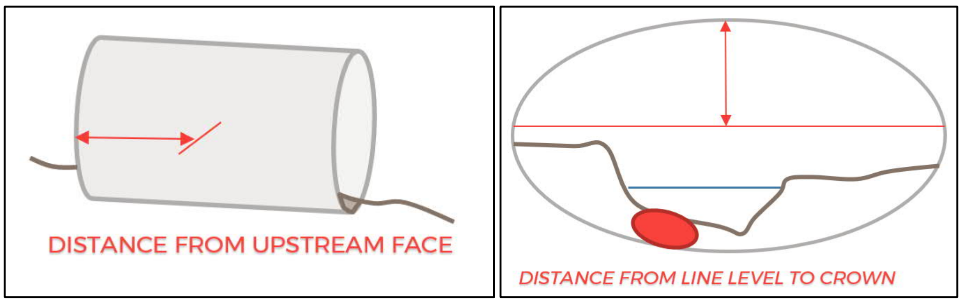


Figure 75: Measurements of cross-section locations in AOP structure

The intent of this section to measure a detailed cross-section of the channel interior to the structure. To capture changes in the channel over the length of the culvert (including potential changes in the channel profile), cross-sections are taken at the upstream bounds, downstream bounds, and center of the structure at a minimum. When measuring, begin river-left while facing downstream and measure across the structure to river-right.

Cross sections are intended to capture the small nuances of a channel; it is typical to have 10-12 measurement points in a given cross-section, as shown in the photograph below.

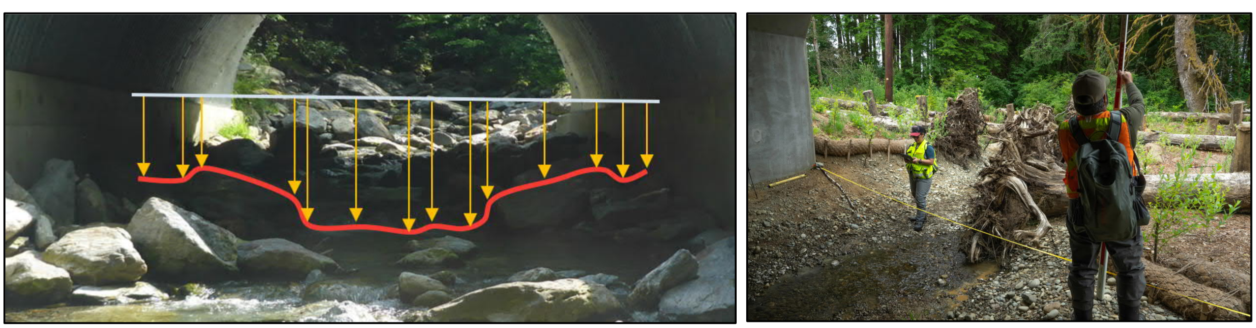


Figure 76: Left: Cross-Section measurements on White River Right: Measurement of the reference height to the top of the culvert.

Each measurement point is assigned a standard description.

EW – Edge of Water: There should only be two points for EW, the point where the water level meets the right bank and where it meets the left bank.

TW – Thalweg: The thalweg is the lowest point in the cross section or the bottom of low-flow channel. Some cross-sections might have multiple low flow channels, the thalweg is whichever one is lowest. There is only one thalweg point in a cross-section.

SB – Streambed: The streambed is any measurement taken for the bottom of the channel. A measurement is taken whenever there is a change in the geometry of the bed to capture the small rises and falls along the channel bottom. All these points are described as streambed.

TOB – Top of Interior Bank: The top of bank refers to the top inflection point where the channel side slope transitions to the channel bank. There should only be two points for TOB, the left TOB and the right TOB.

TEB – Toe of Interior Bank: The toe is the bottom inflection point where the channel side slope transitions to the channel streambed. Depending on the depth of water this point can be above or below the water surface. There should only be two points for TEB, the left TEB and the right TEB.

TAC – Top of Active Channel: The active channel is the portion of the channel that is commonly flowing but above base flow. It is often marked by the ordinary high water or by a break in root vegetation. In many cases the TAC and the TOB are the same point; however, there may be situations where the TOB is higher than the TAC.

BR – Exposed Bedrock: In the event there is exposed bedrock in a cross section, the extents of the bedrock should be measured and included in the cross section.

BAR – Mid/Side Bar: In the event there is a mid/side bar in a cross section, the extents of the bar should be measured and included in the cross section.

