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Locating Your Trail Bridge for Longevity



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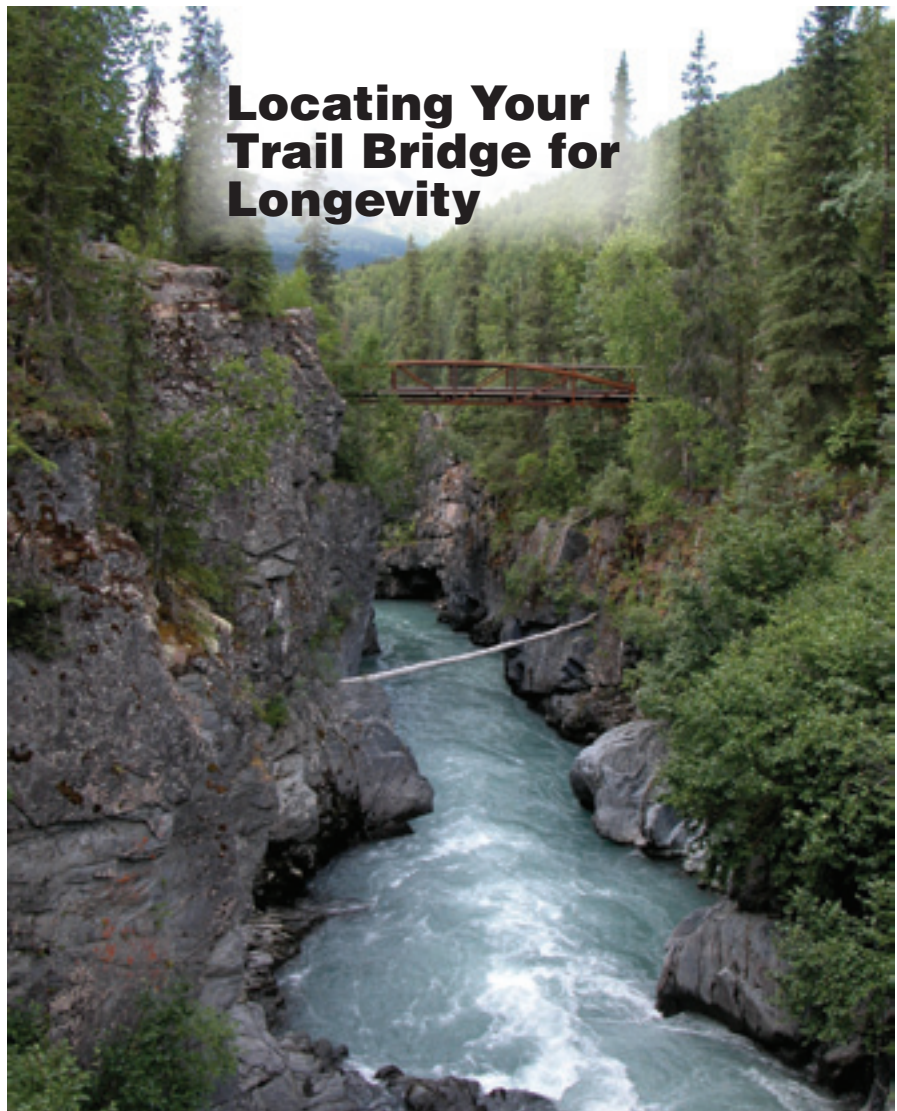
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Locating Your Trail Bridge for Longevity

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8E82A67 Trail Bridge Planning and Siting

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Introduction

Trail bridges that are constructed in a poor location or that are the wrong size are more susceptible to failure. Bridges typically are the most expensive item on a trail, so it's important to get them right the first time. Good bridge siting involves many disciplines. It requires careful attention to preliminary engineering, hydraulics and hydrology, trail alignment, and environmental and geomorphic concerns. All of these concerns must be addressed to make sure that the structure is appropriate for the site.

This report focuses on locating new single-span trail bridges shorter than 50 feet (figure 1), but the same considerations can be used for relocating or reconstructing trail bridges. The National Environmental Protection Act (NEPA) requirements, landownership issues, Federal and State permitting requirements, and trail bridge types are beyond the scope of this report and will not be discussed. You can find more information on trail bridge types, decks, rail

systems, materials, and abutments on the Trail Bridge Catalog Web Site <<http://www.fs.fed.us/eng/bridges/>>.

Highlights...

- Siting trail bridges properly will increase the likelihood that the stream will continue functioning properly and that the bridge will be useful throughout its planned life.
- Knowledge of the Rosgen stream classification system can help resource managers choose suitable sites for trail bridges.
- Trail bridges that are sited properly are less likely to be damaged or destroyed during a major flood.



Figure 1—A new fiber-reinforced polymer trail bridge in the Sam Houston National Forest.

Preliminary Engineering

Preparations for site investigations include collecting topographical maps, infrared photography, remote sensing images, geographical information system (GIS) coverages, and aerial photographs. Topographic maps (figure 2) can help when you are locating a bridge. They show contour lines of the proposed bridge site, the width and slope of the channel, and other important topographical features. Topographic maps may be ordered from the U.S. Geological Survey. Forest Service employees can download maps <<http://fswb.clearinghouse.fs.fed.us/maps/maps.html>>.

Reviewing a number of years of aerial photographs and understanding stream types (figure 3) can help determine whether a stream is stable. Stable streams will show up in the

same location year after year, while unstable streams may change locations or widths in photographs from different years. Two sources of free aerial photographs on the World Wide Web are Google Earth <<http://earth.google.com/>> and Microsoft Virtual Earth <<http://www.microsoft.com/virtualearth/>>. Image quality varies from State to State. Aerial photographs can be purchased from the U.S. Department of Agriculture, Farm Service Agency aerial photography field office <<http://www.fsa.usda.gov>>.

Infrared photographs (figure 4) may show springs, wetlands, or other areas that are prone to being wet, helping designers avoid areas with poor foundation soils where trail and bridge construction is difficult and expensive.

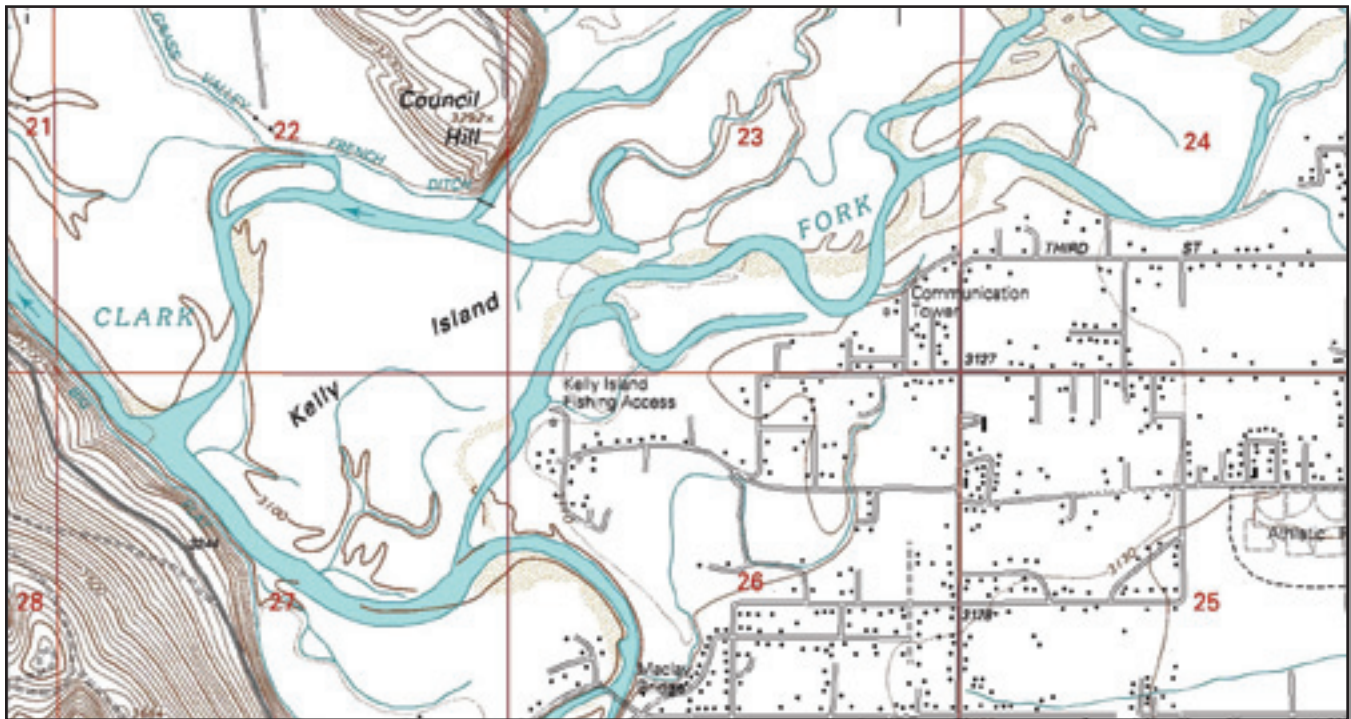


Figure 2—Topographic maps can help when locating suitable sites for bridges. When paired with aerial photographs (figure 3), topographic maps are even more valuable.



Figure 3—A series of aerial photographs taken during different years can help show whether the stream is stable at a proposed bridge site. This photograph shows the portion of Missoula, MT, displayed in the topographic map (figure 2).

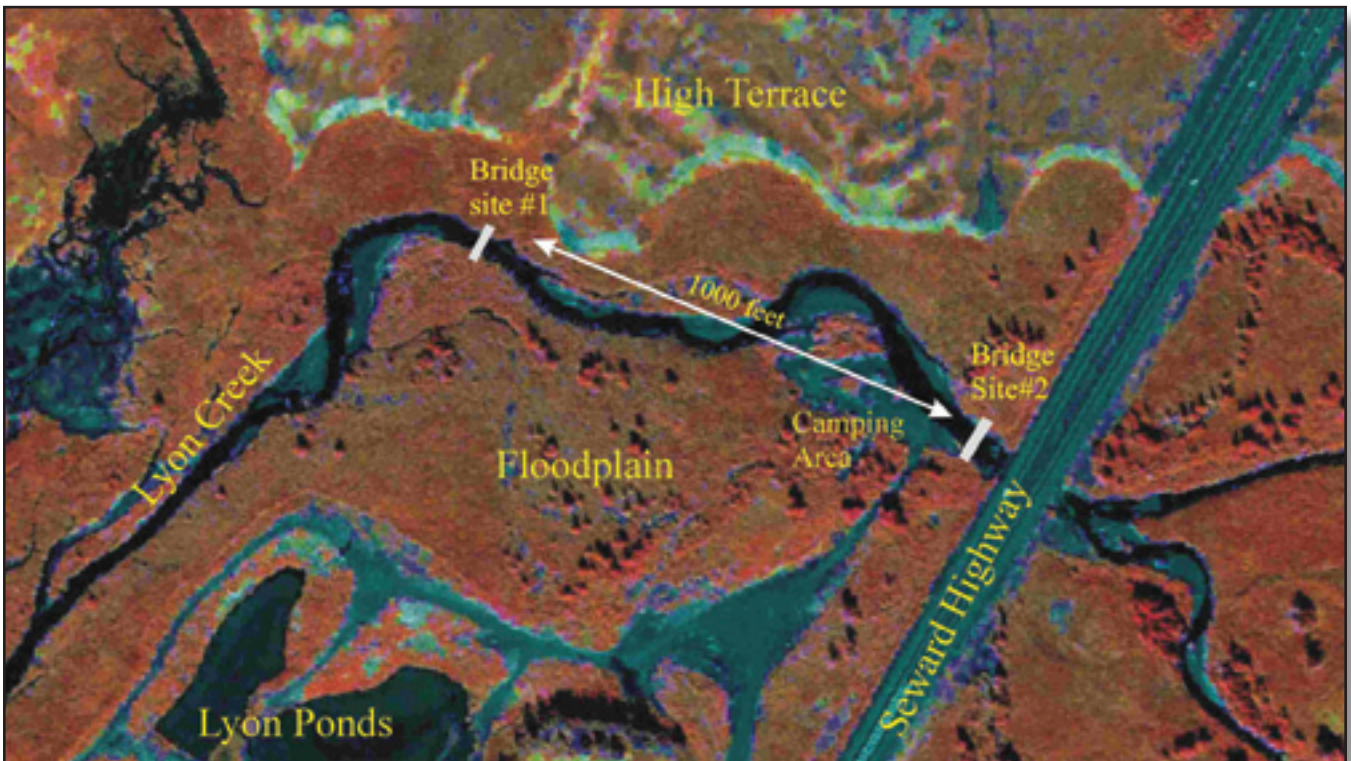


Figure 4—Vegetation growing rapidly in areas that are prone to being wet will be red or orange in infrared photographs.

Site work includes site investigation, site surveys, and geotechnical investigations. Simple investigations are adequate for sites where the abutment locations are controlled by highways, railroads, lined ditches, canals, or dams (figure 5). Other bridge sites require a thorough investigation because of problems associated with stream dynamics, wildlife concerns, or other factors (figure 6). The more complex the site, the more important it is to form an interdisciplinary team. The team may include bridge and transportation engineers, geologists/geotechnical engineers, fisheries and wildlife biologists, hydrologists, botanists, archeologists, and soil scientists.



Figure 5—Some sites are very simple and require only minor site investigation.



Figure 6—More complex sites require in-depth investigation by an interdisciplinary team.

Site investigation includes walking the upstream and downstream reaches and talking to long-time residents about flooding and debris jams. Some questions that should be addressed are:

- What time of year have floods occurred?
- How high does the water get? Does the stream flood over its banks?
- How much debris does the stream usually carry? Is damming a problem?
- Does the stream have ice flow problems?

During field reconnaissance, the stream should be reviewed for dynamic sections where the channel is moving (laterally and vertically) and problem areas that should be avoided, such as deltas, alluvial fans, actively aggrading/degrading sections, sharp bends, multithreaded channels, sloughs, wetlands, and flood plains. Numerous photos (figures 7, 8, 9, 10, 11, and 12) should be taken of the proposed bridge site, banks, stream corridor, and other important features.



Figure 7—A photograph of trail location at a proposed bridge site (Tombigbee National Forest).



Figure 8—A photograph looking at the site of one of the proposed abutments.



Figure 11—A photograph looking upstream from the proposed bridge site.



Figure 9—A photograph looking at the site of the other proposed abutment.



Figure 12—A photograph looking downstream from the proposed bridge site.



Figure 10—A photograph looking at a waterway at the proposed bridge site.

The ordinary high water (OHW) or bankfull stage indicators from flows expected every 1 to 2 years should be identified using geomorphic features in the field (Stream Systems Technology Center 2004). The stream bankfull depth and flows (figure 13) are used for hydraulic modeling and for verifying that the structure will be long enough. In figure 13, Q is the discharge in cubic feet per second. Videos showing how to determine bankfull stage can be viewed at <http://www.stream.fs.fed.us/publications/videos.html> or can be ordered at <http://www.stream.fs.fed.us/>.

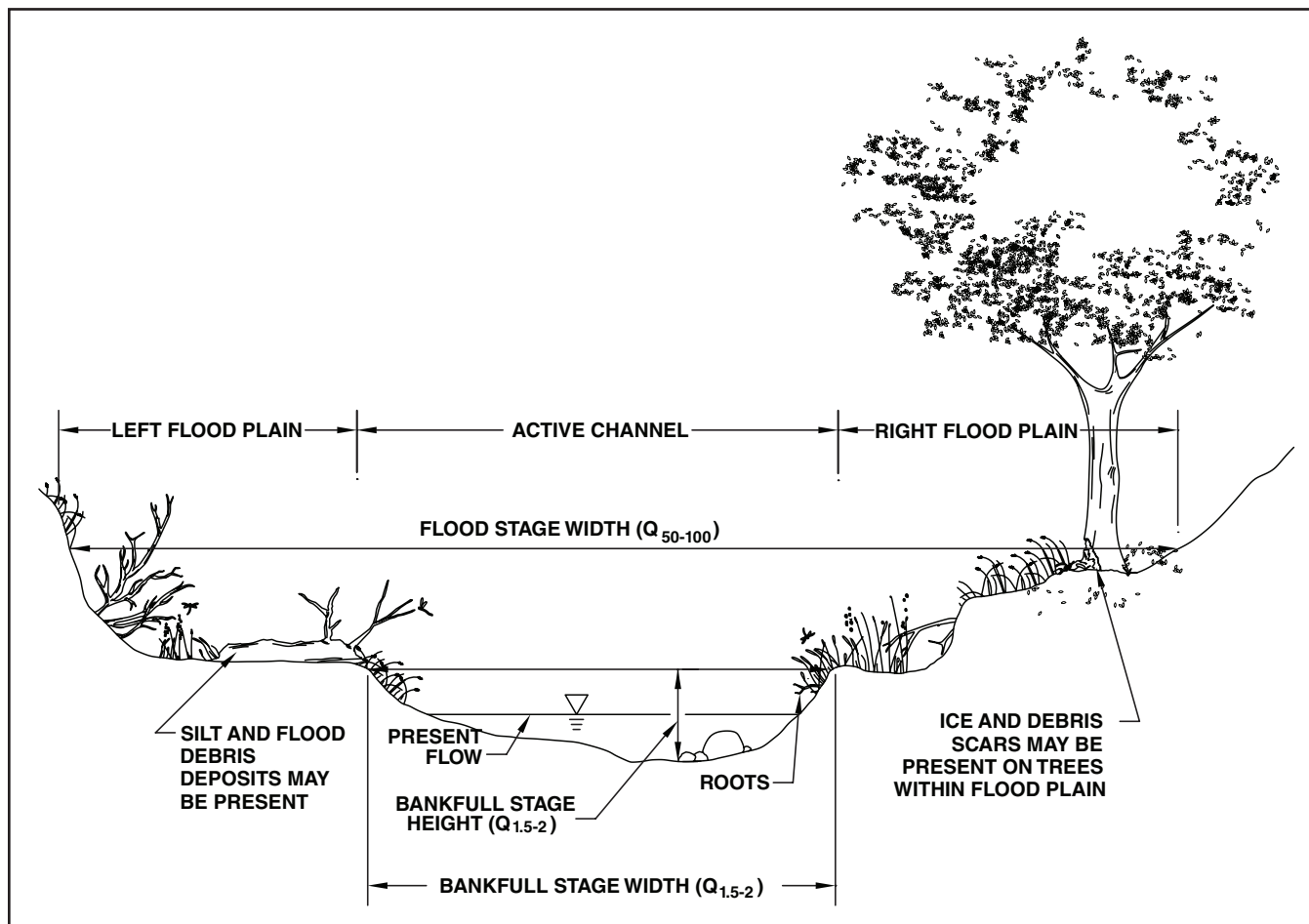


Figure 13—Schematic showing how to determine the bankfull width. Flood stage height Q_{50-100} is about twice the bankfull stage height $Q_{1.5-2}$.

For streams with gauges measuring flows, the Q_2/Q_{bankfull} relationship can be determined using stream-gauge data to validate modeled flow projections. For streams that do not have a gauge, the bankfull flow determined using the bankfull indicators can be compared to the peak flow the model projects for every 1.5 to 2 years (the $Q_{1.5-2}$ flow value).

Also, it is valuable to get a field estimate of the elevation that corresponds to large floods. This elevation can be checked with estimates of the flood peak flows expected every 50 to 100 years (Q_{50-100} flow value) to verify model projections. A rule of thumb used when estimating the flood depth is to determine the approximate maximum bankfull depth in a riffle and double it. This is the depth of the floodprone area in a representative channel section that

might be flooded during a Q_{50} to Q_{100} floodflow. Design criteria that are affected by the floodflow and conveyance across the flood plain include minimum clearances for water and debris, areas where erosion and flooding might be a concern, and the types of trail tread that should be required on the approaches.