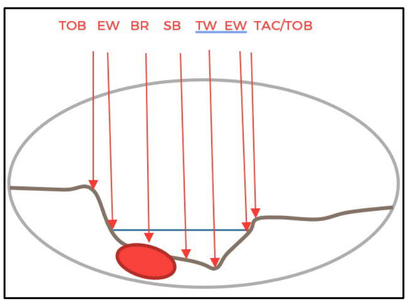


Figure 77: Cross-section Descriptions

To obtain the correct measurements in the field, identify the location of the cross-section to be measured and set the ends of the cross-section by driving stakes into the bank or using a magnetic hook. Tie a line level between the stakes verifying the line is level. Locate the first feature. Using a pocket rod, measure the horizontal distance from the river-left stake to the feature and document the *Horizontal (ft)* in aopMAP. At the same location, use the pocket rod to measure the depth from the line to the channel feature and document the *Vertical (ft)* in aopMAP. Click the radial button for the description code to document the *Description* of the feature.

Figure 78: Using magnet hooks, two field staff measure the interior cross section at Pre-emption Creek (top); while three field staff take interior cross section at Howe Brook (bottom)

D. INTERIOR STRUCTURE CROSS-SECTIONAL DATA

D1. Interior Structure Downstream Cross-Section

1. Length from upstream face of structure (ft):

Length (ft):

87

2. Reference height to crown/low chord of structure (ft):

Height (ft)

5.75

3. Interior Structure Upstream

Measurements (Use '+' to Add Multiple Points)

Horizontal (ft):

4.5

Vertical (ft):

3.85

Description:

EW TW SB TOB TOE TAC BR BAR

Description Abbreviations:
EW - Edge of Water
TW - Thalweg
SB - Streambed
TOB - Top of Interior Bank
TOE - Toe of Interior Bank
TAC - Top of Active Channel
BR - Exposed Bedrock
BAR - Depositional Feature

(measured from river-left to river-right while facing downstream)

2 of 2

Figure 79. Sample Interior Structure Cross-Sectional Data aopMAP

Figure 80: Field team uses the range finder function on the digital Clinometer to measure distance from cross section to upstream face of culvert on Pre-emption Creek (left) and a field member measures the distance from the line level to the crown of pipe on W. Branch Knife River (right)

The protocol user is to use these sections to document stream channel cross-sections at the upstream, downstream, and middle of interior of the structure. The measurements for upstream and downstream cross-sections should be taken inside the culvert within 5-ft of the inlet / outlet.

If the field team observes that there are notable variations in the shape of the interior channel that are not well defined by the upstream, downstream, and middle cross-sections; the user can define additional interior cross-sections to capture these variations. For example, if bedrock is present for a portion of the interior channel, a cross-section should be documented at the bedrock location and at a non-bedrock location.

II-E. Upstream Channel Information (200 Feet Upstream)

This section will document the condition of the upstream channel from the upstream face of the culvert to 200-feet upstream.

II-E1. Upstream Channel Alterations

Document *upstream channel alterations*. Follow the methodology described in section *II-B1. Downstream Channel Alterations.*

II-E2. Typical Upstream Channel Characteristics

Document *typical upstream channel characteristics* including *geomorphic channel type*, *channel bed material*, and *average channel slope*. Follow the methodology described in section *II-B2. Typical Downstream Channel Characteristics.*

II-E3. Upstream Channel Depositional Characteristics

Document the *upstream channel depositional characteristics.* Follow the methodology described in section *II-B3. Downstream Channel Depositional Characteristics*.

II-E4. Upstream Channel Features

Document the *upstream channel features.* Follow the methodology described in section *II-B4. Downstream Channel Features.*

II-E5. Channel Scour

Document the upstream *channel scour.* Follow the methodology described in section *II-B6. Channel Scour*.

II-E6. Upstream Large Roughness Feature

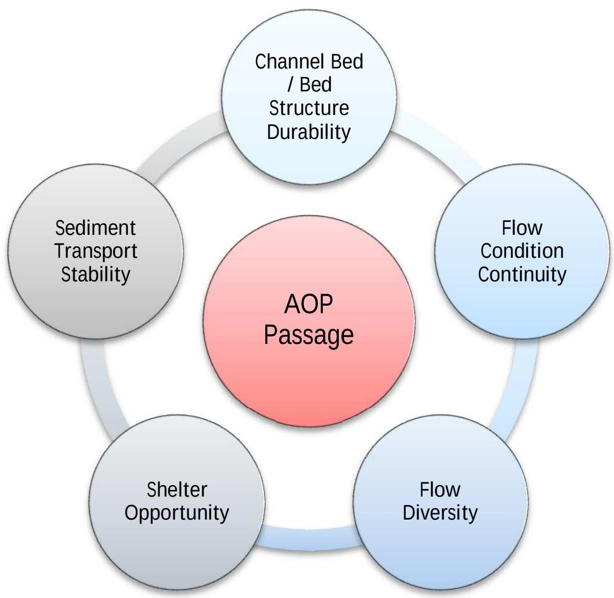
Document the *upstream large roughness features.* Follow the methodology described in section *I-F5. Channel Large Roughness Features.*