The stream should be investigated for at least 1,500 feet upstream and downstream from the proposed bridge. This investigation will help identify factors affecting the structure. For example, streams with bedrock bottoms and banks will have less chance of scour. Additional items that require investigation include:

- Structures upstream and downstream
- Manmade channel control structures, such as dams or weirs

- Natural control points, such as bedrock channels or steps in channels with step ponds, formed by woody debris or rocks
- Potential for movement of bedload and woody debris
- Bankfull indicators and high water marks
- Ice damage, scars, or marks
- Bank and stream channel stability (figures 14 and 15)
- Springs and groundwater flow
- Side channels on trail approaches
- Flood plains and deltas (figure 16)
- Soil types and streambed strata
- Geotechnical information
- Navigational clearance requirements
- Indications of beaver activity

All features that are not normally included in a survey map should be flagged to ensure they won't be missed by the survey crew. A topographic map, typically showing 1-foot contours, should be prepared after site surveys (figure 17) have been conducted. Appendix A includes an example of a site survey map and a checklist. Free software that helps turn survey data into topo maps is available at <http://www.sitetopo.com>. Other commercial terrain modeling software (such as Terramodel, AutoCAD, or MicroStation) can be used for design.



Figure 14—Naturally occurring scour at a bridge.



Figure 15—Scour caused by constricting the channel at the bridge site.



Figure 16—This bridge is on a side stream and in a flood plain. The back-water effect during floods on the main stream has floated this bridge away twice.

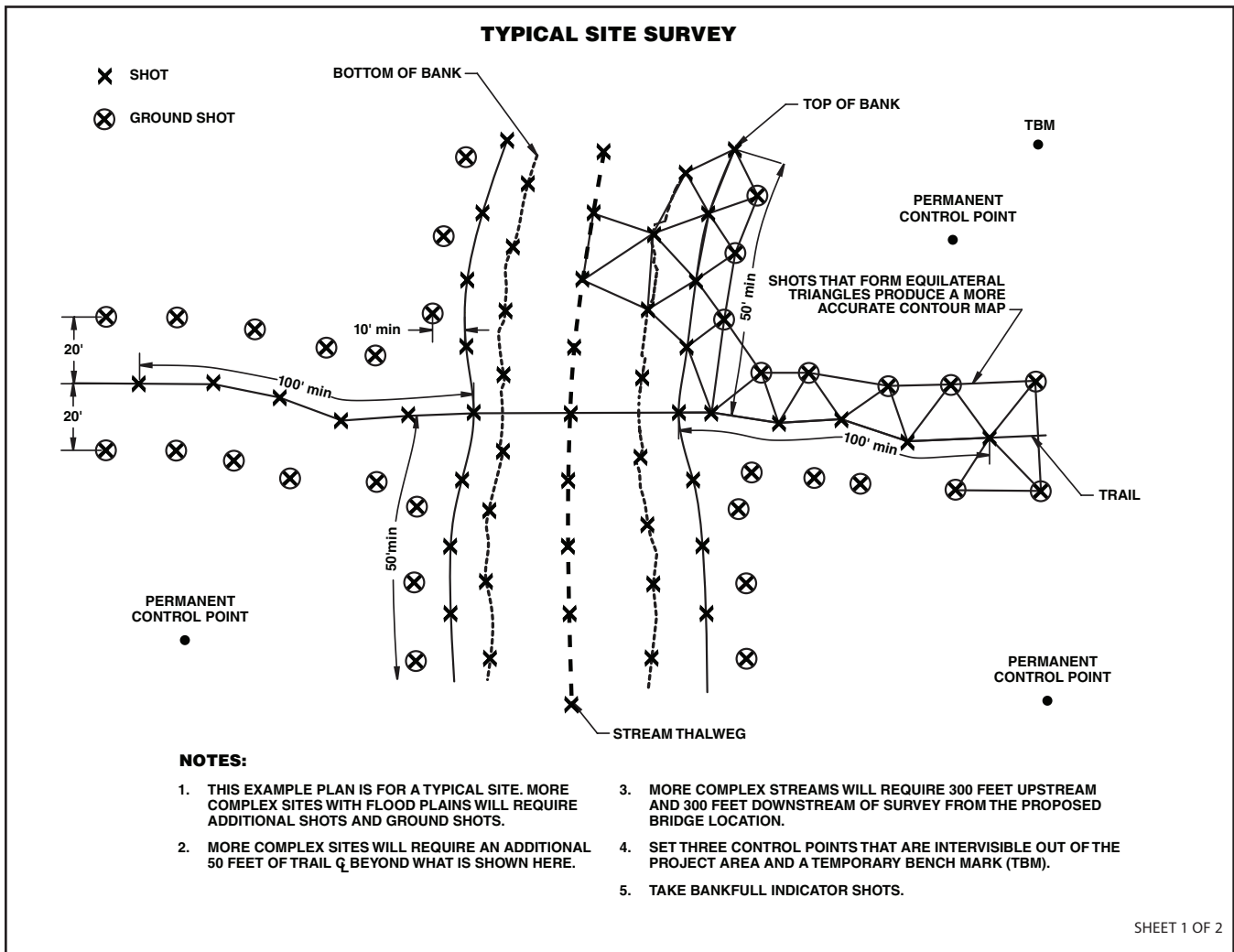


Figure 17—Typical survey points that should be taken to produce a quality topographic map for the trail bridge site.

The amount of geotechnical investigation required varies depending on the site (figures 18 and 19). A geotechnical engineer should investigate the site for soil and bedrock conditions. An easy method used by the Forest Service is the Williamson Probe (Hall and others 2004). The probe works best when used in gravel or sand, which gives the operator an idea of the relative density of the sand and the depth of soft zones encountered. Borings are desirable for sites with unacceptable soils (unstable soils, clays, silts) or highly fractured shear bedrock faces. Bedrock should be assessed for the degree of fracturing, gaps between the fractured

surfaces, the material's hardness, and the degree to which it has weathered.

Wet and unstable sites and sites with clay and silt soils should be avoided, if at all possible. Unsuitable foundation material can cause structures to settle and fail. All major bridge sites should have a geotechnical study completed with at least one boring drilled for each abutment or pier. The type of bridge substructure is site specific and should be designed with the assistance of a geotechnical engineer (Davis 2001, Michigan Department of Transportation 2004).



Figure 18—A rock, cobble, and gravel streambed.



Figure 19—A bridge abutment placed on a bedrock streambank.



Hydraulics and Hydrology

Hydrology calculations should be completed by a hydrologist familiar with the local conditions and streamflows. These calculations should include at least the Q_2 and Q_{100} flows. Streamflow in the United States usually is calculated using regression equations or modeling programs, such as the U.S. Geological Survey National Streamflow Statistics Program or the Hydrologic Engineering Center–Hydrologic Modeling System (HEC–HMS). The results of several models should be compared because discharge calculation is not an exact science.

Other methods for calculating streamflow compare the watershed being crossed to an adjacent watershed with similar physical characteristics that already has hydrologic data. A gauged stream in the adjacent watershed can be used to compare your results and calibrate the modeled streamflow. Discharge measurements (Harrelson and others 1994) are a great way to calibrate the flow model for your site. Try to get at least one discharge measurement above a baseflow

(the streamflow during the drier portions of the year). In addition, a hydrologist should conduct a pebble count and gather substrate information to estimate the channel roughness value and scour potential. The channel roughness values, as well as substrate and streamflow information, will be used to calculate the hydraulics (characteristics such as depth, velocity, and slope) for the site.

Hydraulic calculations can be performed using many different computer programs. Two of the most common programs used in the United States are the Hydrologic Engineering Center–River Analysis System (HEC–RAS, <<http://www.hec.usace.army.mil/>>, figure 20) and WinX-SPRO <<http://www.stream.fs.fed.us/publications/winxspro.html>>, a computer model that analyzes a stream channel cross section to estimate the elevation of the water surface for a given flow, slope, and streambed roughness. Both of these programs are public domain (not copyrighted) and can be downloaded for free.