II-F. Visual Assessment

The assessment team will utilize the visual assessment portion of the protocol to provide qualitative rankings on the five themes that are potential contributing factors to AOP project effectiveness. The five themes are:

- Channel Bed / Bed Structure Durability
- Flow Condition Continuity
- Flow Diversity
- Refuge Opportunity
- Sediment Transport Continuity

The visual assessment is performed to provide nuance and additional information to support the qualitative data collected during the protocol. The visual assessment is an important step in the process as the qualitative data collection points may not tell the complete story for an AOP crossing and several important factors in AOP success may not be well represented in the quantitative data. The Visual Assessment is concluded with the field team documenting their qualitative opinion on whether the structure provides adequate AOP for all species at all stages.



II-F1. Channel Bed/Bed Structure Durability

When considering an assessment of Channel Bed Durability, the assessment team is asked the following questions:

- Are the constructed channel bed materials stable?
- Have any passage blockages developed (headcuts, discontinuity at the ends of the structure)?
- Does the bed have smooth profile transitions in and out of the structure?

Rate the severity bed instability or loss of streambed material observed at the AOP structure from *very stable* to *very unstable*. The field team's observations that indicate bed instability may include exposed subsurface grade control structures, scour in the channel bed, exposure of coarser rock aggregate bedding layers, variations in bed material sizes (coarse areas versus fine areas), deposition of culvert bedding material downstream of the structure, and aggradation or degradation in the AOP structure. The assessment team should document the bed condition and any suspected evidence of instability with photographs. In subsequent years, the assessment teams could use a comparative analysis of photographs to help determine the stability / durability of the channel bed.

Degree of Bed Durability				
Very Stable	**Moderately Stable**	**Mixed Stability**	**Moderately Unstable**	**Very Unstable**
Greater than 90% of the channel bed shows no signs of bed material movement. No notable scour hole formations, headcuts, or profile discontinuities	More than 80% of the channel bed shows no signs of bed material movement. Some channel areas have observable coarsening of surface sediments.	Channel bed is generally stable throughout the structure with more than 70% of the bed material showing little signs of movement. Some localize scour hole formations, but they do not impact the overall hydraulic performance of the structure.	Large areas (more than 50%) of the channel riffles are showing evidence of movement. Significant scour hole formations notable that are impacting flow paths. Small areas (less than 20%) of structure foundation or bottom are exposed.	Less than 40% of the channel bed material remaining. Mass movement of bed sediments occurring within structure and significant exposure of structure bottom or foundations
1	***2***	***3***	***4***	***5***

Figure 81: Bed instability: White River is Very Stable with no signs of bed movement (left); Pre-emption Creek is Very Unstable, the lower spray paint marker indicates original streambed elevation, higher spray paint marker indicates original interior bank elevation (right)

Rate the extent of AOP passage blockage from no blockage to full blockage. Blockages may include woody debris, sediment, trash, or vertical drop. Document blockages with photographs.

AOP Debris Blockage				
No Blockage	**Minor Blockage**	**Weak Species Blockage**	**Significant Blockage**	**Full Blockage**
Interior channel is largely free from debris, no blockages or obstructions to flow are present.	Interior channel has debris formations that impact flow conditions but allow for flow depth and velocity combinations comparable to other channel areas.	Interior channel has moderate sized debris formations that significantly impact flow conditions causing higher than typical velocity conditions for the channel.	Interior channel has significant debris formations that fully alter flow conditions causing very high velocity conditions for the channel.	Interior channel has multiple significant or complete debris blockages. No undisturbed open channel flow is observable.
1	***2***	***3***	***4***	***5***

Figure 82: AOP Blockages: No blockage of W. Branch Knife River (left) and Significant blockages of left barrel of East Branch Beaver River (center) and Tributary to Saint Louis River (right)

Rate the abruptness of transition in and out of the AOP structure from no visible transition to a major transition. An AOP structure has no visible transition when the channel profile has no observable changes either upstream or downstream of AOP structure and inside the structure. A major transition is observed when there is an abrupt change to the streambed profile at the inlet, within the AOP structure, or at the outlet.

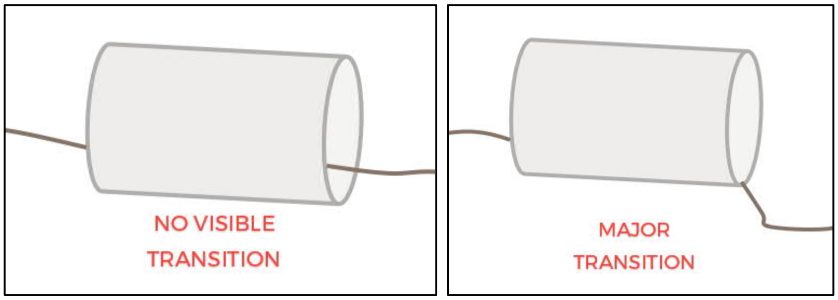


Figure 83: Profile transitions

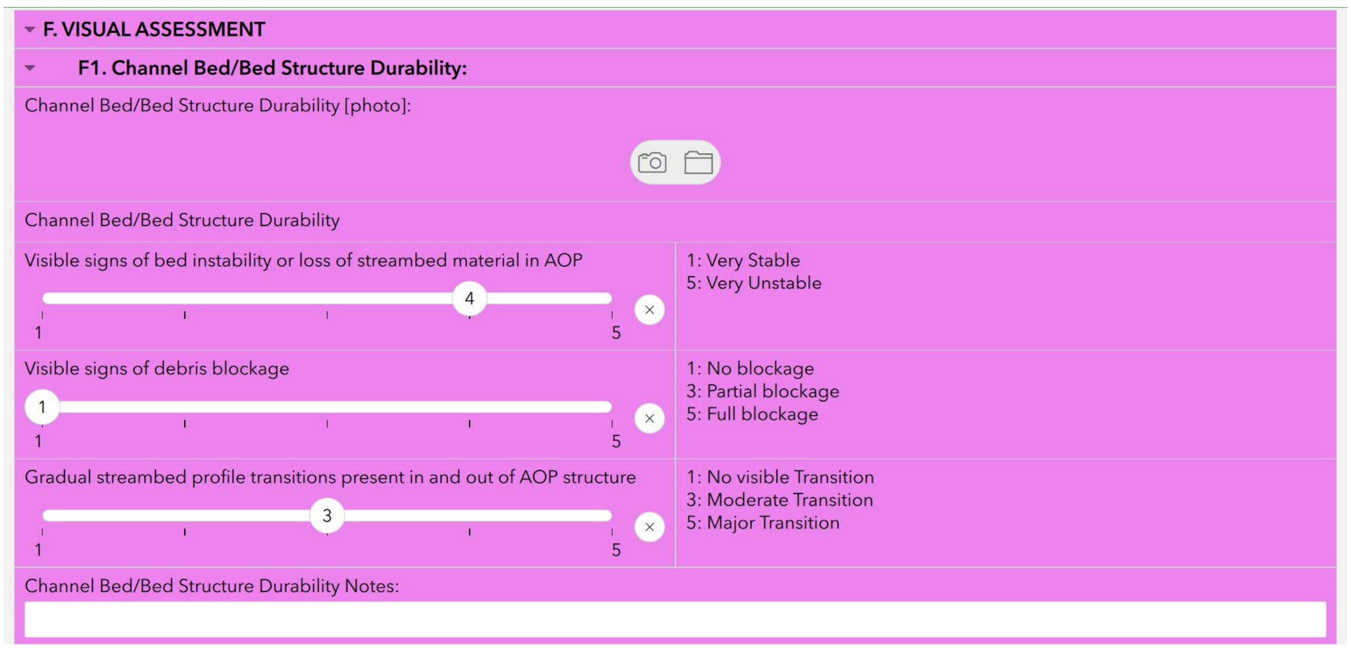


Figure 84: Sample of Channel Bed/Bed Structure Durability aopMAP

II-F2. Flow Condition Continuity

When considering an assessment of Flow Condition Continuity, the assessment team is asked the following questions:

- Do we have rapid contractions and expansions of flow entering and existing the structure that could inhibit passage or stability?
- Does the channel support maximum low flow depths and velocities documented in other areas of the channel?
- Are we losing baseflow due to piping through the constructed bed?

Rate the severity of contraction and/or expansions at the AOP structure from *none* to *excessive*. Observations may include:

Degree of Contraction and Expansion						
Contraction >30%	**Contraction <25%**	**Contraction <10%**	**None**	**Expansion <10%**	**Expansion <25%**	**Expansion >30%**
The crossing's interior channel low flow and top of active bank widths are greater than 30% narrower than the approaches.	The crossing's interior channel low flow and top of active bank widths that are 10% to 25% narrower than the approaches.	The crossing's interior channel has low flow and top of active bank widths that are up to 10% narrower than the upstream and downstream approach channel widths.	The crossing's interior channel has low flow and top of active bank widths that match the upstream and downstream approach channel widths.	The crossing's interior channel has low flow and top of active bank widths that are up to 10% wider than the upstream and downstream approach channel widths.	The crossing's interior channel low flow and top of active bank widths that are 10% to 25% wider than the approaches.	The crossing's interior channel low flow and top of active bank widths are greater than 30% wider than the approaches.
-3	***-2***	***-1***	***0***	***1***	***2***	***3***

Rate the continuity of the flow condition from the reference reach to the AOP structure from *replication* to *changed.* An observation of no change in the flow condition upstream or downstream of the structure and through the structure rate replication.