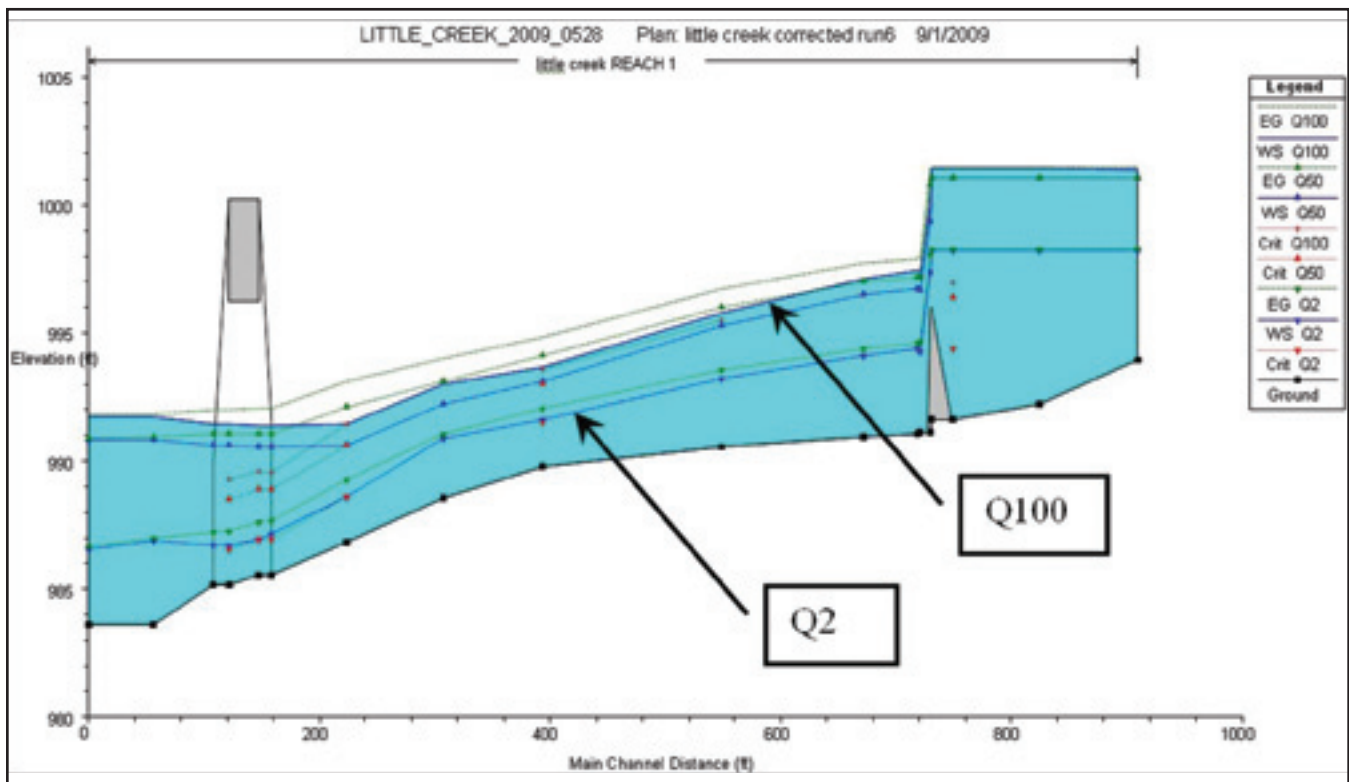


Figure 20—Example water elevation profile produced by the Hydrologic Engineering Center–River Analysis System.

After calculations are completed, verify results with field observations, such as bankfull stage indicators, high-water marks, streambed strata, stream velocity, and information from local residents.

A scour analysis should be completed for every stream-crossing project. This analysis considers the stream velocities and the materials on the bottom and banks of the channel to determine how much the bottom and banks might erode at different flows.



Figure 21—This bridge is set high to allow rafters to pass underneath.

The seasons of the peak flows and their causes should be taken into account during bridge design so the bridge can be constructed when flows are low. The timing of peak flows varies from region to region. For instance, the peak flows may be caused by spring runoff from mountain snowpack or by hurricanes or monsoons. Construction also should be scheduled during periods when fish are not migrating or spawning.

Navigational clearance is required in many streams and must be provided at high water. Minimum clearance for navigation varies, depending on the type of boat traffic. Floating trees or debris present another problem during floods. The minimum clearance (freeboard) for floating trees can be estimated as half of the root wad's longest dimension, plus 1 meter added for safety (figures 21 and 22). This estimate is conservative and should be based on the size of the root wads of the largest trees that the stream can transport during design floods.



Figure 22—Rafters enjoying a day on the river.

Geomorphic Concerns

The geomorphology of the watershed and channel play key roles when locating bridges. Basic geomorphic principles help designers understand the geomorphic processes and difficulties that can arise when bridges cross streams at various positions in the watershed. These processes change with the crossing's location in the watershed and along the reach that will be crossed. Channels are extremely dynamic, responding to changes in the watershed by propagating changes downstream to upstream and vice versa, depending on the channel's elevation in the watershed, the type of disturbance, and the channel types along the stream. To choose the best location for a bridge, the designer should address the following questions:

- Where is the crossing location in the watershed and how does the stream transport water, sediment, and wood?
- How is the channel configured?
 - ◇ What is the degree of channel containment/entrenchment?
 - ◇ During high flows is water conveyed in the flood plain (flood plain conveyance)? If so, how much? Are there side channels or flood swales?
 - ◇ Can the stream move laterally and affect the crossing during the structure's design life? Are the stream's banks erodible or not?
 - ◇ What is the range of vertical fluctuation of the streambed during the structure's design life?
- How well does the trail and bridge alignment mate with the stream alignment?
- Is the channel stable?
- Is the channel adjusting to recent large-scale disturbances (such as landslides)?

The location of a stream reach in its watershed determines the reach's channel morphology and responsiveness to natural or manmade disturbances (Gubernick and others 2003). Slope, discharge, sediment, and vegetation are the main controlling factors. The way a channel is configured provides information that can help you decide whether a crossing is in a good, safe location or whether the location

will require extensive analysis and design and where the crossing may be costly. Channel classification has been an excellent tool for describing stream configurations and for interdisciplinary communication. The two main channel classification schemes are Montgomery and Buffington (Montgomery and Buffington 1993) and Rosgen (Rosgen 1994).

The Montgomery and Buffington system is based principally on watershed position, slope, and the geomorphic description of bed characteristics. Additional information may be found at <<http://www.fgmorph.com/>>.

The Rosgen system (figures 23 and 24) is based on slope, entrenchment ratio (figure 25), bankfull width to bankfull depth ratio, sinuosity, and bed material. Both the Rosgen and the Montgomery and Buffington systems have utility, but this report relies on the Rosgen system (Rosgen 1994, 1996). The U.S. Environmental Protection Agency has developed a watershed management training Web site. The analysis and planning modules include the "Fundamentals of the Rosgen Stream Classification System" <<http://www.epa.gov/watertrain/>>.

At an ideal bridge crossing, all floodwater and debris would stay in the confines of the existing channel. Such crossings would have high banks with a narrow flood plain or no flood plain at all. Rosgen's channel classification system illustrates that certain channel types are more vertically contained than others.

The entrenchment ratio is the flood stage width (see figure 13) divided by the bankfull width.

In channels with low entrenchment ratios (channel types A, B, F, and G, see figure 24), the majority of the discharge remains in the confines of the bankfull or active channel area even during floods (the flooded area does not get wider and wider as water rises, figures 26, 27, 28, and 29). When a bridge crosses such channels, it is relatively easy to provide good vertical clearance between the stream and the bottom of the bridge's girder. Channels with high entrenchment ratios (channel types C, D, DA, and E, see figure 24) tend to have active flood plains with low banks (figures 30, 31, and 32). Bridges built at such sites will require deep fills to provide enough vertical clearance. Streams with high entrenchment

ratios often require additional drainage structures on the flood plain and wider crossings. Bridges built on such

streams may pose problems for animals that need to cross the area.

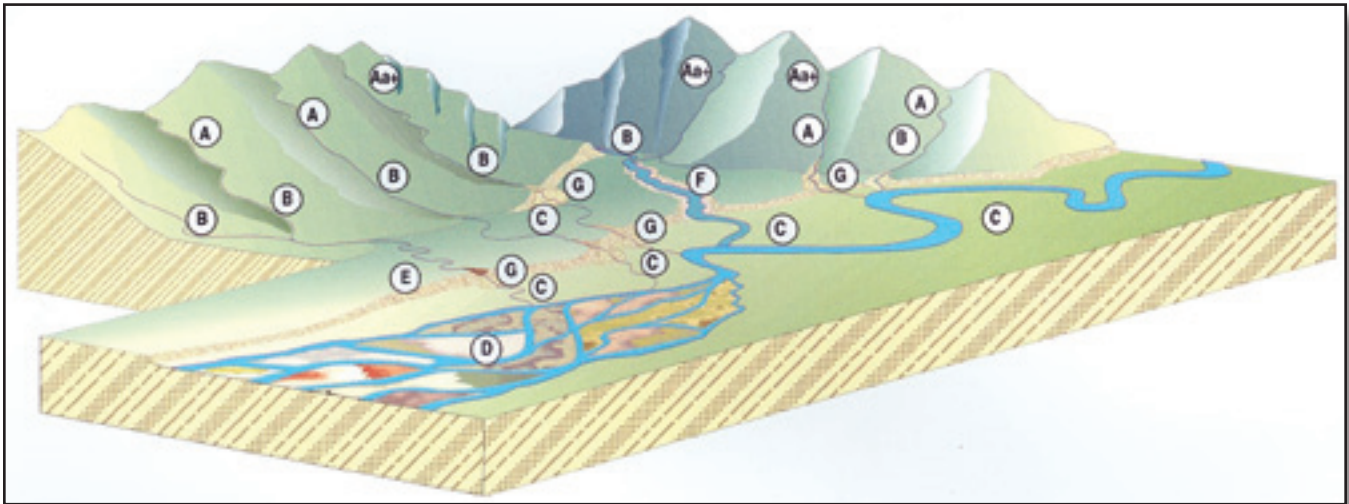


Figure 23—The Rosgen system of stream classification showing examples of a broad-level delineation of stream types. (Rosgen 1998, courtesy of Wildland Hydrology).

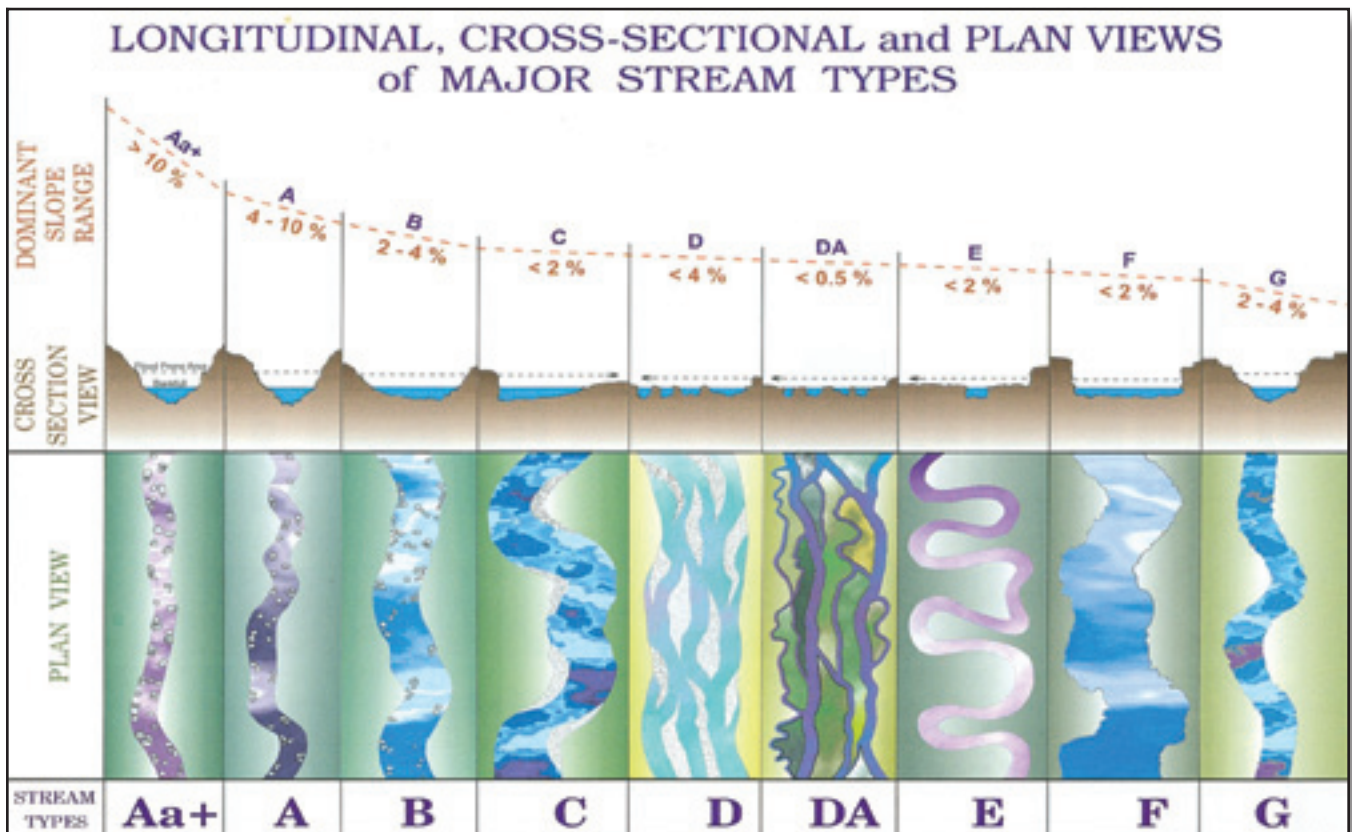


Figure 24—Broad-level delineation of major stream types showing longitudinal, cross-sectional, and plan views (Rosgen 1998, courtesy of Wildland Hydrology).

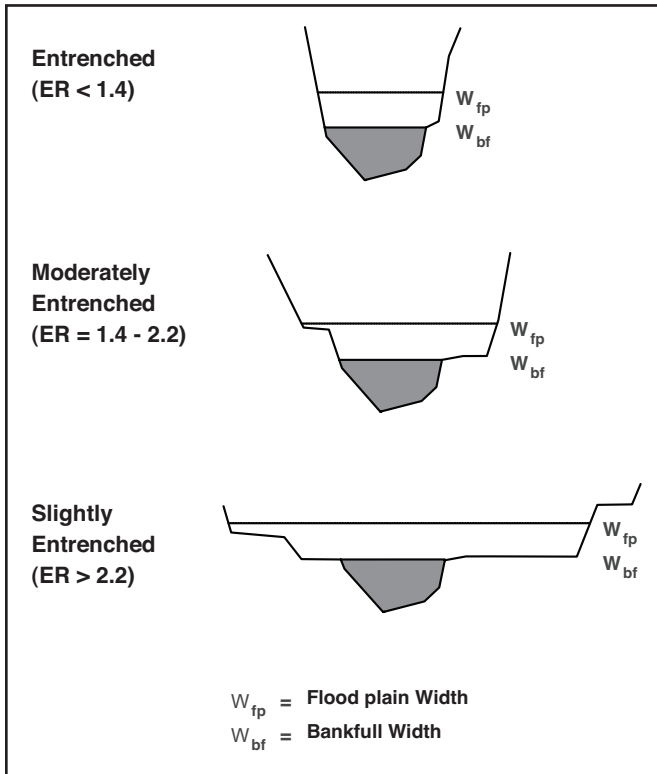


Figure 25—Illustration of different entrenchment ratios (ER). W_{fp} is the width of the flood plain. W_{bf} is the bankfull width.



Figure 27—Type B channel.



Figure 28—Type F channel.



Figure 26—Type A channel.



Figure 29—Type G channel.



Figure 30—Type C channel.



Figure 31—Type D channel.



Figure 32—Type E channel.

Identifying how much water flows over a flood plain and the width of the floodflow is a major consideration when channels are only slightly to moderately entrenched (entrenchment ratio of 1.4 or greater). Bridge designs should consider flood plain conveyance, the width of the bridge's

opening, its vertical clearance, and the site's scour potential. If the flood plain has high conveyance, constrictions increase the chance that erosion may scour the streambed and the banks.

At a minimum, the bridge should span the stream's bankfull width with no piers in the stream. Additional culverts, slab structures (such as low water crossings), or fords can help reduce the constriction caused by trail approaches and help maintain a functioning flood plain. If crossings must be located in these areas, riprap or other materials are recommended to prevent excessive scour of bridge abutments.

All stream channels migrate laterally over time. Confined channels usually migrate more slowly than unconfined channels because of their underlying geology and bank composition. If the banks are composed of highly erodible materials (noncohesive finer grained sands, gravels, and cobbles), the banks adjust more easily than if they are composed of nonerodible materials (boulders, bedrock, and cohesive materials). Vegetation can also be a major factor influencing a bank's susceptibility to erosion. When deeply rooted vegetation is present, banks are less erodible. Material alone is not always the sole indicator of the likelihood of lateral movement. Streams with low entrenchment ratios and lower width-to-depth ratios (channel types A, B, F, and G, see figure 24) tend to have lower migration potential (less lateral movement) than those with high entrenchment and high width-to-depth ratios (channel types C, D, and E, see figure 24). Type E channels and channels with dense, deep-rooted woody vegetation can be very stable.

A transport reach (typically a length of river with moderate slopes) has a heavily armored streambed and tends to be stable (channel types A, B, and G, see figure 24). A response reach (typically a length of river with gentler slopes) usually has a fine-grained, noncohesive streambed (channel types C, D, DA, E, and F, see figure 24) and is more susceptible to scour and erosion. Streambeds in transport reaches tend to be less susceptible to downcutting (when the streambed is cut away and material washes downstream). Streambeds in the response reaches tend to aggrade (when the streambed is built up by materials that washed downstream)

or degrade more readily with changes in sediment supply and discharge.

In streams where the response reaches are composed of cohesive materials (clay), the channel tends to be very stable and may have good sites for crossings. Establishing solid foundations at such crossings can be very expensive. Flood plain issues and stream sinuosity will need to be addressed.

Depending on their depth, headcuts (when a channel causes localized erosion upstream) can undermine bridge foundations or materials intended to prevent scour, such as riprap or gabion baskets filled with stones. Characterize the bed materials, using a longitudinal profile to determine potential headcut locations. A method to evaluate headcuts and vertical changes in the streambed is provided in “Stream Simulation: An Ecological Approach Providing Aquatic Organism Passage at Road-Stream Crossings” (Stream Simulation Working Group 2008).

When a wide stream flows into a narrow bridge opening or when the structure is not hydraulically aligned with the stream, back eddies can form, constricting the portion of the channel with unrestricted flow. Sediment transport and localized scour will increase. Field evidence of this condition includes aggradation above the structure, usually seen in the longitudinal profile as a flat wedge of sediment or as gravel bars. Bank scour can occur above or below the constriction because the changes in the channel’s cross section create back eddies, increasing the boundary shear stresses and directing flow into the banks instead of parallel to them. Bed scour commonly occurs downstream, caused by increased outlet velocities and increased slope of the water’s surface. Avoid locating structures in reaches with poor hydraulic alignment, such as a curve. If a structure is not aligned hydraulically, the flow could be restricted, raising the stream’s surface. Bank armor may be needed farther up and downstream from the structure than if the structure had been hydraulically aligned.

Understanding how dynamic landforms behave over time can help when planning for maintenance and when considering alternative bridge designs or locations. For example, active alluvial fans are sediment deposition zones. Their channels change location frequently, sometimes

rapidly, when sediment and debris deposits cause the channel to seek a lower level along the path of least resistance. If a crossing is on an active fan, streams can abandon their historic channels after a flood event, depositing trees or excessive sediment in the channel upstream. The crossing may fail catastrophically because of sediment or debris deposition, (which can reduce the area where the stream can flow, its cross section) at the structure.

It’s best to avoid active fans. If you must locate a crossing in such areas, the best crossings would be below the alluvial fan or near its apex. These locations are beyond the active areas and may be better suited for siting a structure that will survive with the least maintenance.

In addition, low-cost structures such as a simple ford or low-water crossing may be most appropriate in flood plains or on alluvial fans.

If the crossing must be on an alluvial fan, large channel changes should be anticipated and the design should minimize the downstream consequences of the structure’s failure by reducing the possibility that the stream could cut a new channel around the structure (Grant 1988).

All channels need to be assessed for stability at both the watershed (broadest) and reach (more narrowly focused) scales. It is particularly important to identify systemwide instability such as head cutting, because the structure’s design needs to account for predicted changes in the channel. It is best to avoid crossings in unstable channels because predicting changes in width and depth can be difficult. System-wide instability usually can be seen in a series of aerial photos as noticeable changes in channel width, rapid growth and movement of depositional bars, alluvial fans at tributary mouths, and so forth. Frequently, large-scale channel changes are associated with land-use changes such as mining, agriculture, subdivision and road development, or logging.

As a rule of thumb, the heavily armored transport reaches (channel types A, B, and G with cobble and larger substrates) tend to be more stable and less affected by watershed changes than the response reaches (channel types C, D, E and F, see figure 24).