Flow Condition Continuity				
Replication	**Minor Variation**	**Functional**	**Significant Variation**	**Changed**
The crossing's interior channel's average flow depth, width and velocity match the flow conditions in a reference reach riffle.	The crossing's interior channel's average flow depth, width and velocity are all within 10% of the flow conditions in a reference reach riffle.	The crossing's interior channel's average flow depth, width and velocity are all within 20% of the flow conditions in a reference reach riffle.	The crossing's interior channel's average flow depth, width and velocity are all within 30% of the flow conditions in a reference reach riffle.	The crossing's interior channel's average flow depth, width and velocity are more than 50% deviated from the flow conditions in a reference reach riffle.
1	***2***	***3***	***4***	***5***

Rate the percentage of baseflow observed piping through the bedding material. If no piping is observed, select 0%. If flow is observed entering the AOP and fully piping below the bed material, select 100%.

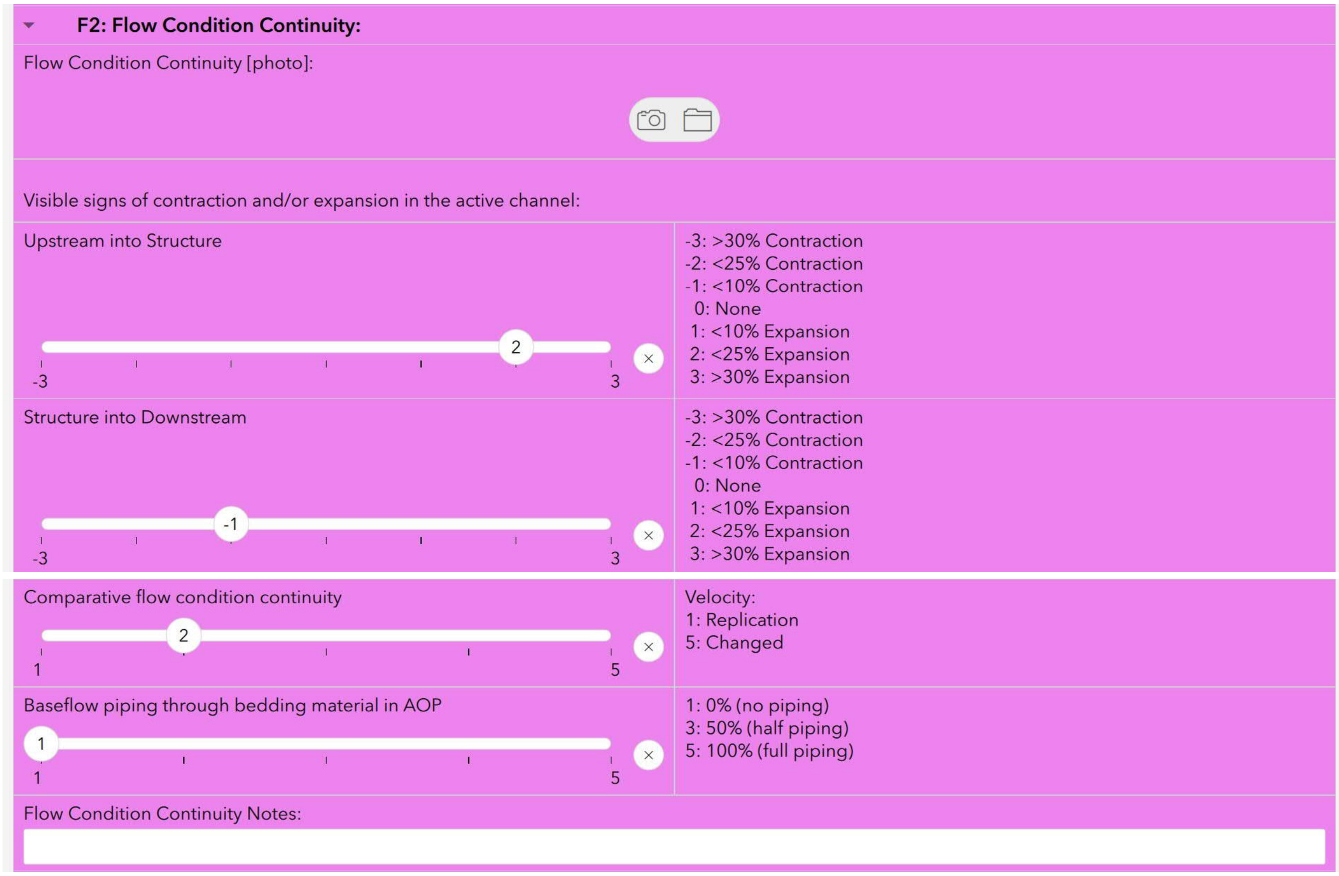


Figure 85: Sample of Flow Condition Continuity aopMAP

II-F3. Flow Diversity

When considering an assessment of Flow Diversity, the assessment team is asked the following questions:

- What degree or flow diversity is necessary in a structure to allow passage of all species within a system?
- Are there certain flow regimes in the reference reach channel that hold more value for passage than others and are they present in the AOP crossing?
- Does the degree of flow diversity in the structure need to be analogous to the diversity supporting habitat in other areas of the stream?

Rate the presence and distribution of roughness features observed at the AOP structure and in the natural channel. Roughness features cause drag on the channel flow, which increases velocity diversity. Roughness features include baffles and boulder clusters. In addition to the presence of roughness features observe their distribution within the AOP structure. If no roughness or very limited roughness features are observed, select limited. If roughness features are present but not well-distributed through the AOP structure, select several, not well-distributed. If roughness features are present throughout the AOP structure, select several, well-distributed. Complete the same rating for the reference channel.

Roughness Features				
Several Well Distributed				**Limited Not Well Distributed**
Interior channel includes multiple channel large roughness features / protrusions that impact flow causing eddying and stagnation areas. The large roughness features are well distributed throughout the channel improving the overall diversity of flow conditions	Interior channel includes multiple large roughness features. The large roughness features are slightly clustered or distributed with coverage gaps and improve the diversity of less than 75% of the channel.	Interior channel includes multiple large roughness features. The large roughness features are clustered into limited areas and only improve the diversity within 50% of the channel.	Interior channel has few of highly clustered large roughness features. The features impact limited areas and improve the diversity of less than 25% of the channel.	Little or no large roughness features are present in the interior channel.
1	***2***	***3***	***4***	***5***

Rate the flow path diversity observed at the AOP structure from *poor* to *optimal*. There are four condition regime that contribute to habitat optimal flow diversity conditions:

The assessment team will need to observe velocity and depth combinations within a systems reference reaches to define slow, fast, deep and shallow as each system and the AO supported by the system have unique considerations. Observe how many flow patterns are present in the AOP structure. Complete the same rating for the reference channel.

Don't get too focused on the 4 flow regimes, rely on the fish biologist. Consider this as a comparative exercise. How does the channel outside look and how does the channel inside compare? We do not want to change this to a straight comparative ranking (Still want absolute), b/c we've seen systems with poor flow diversity (think of alike a deep flowing wetland) that would rate very well.

Flow Path Diversity				
Complex	**Well Varied**	**Moderately Varied**	**Somewhat Varied**	**Uniform**
All flow condition regimes are present. Multiple flow paths exist through riffle / cascade areas.	All four flow condition regimes are present. Few defined flow paths exist through riffle / cascade areas.	Only three (3) of the four (4) flow condition regimes are present.	Only two (2) of the four (4) flow condition regimes are present.	1 flow condition regime and a single flow path.
1	***2***	***3***	***4***	***5***

Figure 86: Flow path diversity: Optimal diversity (left); Poor diversity at Blooms Ditch (right)