Trail Alignment

A good horizontal trail alignment should provide adequate stopping sight distances for the design trail speed at the approaches (figure 33). An ideal bridge approach, such as a straight approach, would allow off-highway vehicles (OHVs) and bicycles to see oncoming traffic. Curves can be constructed adjacent to the bridge, but vegetation may have to be thinned to improve visibility. Bridges constructed perpendicular to the stream are the shortest structures and usually cost less, but may cause safety problems on the approaches because of inadequate sight distances and a tight turning radius, especially when the trail parallels a stream with brushy banks before making an abrupt 90-degree turn onto the bridge (figure 34).



Figure 33—This bridge is on a good alignment that allows OHV riders to see oncoming vehicles.



Figure 34—This alignment causes a blind spot for oncoming traffic.

Vertical trail alignment is also important. Bridges with a slight grade will shed water (figure 35). Bridges at the low point of a sag curve in the alignment may have maintenance and safety problems because gravel and debris will collect on the bridge deck or water will pond and freeze there (figure 36). Less efficient alignments are acceptable when you wish to maintain well-vegetated banks or high stream sinuosity, preserve large trees, or protect wildlife habitat. Straightening stream channels or modifying channel alignments is not recommended and requires complex hydraulic and geomorphic investigations.



Figure 35—This bridge has a slight grade, allowing water and debris to run off the bridge deck.



Figure 36—Gravel collects on the deck of this bridge because it is in the low point of a sag curve.

Environmental Concerns

Wildlife and fisheries concerns, including those involving threatened or endangered species, should be taken into account when siting a bridge. For example, seasonal construction closures may be needed near salmon spawning habitat in Alaska (figure 37) or Indiana bat roosting trees in the Midwest.

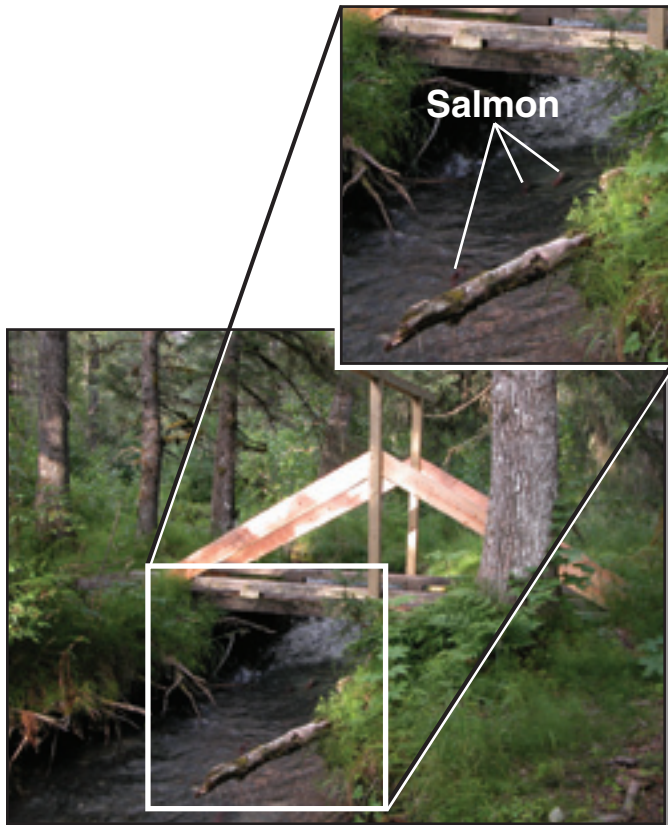


Figure 37—Salmon habitat may need to be considered when siting a bridge in the Northwest.

Carefully study the geologic and other hazards of the area where the proposed bridge will be located. Locations to avoid include:

- Avalanche chutes (figure 38)
- Springs/seeps
- Wetlands
- Areas with excessive snow loads
- Streams with problems of debris flow or that have high debris loading
- Areas on or below earthflows
- Areas low in flash flood channels
- Areas prone to rock fall
- Areas prone to wind throw or with many dead or dying trees
- Alluvial fans and other unstable areas



Figure 38—Avalanche chutes should be avoided when siting bridges.



Summary

Investigating a trail bridge site properly, paying attention to geomorphic indicators, and understanding how streams and watersheds function can help minimize problems associated with bridge location and construction. Channel classification provides a simple framework to help

designers understand the potential problems that may exist at any bridge location. Proper bridge siting requires an interdisciplinary approach to ensure that designers select the best bridge site location.

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Web Sites

Information on Siting Trail Bridges

Stream Classification and Identification

Fundamentals of the Rosgen Stream Classification System

http://www.epa.gov/watertrain/stream_class/

Montgomery and Buffington

http://www.fgmorph.com/fg_4_11.php

A Guide to Identification of Bankfull Stage in the Northeastern United States

<http://www.stream.fs.fed.us/publications/videos.html>

Stream Channel Reference Sites: An Illustrated Guide to Field Technique

<http://www.stream.fs.fed.us/publications/PDFs/RM245E.PDF>

Hydraulics and Hydrology

NRCS Hydraulics and Hydrology Training

http://www.wsi.nrcs.usda.gov/products/w2q/H&H/Training/trng_ser.html

USGS National Streamflow Statistics Program

<http://water.usgs.gov/software/NSS/>

WinXSPRO: A Channel Cross-Section Analyzer

<http://www.stream.fs.fed.us/publications/winxspro.html>

Hydrologic Engineering Centers River Analysis System (HEC-RAS)

<http://www.hec.usace.army.mil/software/hec-ras/>

Aerial Photographs and Topographic Maps

Google Earth

<http://earth.google.com/>

Microsoft Virtual Earth

<http://www.microsoft.com/virtualearth/>

Forest Service Topographic Maps (available only to Forest Service employees)

<http://mapmaker.esri.com/fstopo/>

(User ID: fstopo, Password: maps)

This site provides Primary Base Series (PBS) or Single Edition Series (SES) maps as a raster image of the Forest Service 1:24,000 scale topographic map, including the collar information (legends and other text outside the map).

Trail Bridge Types

Trail Bridge Catalog

<http://www.fs.fed.us/eng/bridges/>

Crossings

Low-Water Crossings: Geomorphic, Biological, and Engineering Considerations

<http://www.fs.fed.us/eng/pubs/pdf/LowWaterCrossings/>

Additional Information

U.S. Department of Agriculture, Forest Service, Stream Systems Technology Center

<http://www.stream.fs.fed.us/>

U.S. Department of Agriculture, Forest Service, National Technology and Development Program, Stream Simulation: An Approach To Providing Passage for Aquatic Organisms at Road-Stream Crossings

<http://www.fs.fed.us/eng/pubs/pdf/StreamSimulation/>

U.S. Army Corps of Engineers–Hydrologic Engineering Center (HEC)

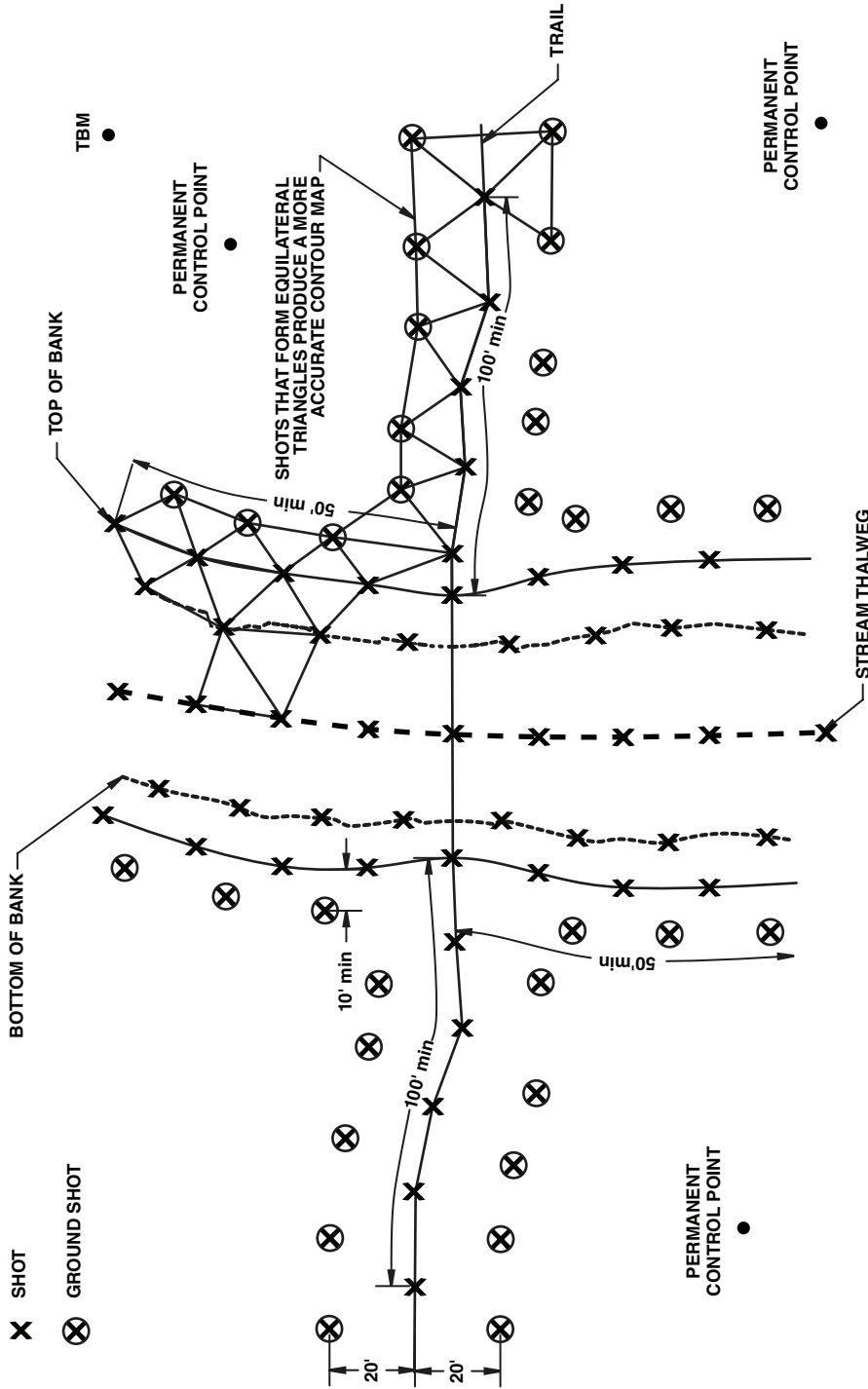
<http://www.hec.usace.army.mil/>

U.S. Geological Survey, Water Resources

<http://water.usgs.gov/>

Appendix A—Example of a Site Survey Map and Checklist

TYPICAL SITE SURVEY



NOTES:

1. THIS EXAMPLE PLAN IS FOR A TYPICAL SITE. MORE COMPLEX SITES WITH FLOOD PLAINS WILL REQUIRE ADDITIONAL SHOTS AND GROUND SHOTS.
2. MORE COMPLEX SITES WILL REQUIRE AN ADDITIONAL 50 FEET OF TRAIL & BEYOND WHAT IS SHOWN HERE.
3. MORE COMPLEX STREAMS WILL REQUIRE 300 FEET UPSTREAM AND 300 FEET DOWNSTREAM OF SURVEY FROM THE PROPOSED BRIDGE LOCATION.
4. SET THREE CONTROL POINTS THAT ARE INTERVISIBLE OUT OF THE PROJECT AREA AND A TEMPORARY BENCH MARK (TBM).
5. TAKE BANKFULL INDICATOR SHOTS.

FOREST RESPONSIBILITY FOR TRAIL BRIDGE INFO CHECKLIST

REQUIRED INFORMATION:

SITE PLAN (1:1) - ELECTRONIC DWG OR DXF FILE

- NORTH ARROW
- SCALE
- STATIONING
- CONTOURS (MAJOR & MINOR & LABELS)
- TEMPORARY BENCH MARK & CONTROL POINTS (LABELED)
- HIGH-WATER MARK (LABELED)
- ϕ TRAIL
- ϕ STREAM
- TOP OF BANK
- BOTTOM OF BANK
- SHOTS & GROUND SHOTS
- BREAKLINES } ON SEPARATE LAYERS
- TINS }

PROFILE (10:1) - ELECTRONIC DWG OR DXF FILE

- PROJECT PROFILE
- STATIONS
- ELEVATIONS
- HIGH-WATER MARK
- * ALL FILES SHALL BE CLEAN AND EDITABLE WITH NO REFERENCE FILES
BMPs FOR THE FOREST, IF REQUIRED
- * SEE TYPICAL SITE SURVEY FOR SURVEY REQUIREMENTS.

APPROVAL INFORMATION EXAMPLE:

SUBMITTED	AREA ENGINEER	PRINT NAME
REVIEWED	DISTRICT RANGER	"
RECOMMENDED	PROGRAM OFFICER	"
APPROVED	FOREST SUPERVISOR	"

USER INFORMATION: (CHECK ALL THAT APPLY)

- | | | |
|-------------------------------------|-------------------------------------|--------------------------------------|
| <input type="checkbox"/> PEDESTRIAN | <input type="checkbox"/> MOTORCYCLE | <input type="checkbox"/> GROOMER |
| <input type="checkbox"/> BIKE | <input type="checkbox"/> HORSE | <input type="checkbox"/> OTHER _____ |
| <input type="checkbox"/> ATV | <input type="checkbox"/> SNOWMOBILE | _____ |

NOTES: OTHER INFORMATION OR DESIGN CONSIDERATION (i.e ACCESSIBILITY)

- BMPs FOR THE FOREST, IF REQUIRED
- OTHER _____
- _____
- _____
- _____

Appendix B— Example of Trail Bridge Design Folder

The following outline shows one way to set up a Trail Bridge design folder.

Section 1—General Information

- Executive Summary
- Aerial Photographs
- Quad Map
- Photographs
- National Environmental Policy Act Compliance
- Other Information

Section 2—Topographical Survey

- Topographical Survey Map
- Survey Notes
- Survey Photographs
- Other Survey Information

Section 3—Hydraulics and Hydrology

- Stream Classification
- Basin Area Map
- Infrared Photographs
- Regression Calculation for Flow
- Hydraulic Survey
- Hydraulic Analysis
- Hydraulic Recommendations

Section 4—Geotechnical Investigation/Substructure

- Soil Classification
- Soil Investigation
- Foundation Recommendations
- Description of Additional Geotechnical Investigations Required

Section 5—Structural Design/Superstructure

- Design Criteria: See FSH 7709.56b—Transportation Structures Handbook, Chapter 7—Structural Design, section 7.6—Trail Bridges
 - Bridge Width: See section 7.61 and the Trail Bridge Design Criteria table
 - Loads: See section 7.62
 - Pedestrian
 - Snow
 - Wind
 - Groomer
 - Light vehicle
 - Load Combination: See section 7.63
 - Railings: See section 7.66 and the Trail Bridge Design Criteria table
 - Length: See Hydraulics and Hydrology
- Sample Calculations for Bridge Superstructure
- Standard Plans To Be Utilized
- Special Project Specifications for Prefabricated Bridges
- Superstructure Recommendations

Section 6—Cost Estimate/Permits/Other Information

- Cost Estimate
- Permits
- Special Requirements—Timing, Helicopter, and So Forth
- Alternative Sites To Be Considered
- Additional Information

The following table is from FSH 7709.56b—Transportation Structures Handbook, Chapter 7—Structural Design, section 7.69—exhibit 01.

Trail Bridge Design Criteria

TRAIL DESIGN USE	CLEAR WIDTH	LIVE LOAD	RAILING HEIGHT
Hiker/Pedestrian	3 feet ⁵	Pedestrian or snow load	42 inches
Mountain Bike	4 feet	Pedestrian or snow load	54 inches
Pack and Saddle	5 feet w/o railing 6 feet w/ railing	Pedestrian or snow load	54 inches
Cross Country Skiing	6 feet	Pedestrian or snow load Groomer where applicable	Site specific
Motorcycle	42 inches	Pedestrian or snow load	42 inches
Snowmobile	6 feet	Pedestrian or snow load Groomer where applicable	Site specific
All-Terrain Vehicle	50 inches	Pedestrian or snow load	42 inches

Notes:

1. Widths shown are recommended minimum clear widths between railings or curbs. Use design parameters developed for each particular trail, which may recommend narrower bridge width. If groomers are to be used on the trail, check the specific groomer machines for the necessary width.
2. See section 7.62 for a description and minimum requirements of pedestrian live load.
3. Railing height is the minimum if railing is required. Provide analysis to determine whether railings may be eliminated.
4. For trail bridges that require access for light administrative vehicles, a minimum width of 8 feet is required. The design live load shall be AASHTO H-5 (10,000 pounds) vehicle loading.
5. Except footlog bridges should not be less than 10 inches.

Appendix C—Example of a Trail Bridge Executive Summary

The following imaginary information shows how to write an executive summary.

General Information

“Snow Dog Creek” Trail Bridge is a mountain biking and hiking bridge located on trail G4, 2.8 miles from Dogsled trailhead. The bridge is at longitude 90°54'10"E, latitude 56°34'05"N. The bridge crosses Snow Dog Creek and is a small, 25-foot-wide stream, which has fish spawning at the site. See the attached quad map with location marked in folder.

Site reconnaissance was done on June 25 by John Barger, Scott Groenier, and Rod Dell'andrea. Additional sites were reviewed upstream and downstream and no better locations were found within 300 yards. No ice damage was seen, but medium size debris was observed at the site. A small seep occurs just downstream of the structure on the right side facing downstream.

The project is scheduled for construction during the summer of 2005 by contract. The environmental assessment was completed in 2002 and a record of decision was made in May of 2003. Aerial infrared photos and photographs of the site are in the design folder.

Survey

The bridge was surveyed on July 26, 2004, by the Chugach Survey Crew, consisting of Zack Smith and Pete Doe. Two control points and a temporary benchmark were set for the survey. The design folder contains copies of the survey notes, photographs, and a topographical survey map of the site. The survey points, established by a hand-held geographical positioning system unit, use the Universal Transverse Mercator (UTM) coordinates.

Hydraulics and Hydrology

The stream is classified as a Type B3 stream with gravel bottom and sides. Streamflow estimates were made using the regression equations for Alaska from the U.S. Geological Survey publication “Estimating Magnitude of Peak Flow for Alaska.” The Q_2 is estimated at 87 cubic feet per second and the Q_{100} is estimated to be 400 cubic feet per second.

A hydraulic survey of the stream was completed on July 26, 2004, by Bill Macfarlane and John Barger. The bankfull width is about 26 feet and the mean depth is about 0.8 feet. The velocity was 2.3 feet per second when the stream was running less than bankfull. The Mannings Number (0.38) was back-calculated from the survey. The slope of the stream is 0.5 percent obtained from water slope over 300 feet. High water marks were flagged in the field and included in the survey.

The stream was modeled using WinXSPRO. The Q_{100} elevation is estimated at 1.9 feet. The minimum freeboard should be 3 feet based on wood debris in the watershed.

The bridge is recommended to be placed on stable ground above elevation 96.00 and 3 feet away from the top of the bank.

Geotechnical Investigation

John Barger completed the soil investigation on July 28, 2004, using a Williamson Probe. The soil is 2 feet of organic material over glacial deposited cobble and gravel. The blow counts were 30 blows per foot into the cobble and gravel.

An allowable strength of 2,500 pounds per square foot should be used for this site following International Building Code recommendations for this type of soil. The recommended foundation is a spread footing placed down to frost depth.

Superstructure Design

The required bridge length is 30 feet center of bearing to center of bearing. Bridge width inside of rail to inside of rail should be 4 feet for hiking. The railing should be 42 inches high. The three rails should have a maximum opening of 15 inches.

Design loads for the structure will be 85 pounds per square foot for pedestrian load, 300 pounds per square foot for snow loads, and 90 miles per hour for wind loads.

The bridge will be a prefabricated structure and will be required to be stamped by a professional engineer. Plans and calculations will be added to the design folder when they become available.

Permits

The bridge will be outside of the flood plain. Snow Dog Creek is not a navigable water, so no permits are required for this structure. A set of plans will be sent to the U.S. Army Corps of Engineers to verify this determination.

Cost Estimate

The bridge superstructure is estimated at \$25,000. The bridge will have to be flown to the site by helicopter. The site is remote. A base camp at the bridge site will be needed for construction. The total cost of the bridge superstructure and installation is estimated at \$60,000.

Alternative Locations

No other sites were considered for this bridge.

Special Requirements

No instream construction will be allowed from June 15 through October 1 because fish spawn at the bridge site.

Appendix D—Hydraulic Structure Initial Site Examination Form

HYDRAULIC STRUCTURE INITIAL SITE EXAMINATION FORM			
(DATA SHEET FOR FORDS, BRIDGES, AND CULVERTS) (INCLUDE SITE SURVEY, LONGITUDINAL PROFILE, AND CROSS-SECTIONS)			
FOREST		ROAD (TRAIL) NAME	
STRUCTURE NAME		STREAM NAME	
STRUCTURE NUMBER	LOCATION		
	SECTION	TOWNSHIP	RANGE
A. HYDROLOGIC & HYDRAULIC DATA			
1. SHOW ON A 15 MINUTE TOPOGRAPHIC MAP DRAINAGE AREA		2. NAME OF CLOSEST GAGING STATION	
3A. MANNING'S ROUGHNESS COEFFICIENT (N):		500' UPSTREAM:	3B. AVERAGE STREAMBED SLOPE 500' DOWNSTREAM:
4. DESCRIBE CHARACTER OF STREAM BED MATERIAL AND STREAM BANKS WITHIN THE 1000-FOOT AREA:			
5A. AMOUNT OF DEBRIS IN CHANNEL		5B. TYPE OF DEBRIS	
B. WATER ELEVATIONS			
6A. DATE AND FLOW DEPTH AT TIME OF SURVEY:	6B. EST. BASE FLOW DEPTH	OCCURS	MONTH
		6C. EST. EXTREME HIGH WATER DEPTH (HOW DETERMINED ?)	
6D. CAUSE AND SEASON OF FLOODS:			
B. OTHER CHANNEL CHARACTERISTICS			
1. NOTE EVIDENCE OF INSTABILITY OF BANKS OR SCOUR			
2A. STRAIGHT CHANNEL, OR NOTE DEGREE OF SINUOUSITY		2B. HIGH FLOW ANGLE OF APPROACH (PARALLEL OR IMPINGING?)	
3. CHANNEL STABILITY (AGGRADATION, DOWNCUTTING, LATERAL CHANNEL MIGRATION, ETC)			
4. CHANNEL CLASSIFICATION (ROSGEN OR OTHER)			
5. CHANNEL ENTRENCHMENT (RATIO = FLOOD-PRONE / BANKFULL WIDTH)			
6. UPSTREAM / DOWNSTREAM STRUCTURES AFFECTING SITE (DAMS, BRIDGES, ETC.)			
7. OTHER SITE ASSESSMENT FACTORS			
C. FOUNDATION CONDITIONS			
1. CHARACTER OF SURFACE OR LOCAL MATERIALS:			
2. ESTIMATED DEPTH TO BEDROCK FEET	2A. BEDROCK TYPE & CONDITION		
3. ANY SPECIAL FOUNDATION CONDITIONS? INVESTIGATION NEEDED? EXPLAIN:			
D. EXISTING STRUCTURE			
1. TYPE OF EXISTING STRUCTURE	1A. NO & LENGTH OF SPANS	1B. TYPE OF CULVERT	1C. SIZE
2. WATERWAY OPENING FEET WIDE OR SQUARE FEET		2A. WATERWAY ADEQUATE? <input type="checkbox"/> YES <input type="checkbox"/> NO	
3. STRUCTURE AFFECTED BY: DEBRIS <input type="checkbox"/> ICE <input type="checkbox"/> DAMAGE <input type="checkbox"/> SCOUR <input type="checkbox"/>		4. DOES STRUCTURE CONSTRICT THE NATURAL CHANNEL: YES <input type="checkbox"/> NO <input type="checkbox"/>	
5. CONDITION OF EXISTING STRUCTURE:			
E. PROPOSED STRUCTURE			
1. BRIDGE OR LOW-WATER CROSSING TYPE		1A. LOADING (JUSTIFY IF OTHER THEN HS 20)	

Appendix D—Hydraulic Structure Initial Site Examination Form

1B. WIDTH	1C. SUBSTRUCTURE OR SPECIAL NEEDS		
2. TYPE OF CULVERT			2A. SIZE
2B. CULVERT DESIGN ISSUES?			
2C. CORROSION OR ABRASION CONCERNS?		2D. TYPE OF FILL MATERIAL TO BE USED	
F. MISCELLANEOUS DATA			
1. TIME AND DURATION OF CONSTRUCTION SEASON		2. RIPRAP IS AVAILABLE YES <input type="checkbox"/> NO <input type="checkbox"/>	2A. DISTANCE FROM SITE AT _____ MILES
2B. DESCRIPTION OF RIPRAP MATERIAL			
3. TRAFFIC CONTROL AND SAFETY NEEDS			
4. ROADWAY ALIGNMENT AND GRADE (ADEQUATE?)			
5. CHANNEL OR STRUCTURE ALIGNMENT CHANGES RECOMMENDED (SHOW ON COPY OF SITE PLAN)			
6. ARE DIKES OR BANK PROTECTION REQUIRED TO CONTROL FLOW (SHOW ON COPY OF SITE PLAN)			
7. DESCRIPTION OF ON-SITE CONSTRUCTION MATERIAL TO BE USED			
8. STORAGE AND/OR WASTE AREAS AVAILABLE FOR CONSTRUCTION (LOCATION, SIZE, AND DESCRIPTION)			
9. WHAT IS THE MAXIMUM LENGTH OF GIRDERS THAT CAN BE HAULED TO THE SITE? FEET			
10. METHOD OF CONSTRUCTION CONTRACT <input type="checkbox"/>		FORCE ACCOUNT <input type="checkbox"/>	TIMBER PURCHASER <input type="checkbox"/>
11. OTHER REMARKS AND SPECIAL RECOMMENDATIONS			
G. FISH AND OTHER WILDLIFE PASSAGE CONSIDERATIONS			
1A. IS FISH PASSAGE REQUIRED? YES <input type="checkbox"/> NO <input type="checkbox"/>	1B. IF YES, WHAT SPECIES AND LIFE STAGES?		2. IS PASSAGE FOR OTHER SPECIES REQUIRED? (TERRESTRIAL, CRAWLING, SWIMMING) YES <input type="checkbox"/> NO <input type="checkbox"/> WHICH?
3. SPECIAL/IMPORTANT CONSIDERATIONS FOR HABITAT PROTECTION?			
4. FOREST BIOLOGIST RECOMMENDATIONS			
PREPARED BY: _____		DATE _____	FOREST ENGINEER REVIEW: _____
			DATE _____
FIELD SITE SKETCH, LONGITUDINAL PROFILE, AND CROSS-SECTIONS			

Adapted From: Form R5-7700-71

Notes

Notes

About the Authors

James “Scott” Groenier began working for MTDC in November 2003 as a civil engineering project leader. Groenier earned a bachelor’s degree from the University of Wisconsin at Madison and a master’s degree from Montana State University. He worked for the Wisconsin and Illinois State Departments of Transportation before starting his career with the Forest Service. He has worked as the east zone structural engineer for the Eastern Region and as a civil engineer for the Ashley and Tongass National Forests.

Robert A. Gubernick is the engineering geologist and the lead fish passage/hydraulic engineer for the Tongass National Forest. He received a bachelor’s degree in geology from Utah State University in 1983 and took graduate training in geomorphology at the University of Washington during 1996 and 1997. He has worked all over Alaska as a geologist and project/design engineer for the Tongass and Chugach National Forests and for the Bureau of Indian Affairs. He is a member of the FishXing development team <<http://www.stream.fs.fed.us/fishxing>>, the San Dimas Technical Aquatic Organism Passage Team, and is a member of the technical advisory committee for HEC 26 (Federal Highway Administration national fish passage manual). He was recognized as regional engineer of the year for the Alaska Region and as national engineer of the year for engineering applications during 2003. In 2005, he received the Alaska Regional Foresters Award for Natural Resource Stewardship.

Library Card

Groenier, James “Scott”; Gubernick, Robert A. 2010. Locating your trail bridge for longevity. Tech. Rep. 1023–2808P–MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 30 p.

Selecting the proper location for a bridge is as important as determining the characteristics of the bridge itself. This report discusses a commonsense approach, combined with science, to help select sustainable locations for bridges. Problems associated with bridge location and construction can be minimized by conducting a proper site investigation, paying attention to geomorphic indicators, knowing trail design needs, and understanding how streams and watersheds function. Channel classification provides a simple framework to help land managers understand the potential problems that may exist at bridge locations. An interdisciplinary approach is required to incorporate all the considerations involved in choosing the best bridge location for sustainability.

Keywords: channels, classification, flood plains, geomorphology, interdisciplinary, reconnaissance, Rosgen, sites, streams, structures

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Forest Service and Bureau of Land Management employees can search a more complete collection of MTDC’s documents, CDs, DVDs, and videos on their internal computer networks at:

<http://fsweb.mtdc.wo.fs.fed.us/search/>