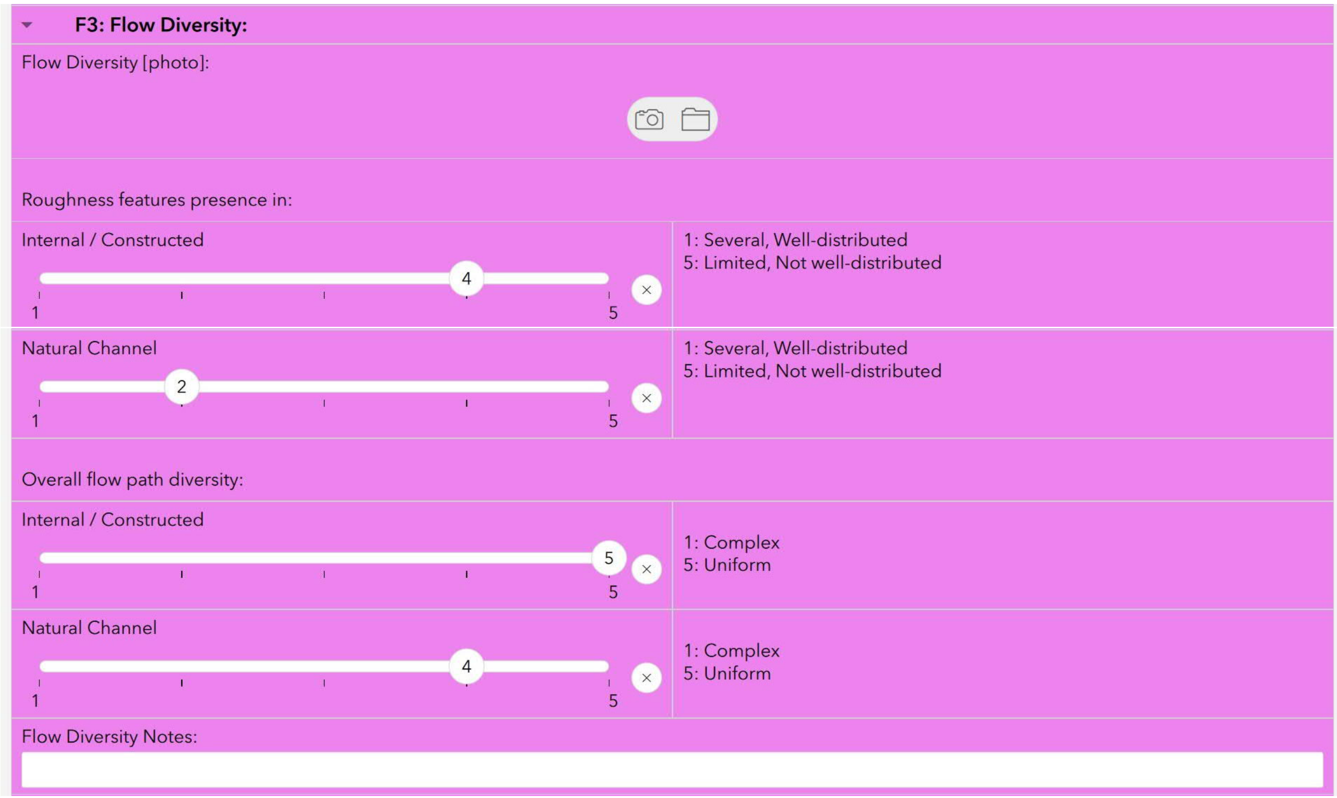


Figure 87: Sample of Flow Diversity aopMAP

II-F4. Refuge Opportunity

When considering an assessment of Refuge Opportunity, the assessment team is asked the following questions:

- How much opportunity are designs providing for weak swimmers to pass via edge effects or otherwise?
- Can opportunity be found without the use of streambanks?

Good refuge opportunities occur when the channel provides continuous edge effect areas with flow stagnation, multiple well-distributed roughness features that form eddy and stagnation areas within short swim distances for weak swimming AO to rest. Poor refuge opportunities occur when the channel has no structures or banks that provide rest areas for AO. Refuge opportunity should be evaluated for both the low flow and high flow conditions. The refuge opportunity should be assessed comparing the opportunities within the AOP structure to opportunities in the natural channel.

Comparative Refuge Opportunity						
Significantly Less	**Less**	**Somewhat Less**	**Same**	**Somewhat More**	**More**	**Significantly More**
The AO structure provides significantly less rest areas for AO when compared to the natural channel outside the AO structure.			The AO structure provides similar rest areas for AO when compared to the natural channel outside the AO structure.			The AO structure provides significantly more rest areas for AO when compared to the natural channel outside the AO structure.
-3	*-2*	*-1*	*0*	*1*	*2*	*3*

Figure 88: Sample of Refuge Opportunity aopMAP

II-F5. Sediment Transport Continuity

When considering an assessment of Sediment Transport Continuity, the assessment team is asked the following questions:

- Is the structure in balance with the upstream and downstream sediment conditions?
- Is the structure functioning as a stable transport reach?

The sediment transport should be assessed comparing the bedload characteristics within the AOP structure to the opportunities in the natural channel. Bedload characteristics should be evaluated based on the size and frequency of the depositional features and bedload size.

Bedload continuity should be evaluated at the AO structure inlet and within the AO structure barrel.

Bedload Continuity						
Degrading			**Balanced**			**Aggrading**
Observed streambed erosion and scour. Exposed AO structure foundations.			AO structure bedload appears stable.			Observed bedload deposition.
-3	***-2***	***-1***	***0***	***1***	***2***	***3***

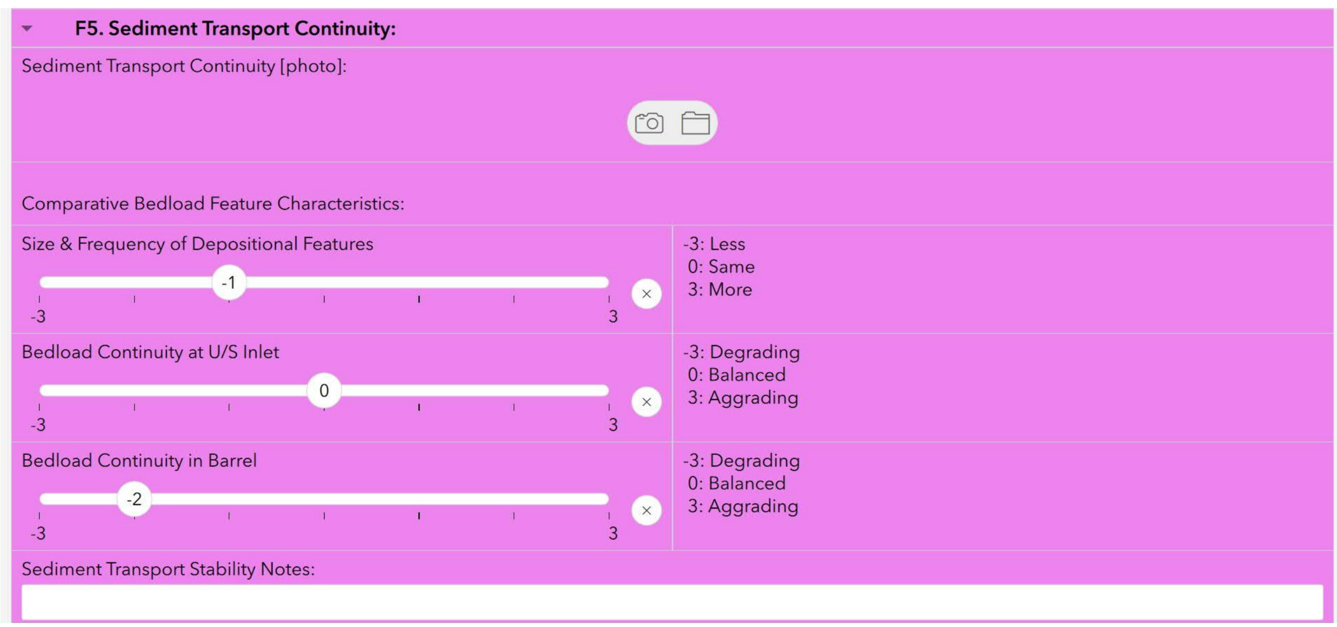


Figure 89: Sample of Sediment Transport Continuity aopMAP

II-F6. AOP Passage Conditions

Based on all the observations, the field team should note their qualitative opinion on whether the AOP provides passage, partial passage, or no passage. This should be based on the best knowledge of the team.

AOP Passage Conditions				
Full Passage		**Partial Passage**		**No Passage**
All species during all life stages at any season could reasonably be expected to pass the AOP		Passage exists for some species or during some life stages or during some seasonal flows		No passage is anticipated for any species during any time of the year
1	***2***	***3***	***4***	***5***

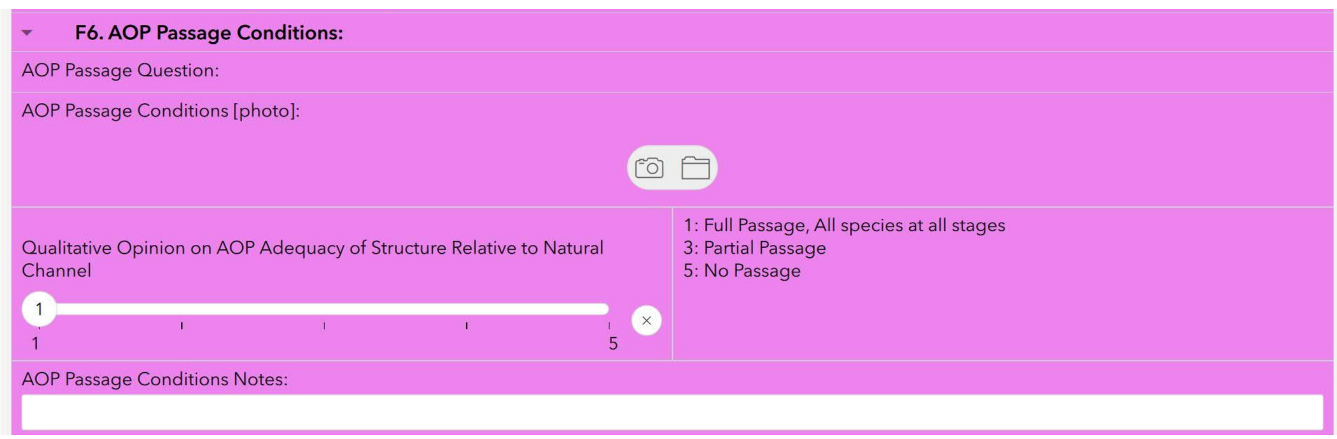


Figure 90: Sample of AOP Passage Conditions aopMAP